Title: Forecasting WIMAX: Integrating Scenario Planning and Bass Model Methodologies

Course Title: Technology Forecasting
Course Number: EMGT 532/632
Instructor: Dr. Daim
Term: Winter
Year: 2009
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Abstract

The primary objective of this paper is to develop a forecast for mobile WiMAX as an emerging technology using Scenario Planning and Bass Model methodologies. To understand why these methods were applied in assessing a forecast for the adoption of WiMAX, the paper will discuss the technology's evolution, functionality, and market competition. Literature review on the methodology and applications of forecasting in the mobile communications industry will be considered to help provide examples of technology forecasting estimations.

The results obtained for each scenario will then be compared and analyzed to the behavior of WiMAX's subscribers in both the United States and Korea. The paper intends to discuss the differences in the United States and Korea models. Significant consumer interest variations, price, and population patterns are presented. The key to forecasting WiMAX's adoption technology rates is to understand the difference in consumer reactions that exists within countries. The analysis will conclude that WiMAX will diffuse in Korea at a faster rate due to high response from imitators.

With big market potential and a clear vision of subscriber needs, the next major evolution is expected to occur in the area of personal broadband services. The WIMAX standard promises to deliver high speed, cost-effective and high quality services with long distance broad coverage.

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1. Introduction

Wireless technologies represent a rapidly emerging area of growth for providing ubiquitous access to the network. Adopted in many applications, they ultimately provide a solution for environments where wires are not desired. While wireless connectivity exists, it is only available in limited physical areas. In business and personal examples alike, there is interest in using mobile computing beyond existing boundaries. WIMAX intends to be the industry's solution to deliver wireless connectivity over longer distances to more locations. Mobile WiMAX makes a target of the mobile market by supporting portability and full-scale mobility for mobile clients.

The WiMAX Forum is at the top of this effort [1]. It represents a cross-industry group of chip set manufacturers, component makers and service providers that recognize the long-term benefits of working with standardized, interoperable equipment. Intel, the world's leading developer of microprocessor chips, and Alvarion, provider of BWA systems, are just a few of the numerous companies that are committed to the design, development and implementation of WiMAX-compliant solutions.

The paper idea resulted from the enthusiasm on the subject. Locally, in the Portland area, Clearwire recently started offering this service. Forecasting the diffusion of WiMAX beyond the Portland area, in the United States and Korea, is of interest. In assessing a forecast for the adoption of WiMAX technology, a structured methodology was followed.

This paper is divided into four distinct scenarios, to which the generalized Bass model formulation is applied. First, it will describe the key elements of WiMAX as a personal broadband service and introduce existing competing technologies. Secondly, it will focus on literature review to understand the selection of forecasting methods and its current applications in the area. Thirdly, it will develop a forecast for mobile WiMAX for each scenario. Subscriber behavior in the United States will be compared to that in Korea. The country of Korea was chosen because it presents key economic, cultural, and technical disparities. The paper will conclude with an analysis of the resulting differences in the patterns of the adoption curves caused by analogous product selection, and disparities between the United States and Korea.

2. Technology Overview

To develop an accurate forecast, one must first review the progression and characteristics of wireless technologies. This is critical in making the correct model assumptions that will be reviewed in the sections to follow.

2.1. Evolution of Wireless Technology

WiMAX technology starts to emerge when the flexibility of wireless is combined with the capability to access the Internet at broadband speeds. **Fig. 1** illustrates the timeline of wireless technology compared to data and mobility characteristics.

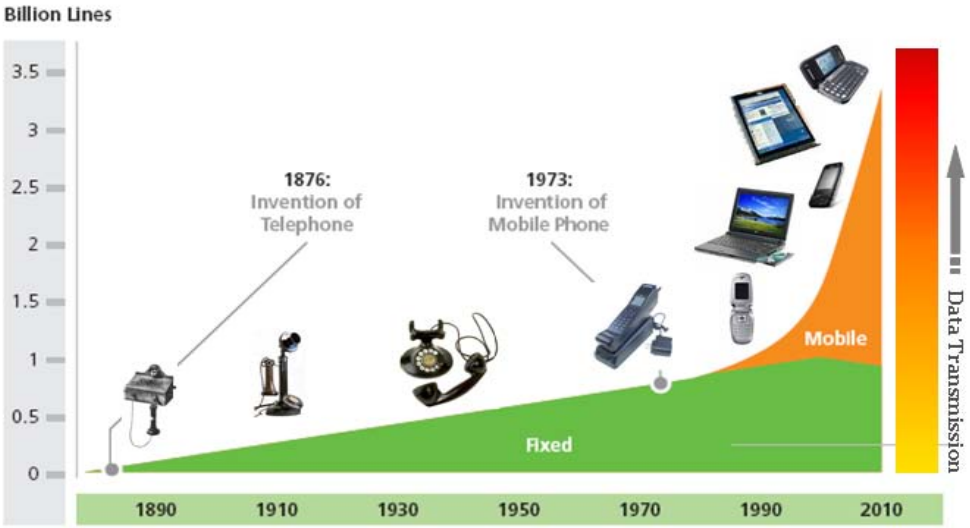


Figure 1. Wireless Technology Timeline [2].

The 1800's:

In 1876, Alexander Graham Bell invented the telephone. Merely 19 years later, Italian inventor, Guglielmo Marconi sent and received the first radio signal across the English Channel [3].

The 1900's:

Wireless technology developed quickly in the 19th century. In 1921, the Detroit Police began utilizing unidirectional radio messaging. Wireless technologies continued to be researched, and by 1973, the world's first mobile phone was introduced. US cellular subscription rates topped 2 million in 1986, and almost a decade later, in 1999, there were over 60 million cellular phone users across the United States [4]. **Figure 1** shows the transition between fixed and mobile lines.

The 2000's:

As consumers became familiar with the technology, the developments that occurred in the communications industry were vital in the area of data transmission. Service providers deployed voice, data, and video devices, enabling technologies for the first camera phones, mobile TV, instant messaging, music players, location-based services, game consoles, internet browsing, and email [5].

2.2. What is WiMAX?

WiMAX is defined as **W**orldwide **I**nteroperability for **M**icrowave **Acc**ess by the WiMAX Forum to promote conformance and interoperability of the IEEE 802.16 standard, ratified in 2005. The Forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL" [6].

WiMAX is a metropolitan access network (MAN) technology; a well-defined wireless technology that provides multiple access modes with wired and wireless connectivity capabilities. WiMAX will conceptually merge both broadband and mobility services; consumers will be able to enjoy broadband speeds away from home, greatly enhancing lifestyles and productivity. **Fig. 2** shows the progression of available services from 2005 to the present.

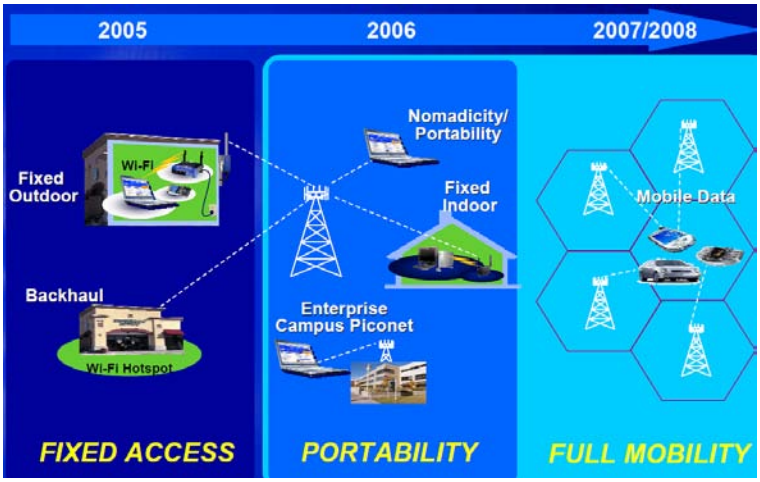


Figure 2: WIMAX Vision [7]

To meet different applications and performance demands, WiMAX specifies two classes of services, which are 802.16d and 802.16e, simply referred to fixed WiMAX and mobile WiMAX. For the purposes of this paper, we will focus on forecasting mobile WiMAX only.

2.3. How WiMAX Works?

The WiMAX standard enables high speed, cost-effective and high quality services. WiMAX is both a broadband wireless access (BWA) standard, and a metropolitan access network (MAN) technology. It supports a variety of wireless connections [8] :

- High-bandwidth metropolitan-area networks (MANs) to home and small-business users, replacing DSL and cable modems;

- Backhaul networks for cellular base stations, bypassing the public switched telephone network;

- Backhaul connections to the Internet for WiFi hotspots.

There are two components to the system – the base station and the receiver. The base station is a tower that connects to the network backbone by sending and receiving data and voice to subscriber equipment. A single WiMAX tower can provide widely coverage up to 30 miles radius at maximum, depending on the tower height, antenna gain and transmission power. The WiMAX communication network is illustrated in **Fig. 3**.

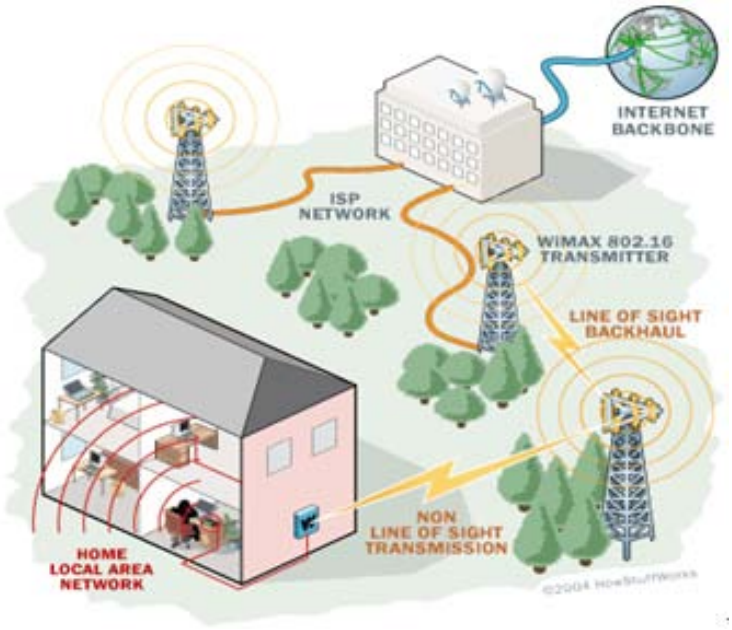


Figure: 3 WiMAX 802.16 Network [9]

3. Competing Wireless Technologies

There are many different types of wireless access technologies that exist today. Despite the differences in area coverage and functionality, many existing technologies can influence the speed of adoption and penetration of WiMAX into the market. As consumers compare technologies, they will choose to purchase the one that best meet their needs. Wi-Fi, HSDPA, 1xEVDO, and LTE are among the most dominant.

3.1. Existing Technologies

A hierarchy of complimentary wireless standards was established to help ensure interoperability and reduce the risk of wireless technology deployment. There are three existing standards, including IEEE 802.15 for the Personal Area Network (PAN), IEEE 802.11 for the Local Area Network (LAN), and 802.16 for the Metropolitan Area Network (MAN). **Fig. 4** summarizes competing technologies according to coverage area and mobility specifications.

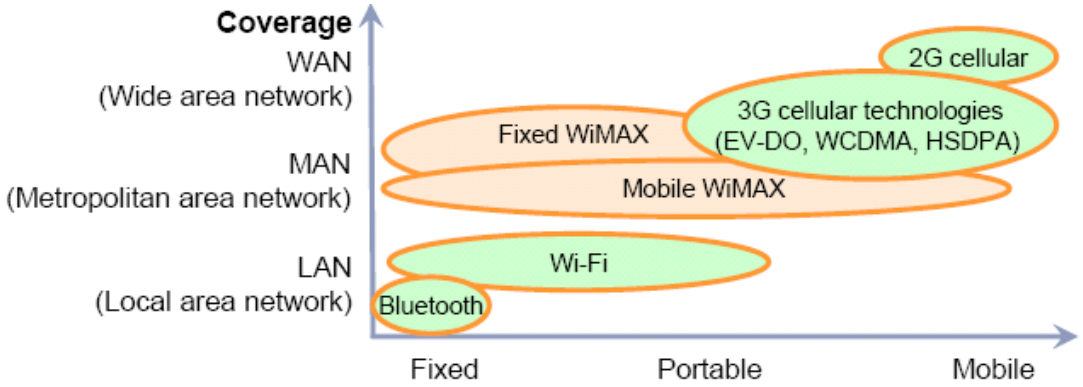


Figure 4: IEEE Wireless Standards and Coverage [10]

Although WiMAX promises significant advantage over existing technologies, it is important to understand the impact of competing technologies listed below.

Wi-Fi

Wi-Fi or Wireless Fidelity is designed based on IEEE802.11 standards. It is a Local Area Network (LAN) that offers low mobility at 2.4GHz band frequency which is universally adopted by most countries around the world [11]. It supports up to 100Mbps download speed throughput using 802.11n, but other versions such as 802.11a/b/g are different, as shown in **Table 1**.

Table 1: Comparison of Competing Technologies

(Intel, 2004)(Andrews et al. 2007)(Motorola, 2007)

Parameter	Mobile WiMAX	Wi-Fi	HSPA	1x EV-DO	WiBro	LTE
Standard	IEEE 802.16e-2005	IEEE 802.11a/g/n	3GPP Release 6	3GPP2	IEEE 802.16e	not available
Peak down link data rate	46Mbps	11Mbps 802.11b	14.4Mbps	Rev A: 3.1Mbps; Rev. B 4.9Mbps	50Mbps	100Mbps (for 20MHz spectrum)
Peak uplink data rate	7Mbps	2Mbps	1.4Mbps initially; 5.8Mbps later	1.8Mbps	30Mbps	50Mbps (for 20MHz spectrum)
Bandwidth	3.5MHz, 7MHz, 5MHz, 10MHz, and 8.75MHz initially	20MHz for 802.11a/g; 20/40MHz for 802.11n	5MHz	1.25MHz	8.75 MHz	1.25, 2.5, 5, 10, 15, and 20MHz
Frequency	2.3GHz, 2.5GHz, and 3.5GHz initially	2.4GHz, 5GHz	800/900/1,800/1,900/ 2,100MHz	800/900/1,800	2.3Ghz-2.4GHz	
Coverage (typical)	< 2 miles	< 100 ft indoors; < 1000 ft outdoors	1–3 miles	1–3 miles	1-3 miles	up to 62miles with degradation after 19miles
Mobility	<37mph	Low	155mph	155mph	<75mph	< 310mph

3G (and 3.5G)

There are many existing versions 3G and 3.5G technologies. HSDPA and 1xEVDO will be compared since they have been widely adopted by major USA telecommunication companies. HSDPA is currently being used by AT&T, T-Mobile, and 1xEVDO by Sprint and Verizon Wireless. Developed by 3GPP (3rd Generation Partnership Project), HSDPA was introduced as the enhancement for its predecessor, WCDMA (3GPP, 2009). 3GPP2 developed 1xEVDO as enhancement for CDMA2000 to provide throughput improvement for data traffic. **Fig. 6** compares spectral efficiency and sector throughput for Mobile WiMAX, HSPA, and EV-DO.

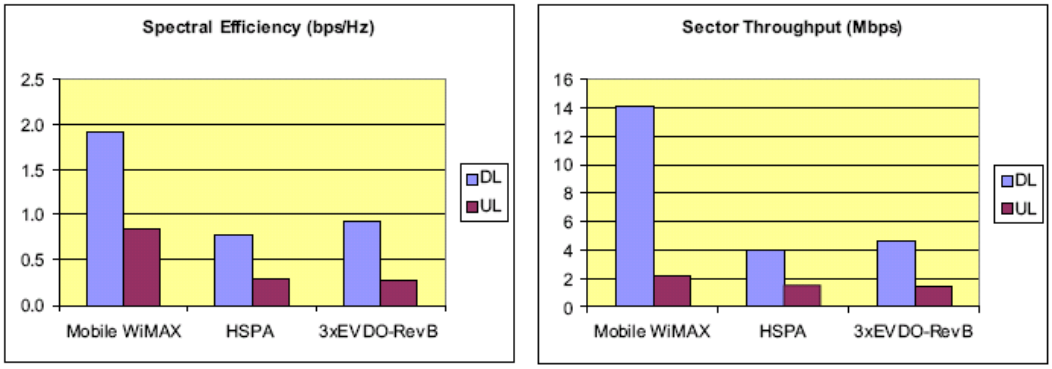


Figure 5: Spectral efficiency and sector throughput comparison [11]

Fixed WiMAX

Finalized on June, 14, 2004, IEEE802.16d standard is the predecessor of mobile WiMAX. The design is focused on fixed and nomadic wireless broadband access. The coverage is up to 30 miles, and the transmission speed reaches up to 75Mbps. The standard is called “fixed wireless” because it uses a mounted antenna at the subscriber site.

WiBRO

WiBro (Wireless Broadband) is the Korean service name for IEEE802.16e, or Mobile WiMAX, international standard. This technology was launched in June 2006. Its success in Korea is attributed to its high speeds and high mobility characteristics.

3.2. WiMAX Technology Advantage

Compared with fixed WiMAX, 802.16d, mobile WiMAX has lower transfer rates, but in turn, offers high mobility. WiMAX technology introduces numerous advances over existing technologies. Cost, Mobility and Data Rate are compared in **Fig. 6**. In addition to these, other characteristics include [12]:

Efficient Spectrum Allocation: the technology is capable of scaling to wide bandwidths, therefore yielding higher data speeds regardless of the number of subscribers supported at that time.

Always On Connectivity: the integration of multiple radios into a single device enables the user to have access to broadband everywhere.

MIMO: Its foundation infrastructure is based on Multiple-input multiple-output (MIMO). It significantly increases in data throughput and link range without additional bandwidth or transmit power.

Extended use of web services: rich multi-media environments are available with broadband wireless connectivity. Connections speeds around 15Mbps are higher than existing technologies.

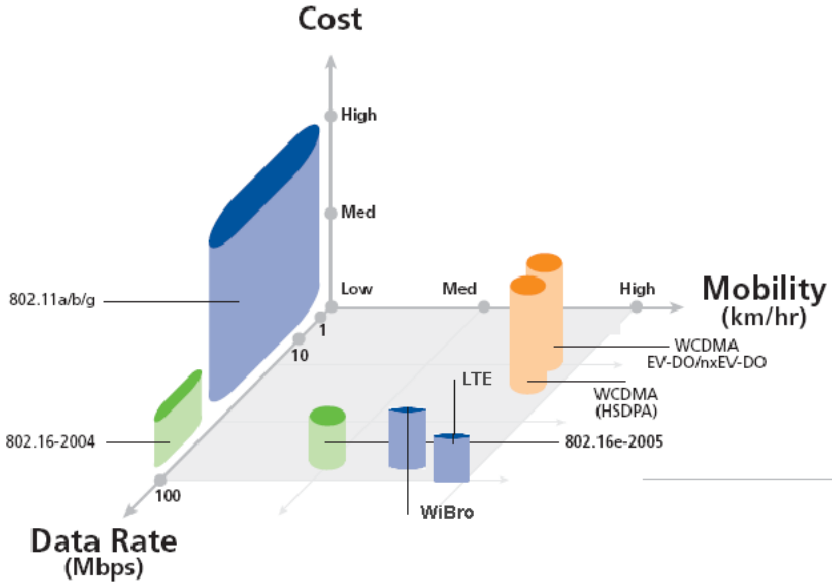


Figure 6 Mapping of Wireless Technologies [13]

3.3. WiMAX vs LTE

Long Term Evolution is the next generation technology that is scheduled to follow WiMAX. As service providers get ready to launch this technology, it could compete with WiMAX for subscribers if its introduction materializes earlier than forecasted. Verizon, AT&T, and Vodafone have expressed interested in adopting LTE. It provides up to 100Mbps (download) and 50Mbps (upload).

Intel is the main force behind WiMAX: the strategy is to largely incorporate WiMAX into Intel's notebooks PC. Though WiMAX is currently leading the WLAN broadband market, it is facing some adoption troubles due to the amount of competition it has encountered. According to the WiMAX Forum Global Congress held in Amsterdam in June 2008, WiMAX must compete with HSPA in terms of mobile data and 3G in terms of voice quality. The advantage of WiMAX lies in the opportunities that arise in developing countries and or cable TV.

4. Literature Review

There are many published definitions of forecasting methodologies. The following section describes the methods selected and discusses the reasons why these offer advantages over other forecasting methodologies.

4.1. Methodology

4.1.1. The Bass Model

Presented by Frank Bass in 1969, the Bass Model is "the only method that addresses the diffusion of an innovation in terms of how information about the product is shared among the pool of potential adopters" [14]. It provides useful information for estimating the first sale and penetration rates of the product. Gary [15] selected the use of the Bass Model for forecasting the long-term infiltration of new technologies and products into the market. Dodds (1973) also preferred the use of the Bass Model over other forecasting methodologies because it is the only model that allows a forecast of turndown in sales when sales seem to be growing.

This methodology was the model of choice in many other industries as well; retails service (Chern et al, 2001), software piracy [16], business telephones [17] recorded music [18], digital imaging in the banking and insurance industries [19], fluid package types [20], vehicles and traffic [21]. Research shows that the Bass model is accurate and it is capable of providing a close forecast when its assumptions are used carefully.

The analytical framework leverages on the knowledge of previously launched products to understand potential markets for new products. It is based on the notion that new products get adopted because of social interactions among users. In fact, the parameter p predicts the likelihood of somebody who has not use the product will use it because of media promotion or from other external factors and q focuses on people who are not using the product but will likely use it because of "word-of- mouth" from those that are already using it or other internal influence [22].

For the purposes of the project, the Bass Model fit very well. Not only did it determine the rate of product diffusion, but also provided key data on consumer behavior that we were looking for in the United States and Korea. Furthermore, the model allows us to be flexible in selecting analogous products that, just like WiMAX, are facing strong technology competition.

4.1.2. Scenario Planning

"Scenario planning is basically an approach to thinking about the future, to try to deal with really difficult uncertainty or unknowability in a useful way" [23]. Scenario planning takes a set of possible scenarios and helps to decide what actions are needed to deal with uncertainties that might occur in the future.

The use of Scenario Planning in this paper has provided a structured methodology to analyze potential impact to the rate of technology penetration. It is necessary to look at possible future situations in many ways and scenario planning provides us with that tool.

Scenario Planning serves primarily to identify factors that could drive change in a system and at the same time create variations in the stories (Fahey and Randall, 1998). Like in the Shell and UPS scenarios, this method clearly provides the tools needed to success in a rapidly changing environment since it helps to brainstorms and be prepared for what may come in the future. Traditional methods of forecasting do not easily open up discussions to interpreting and understanding the future.

This methodology has proven key in many other forecasting studies. A classical example of scenario planning is the United Parcel Service [24]. At the center of this effort, management committees used scenario planning exercises to determine strategies growth and future company position. Another example where scenario planning was successful was in Shell Oil Company [25]. The managing directors at Shell used scenario planning to outline the future of the company. A total of six scenarios represented possible worse and best case situations. Dwight [26] uses scenario planning processes in the Innovative Forest Practices Agreements (IFPA) to capture the expectation of forest management. Other applications include: energy (Silberglitt et al, 2002), public policy [27], environmental research projects (Kagazyo et al, 1997), fuel cell vehicles (Lewis and Dolan, 1999), molecular computation [28], and biotechnology [29].

4.2. Applications

Based on the references available today in the telecommunications industry, both Scenario Planning and the Bass Model are suitable for the objectives of the project. In fact, many scholars and researchers have used a conjoint approach. Scenario planning complements the Bass Model methodology very well in this paper: together the bass model and scenario planning allow us to consider situations that may impact diffusion technology rates.

Murillo and Rendon [30] have used the diffusion model to analyze the adoption rate of wireless broadband in Latin America. They present a pathwork adoption network for 3G cellular and WiFi access. In a similar manner, the Korea and US scenario to follow will discuss indicators that will affect the way WiMAX is diffused. Bouras [31] also used this methodology to determine the impact on broadband growth in Denmark, United States, Japan, Canada, and Korea. Another example is presented by Michalakelis [32] on the diffusion rate of mobile telephony subscriptions in Greece. Further studies ion forecasting mobile internet in Taiwan by diffusion model was also presented and Chu and Pan [33]. They, too, have selected the diffusion theory as a methodological forecasting approach.

Wireless applications and services have been the subject of many research papers and journal articles. In some way or another, they have discussed the diffusion of this technology. Here are some examples, Grantham and Tsekouras [34] on diffusion wireless applications, Grajek and Kretschmer [35] on usage and diffusion of cellular telephony, Madden et al [36] on mobile telephony subscription, Liikanen et al [37] on the diffusion on mobile phones, Jun et al. (2002) on telecommunication service subscribers, Jung et al [38] on consumer adoption of mobile TV.

Just like the Bass model, scenario planning is often as utilized to forecast technological futures. Pagani [39] presented 3G mobile TV by the use of strategic thinking and scenario planning. Pagani and Fine (in press) developed a value network for 3G-4G wireless communications using strategic thinking approach. Here are other examples: Sapio [40] presented scenario analysis as a method to forecast Videotel service, Mitchell et al [41] discussed the application of scenarios to structuring the future of technology, Daymond and Foster [42] presented future possibilities of British television using scenario analysis, Walsh et al [43] applied the scenario planning method to the semiconductor silicon industry. In many ways, the above mentioned readings support Gausemeier et al [44] in developing future potential with scenario management.

4.2.1. Case Study Analysis

WiMAX provides a clear broadband alternative to DSL and cable network. The focus of this case study is fixed wireless applications. Even though this project will focus on mobile wireless applications, we have selected to review this case study because it clearly demonstrated how the diffusion of the technology could be impacted by different market segments. In this case study, two demography scenarios and two market models, residential customers and both residential and small to medium business customers, are analyzed.

Residential Customers. This market depends on the availability of DSL or cable network service. In most cases, rural areas may not have access to broadband access due to lack of infrastructure.

Small and Medium Business. This is the underserved market in most cases because of increased competition. WiMAX technology can meet the needs of this segment by competing with DSL and cable.

WiFi Hot Spot Backhaul: The WiMax technology will be able to fill in the coverage gap in between hot spots. As DSL or cable that provides other services like TV, WIMAX will not only provide internet services but also will provide voice and TV services to customers.

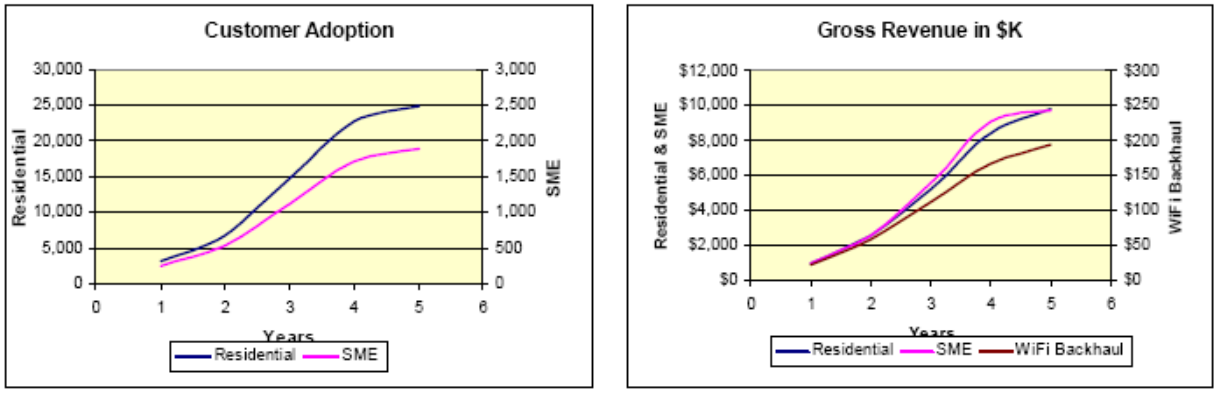


Figure 7 Residential and SME Summary

To address customer needs and penetrate the market segments successfully additional base station sites were added to provide the capacity necessary to address the SME market and to

provide backhaul connections for WiFi hot spots in addition to access for residential market segments. **Fig. 7** illustrates WiMAX adoption rate and revenues. The deployment comparisons and base station deployments show result in benefiting from adding the SME market segment to the residential access connections.

5. Methodology

A structured methodology was used to construct the forecast for the adoption of WiMAX. **Fig. 8** summarizes the steps taken in this analysis. This section will describe the assumptions and data utilized for each methodology.

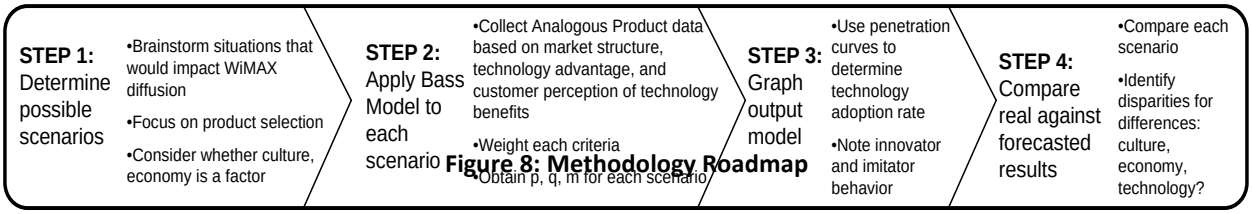


Figure 8: Methodology Roadmap

5.1. Data Collection

There were two parallel efforts in data collection: one concentrated on market and customer behavior of analogous products in the United States, while the other focused on collecting past performance of analogous products in Korea.

It is interesting to explore the differences between economy, culture, technology use and population patterns in both the United States and Korea. The diffusion of innovation focuses on people's attitudes and preferences towards WiMAX. Additional consumer data was collected to understand consumer behavior differences.

5.2. Scenario Selection

This paper presents four distinct scenarios based on the selection of previous analogous products. By analyzing consumer behavior for previous products, one can begin to understand the market of new products. The scenarios selected in **Fig. 9** look at possible adoptions trends in Korea and the United States.

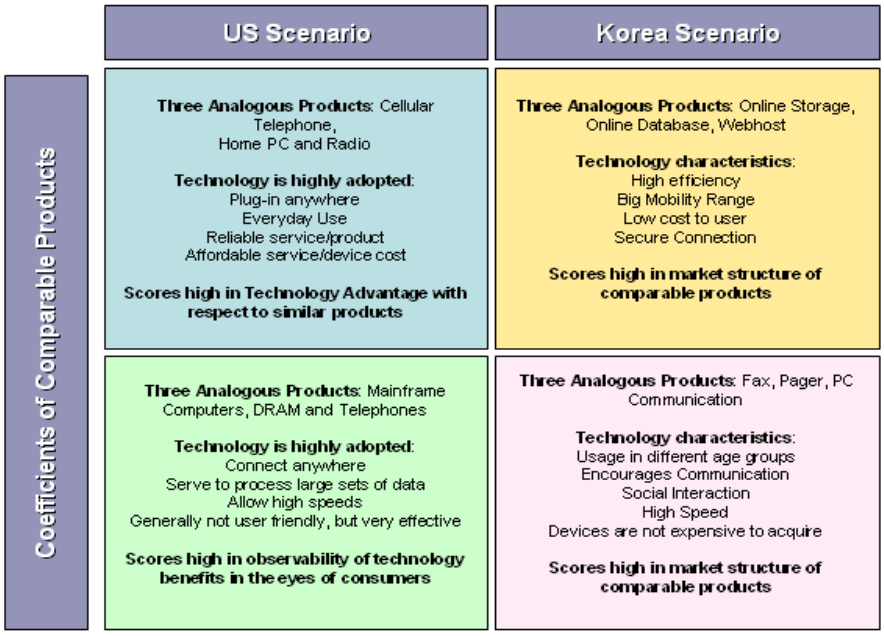


Figure 9 Scenario Summary

Each scenario represents different analogous product characteristics, technology, and market structure. The US scenarios were selected based on products that compared to WiMAX with respect to technology and impact to the consumer. Many of them today are new to the idea of mobile wireless networks. In fact, Clearwire first commercialized mobile WiMAX in September 2008, and it is currently the only service provider in the area. Other service providers are coming up to speed; however, given that most subscribers will likely purchase bundled services, and not WiMAX services exclusively, it will be difficult to obtain real data to compare against forecasted in the United States scenario alone. Therefore, for the purposes of this project, Korea was selected to understand consumer behavior when the technology was introduced. Korea was the first country to offer Mobile WiMAX services, commonly referred to as Wibro. Since 2006, KT and SK Telecom have provided the service successfully. As a result, real data will be evaluated against the forecasted diffusion curves.

Even thought Korea and US are different, it will be interesting to discuss how market, economy, culture, and technology impact the diffusion of WiMAX. To each of the scenarios presented in **Fig. 9**, the Bass Model is applied. The resulting curves will provide estimates on how fast WiMAX will be adopted within the same period in each country.

5.3. Evaluation of Parameters

The knowledge of the market for the new product derives from previous product of similar category. This is the basic principle for choosing parameters *m*, total market potential, *p*, imitators, and *q*, innovators

Since sales data is yet not available for WiMAX technology, ***m*,** the total market potential was estimated from key statistics examined in past research of previously launched products. To determine *m*, Scenario 1, 2 utilized 18.8 Millions. It is the total of the population of the 375 cities where Clearwire provide the service because this paper uses their real-data for comparing with

forecasting. In the case of Scenario 3 and Scenario 4, *m* was based on the population of the country of Korea in combination with previous total market estimations of similar products [46].

	p	q	m
Scenario 1	0.042	0.393	18.8
Scenario 2	0.017	0.524	18.8
Scenario 3	0.002	0.989	47
Scenario 4	0.0002	0.798	47

Figure 10: Parameter Estimation per Scenario

The coefficients of innovation, *p*, and imitation, *q*, have stronger mathematical fundamentals. **Fig. 10** summarizes parameter estimates for each scenario. Coefficient estimates were calculated based on a weighted average that took into account market structure, relative technology advantage, and technology benefits. The weights given to each product score range from 1 to 10 and is subjective based of the team's knowledge of the product. **Fig. 20** and **Fig. 21** include details on product scores.

5.4. Estimation of Demand Forecast

To construct the forecast for the diffusion of WiMAX technology, parameter estimates of *m*, *p*, and *q* are utilized as expressed by, [14]

$$S(t) = p + (q/m)\, N(t-1)$$

where,

S (t) is the number of new adopters for the product during the time period t
N(t-1) is the cumulative number of adopters for the new product through the previous time period, t-1

These parameters will illustrate how fast or slow the adoption of WiMAX will occur. Market benchmark of new technology introductions in the telecom industry is used to complement potential market forecasts for WiMAX.

The model attempts to predict how many customers will eventually adopt the new product and when they will adopt. If q>p, then imitation effects dominate the innovation effects; on the other hand, if *q*<*p*, then innovation effects will dominate and the highest sales will occur at introduction and sales will decline in every period after that. Furthermore, the lower the value of *p*, the longer it takes to realize sales growth for the innovation. When both *p* and *q* are large, product sales take off rapidly and fall off quickly after reaching a maximum [47].

6. Analysis of the Results

Forecasting results are critical for management as it provides data that helps plan and implement strategies for the future. In this section of the paper, forecasting results will be explained.

6.1. US Scenarios

The penetration curves are steep and promises high product adaptability within the first decade of the life of the product. As the population of the United States becomes more

accustomed to getting things done 'on the go', the introduction of WiMAX services will prove successful. **Fig. 11** illustrates this trend – in the first five years, the product reaches ~40% penetration, reaching 95% penetration by year 15.

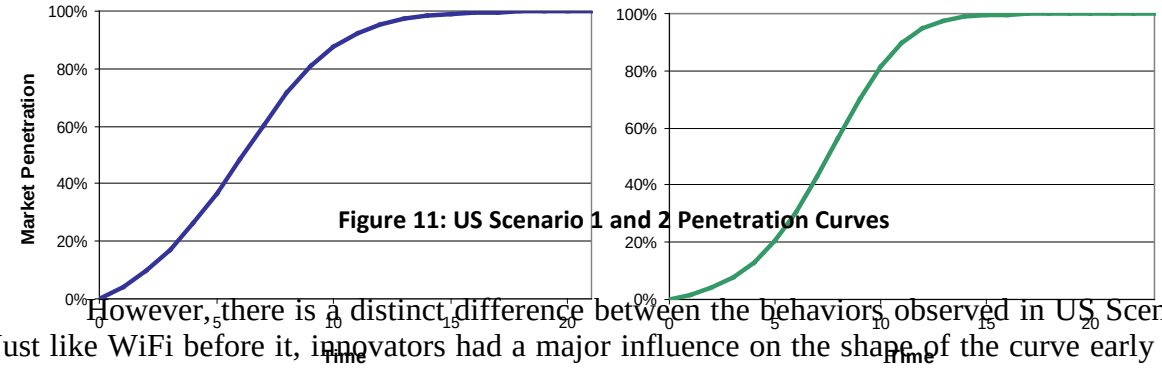


Figure 11: US Scenario 1 and 2 Penetration Curves

However, there is a distinct difference between the behaviors observed in US Scenarios. Just like WiFi before it, innovators had a major influence on the shape of the curve early in the adoption curve. **Fig. 12** compares innovator and imitator influence on the adoption curve. As the number of imitators increases, the number of innovators decreases over time.

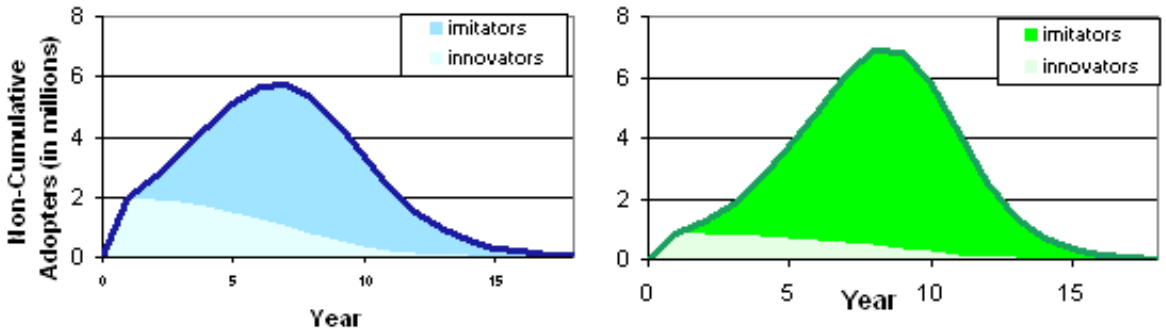


Figure 12 Imitator and Innovation Comparison for US Scenario 1 and 2

The influence of innovators is greater in Scenario 1 than it is in Scenario 2. Despite apparent similarities of the list of analogous products, the products chosen for Scenario 1 offer high mobility and connectivity access, whereas, in Scenario 2 high speeds are combined with capability to process large sets of data. From this observation, it shows that consumers are more interested in mobility rather than high speeds. WiMAX intends to offer both of these functionalities, that is, mobility at broadband speeds.

Furthermore, the actual WiMAX Clearwire subscribers [48] are compared with the outcome of the forecast that resulted from the Bass Model. **Fig. 13** summarizes the first two years of the life of the technology for Clearwire. Although Clearwire is not the only service provider in the United States, it was chosen for this comparison because of its growing presence in United States. This is mainly why the real data falls short of the forecasted subscriber numbers. The economic slowdown is another reason for the disparity. **Fig. 22 and 23** intends to summarize other service providers that are entering the WiMAX markets. Since most of them do not exclusively provide WiMAX services, such is the case for Clearwire; it was difficult to distinguish the specific number of WiMAX subscriptions. The Mean Absolute Error (MAE) is 800,000 subscribers. In future studies, it is recommended to include subscriber data for other service providers as it becomes available in order to close the gap between real and forecasted lines in **Fig. 13**. Scenario 1 was chosen to compare against real data.

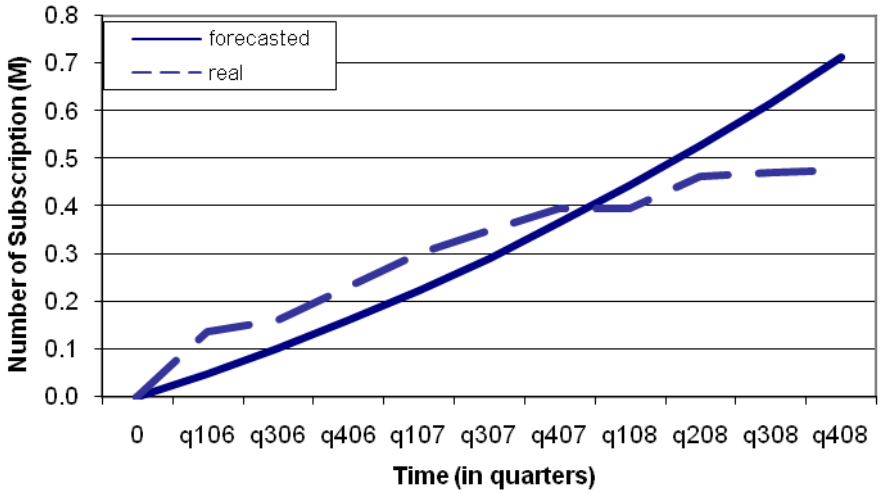


Figure 13 Real Compared to Forecasted No. of Subscribers

6.2. Korea Scenarios

The penetration curves start of slow, but show rapid growth due to high imitator adaptability. Consumers in Korea are familiar with wireless technologies so there is not much room for innovators to get a noticeable head start. **Fig. 14** illustrates that once the product is released and established into the market, the imitators will dominate the penetration curve.

The difference between Scenario 3 and Scenario 4 is primarily defined by the time it takes for imitators to start adopting WiMAX. The influence of imitators start earlier in Scenario 3 compared to Scenario 4.

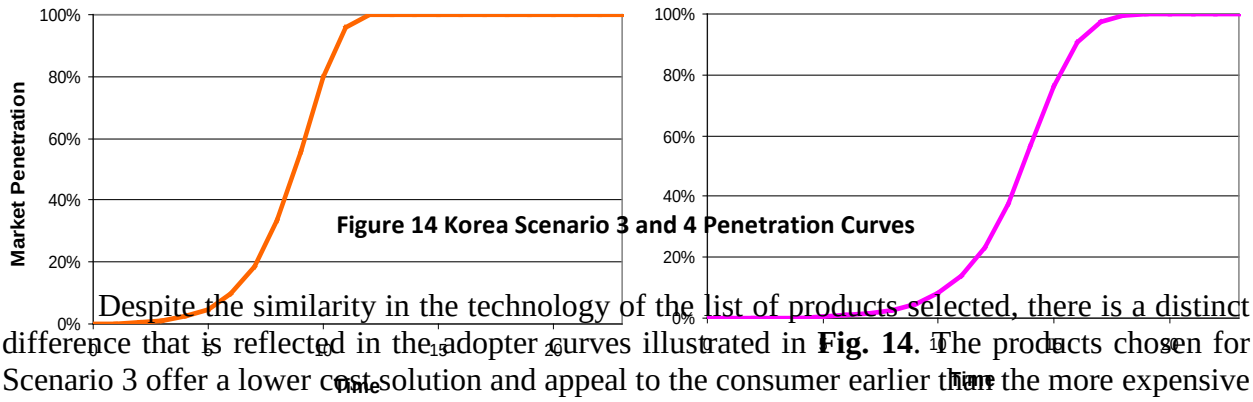
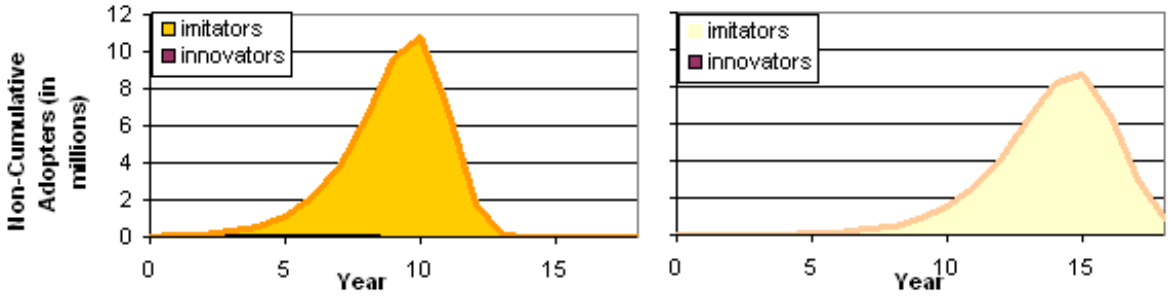


Figure 14 Korea Scenario 3 and 4 Penetration Curves

Despite the similarity in the technology of the list of products selected, there is a distinct difference that is reflected in the adopter curves illustrated in **Fig. 14**. The products chosen for Scenario 3 offer a lower cost solution and appeal to the consumer earlier than the more expensive alternative. Scenario 2, on the other hand, offers services to a wider age group selection. With services capable of social networking and communication, adoption was slower to allow for consumer familiarity. WiMAX intends to penetrate both segments at low costs.



Furthermore, the actual data for WiBro is compared with the outcome of the forecast that resulted from the Bass Model. The ideal forecasting model would match the number of actual subscribers to the forecasted quantities. **Fig. 16** summarizes the first two years of the life of the technology in Korea. Since its introduction in 2006, KT Telecom has dominated the market. The Mean Absolute Error (MAE) is 50,000 subscribers. Scenario 3 is used to compare against real data from KT Telecom.

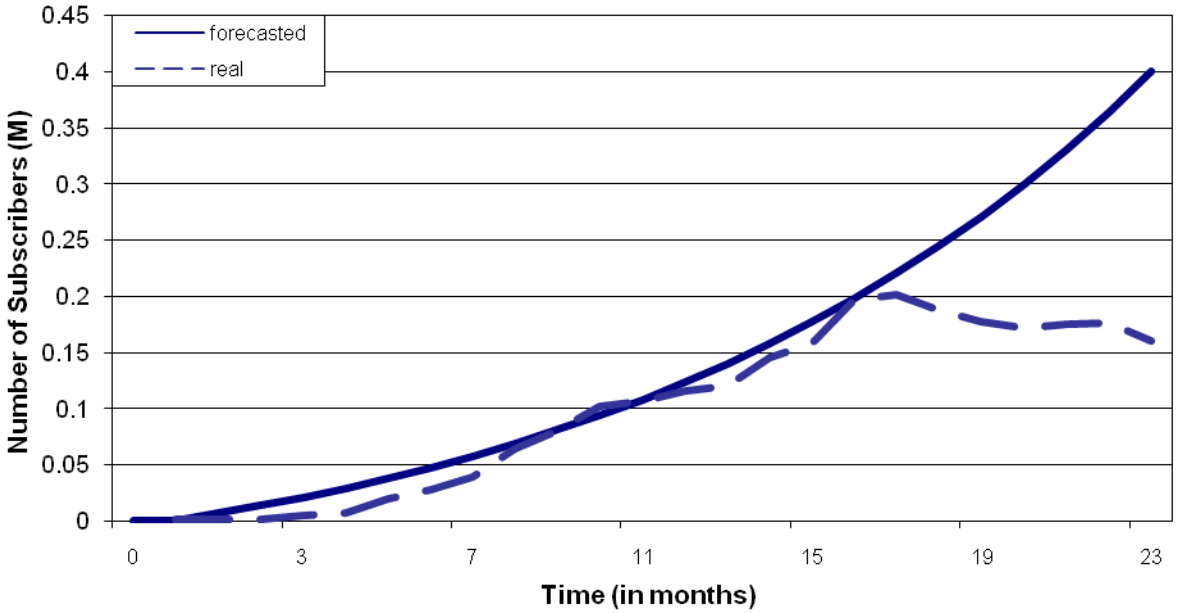


Figure 16 Actual Compared to Forecasted Subscribers

The dip observed at month 18 is explained by several market occurrences, product competition, and the economy. 1) the competition with LTE in Korea might have a bigger impact on the penetration of WiMAX than previously expected; its services offer faster speeds at comparable costs. Its introduction is targeted for 2010, but Samsung, Verizon, and LG are already taking steps to pull that date in. Korean consumers seem to easily adopt new technologies. As seen in **Fig. 15**, there is not much impact of innovators; once consumers are introduced to the technology, they are expected to adopt quickly. 2) According to the Institute for International Economics and Trade (KIET), Korea's private consumption decreased in 2008 (KIET, 2009). **Fig. 17** intends to show the impact and support the disparity between forecast and real curves. The worldwide economic slowdown in 2008 has also tampered WiMAX infrastructure development.

	2007	2008				
	year	Q1	Q2	Q3	Q4	year
Growth rate of GDP	5	5.8	4.8	3.8	-3.4	2.5
Private Consumption	4.5	3.4	2.3	1.1	-4.4	0.5

Figure 17 Korean Economic Indicators (Korean National Statistics Office, 2009)

6.3. In Comparison

In 2001, OECD study ranked United States fourth among 30 countries in broadband adoption, but that same study in 2006 showed that the United States fell to fifteenth place in broadband adoptions. However, it is interesting to note that within that same period, Korea went from ranking fourth in 2001 to first [49]. From our forecasting results, broadband technology adoption is faster in Korea and slower in America. For the adoption of WiMAX, Korea has more imitators than innovators; this trend is different in the United States. It offers an interesting analysis to identify the factors that influence the diffusion curves. What caused the differences in behavior? **Fig. 18** summarizes possible factors that may impact technology adoption.

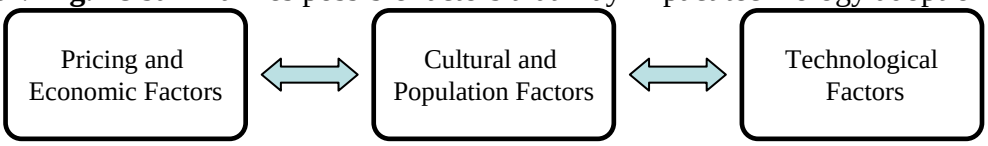


Figure 18 Factors that impact adoption

Price: WiMAX-focused startup Clearwire led by Intel, Motorola, and Sprint could help broaden the portfolio of wireless enabled consumer electronic devices by lowering the cost of broadband services. The cost of broadband service is significant higher in the United States, $40 per month, in comparison to only $14 per month in Korea. WiMAX is expected to overcome this difference and gain market confidence (Correa, 2007). **Fig. 19** summarizes actual prices per month.

Comparing Wimax price per month (Y1500=$1)(1GB=1000MB)

	One day unlimited	Unlimited	2 GB per month	Minimum Subscription Price
SK(KOREA)	unknown	None	$14 before 2GB	$7 before 500MB
			$0.017/MB(=$17/GB) After 2GB	$0.034/MB(=$34/GB) after 500MB
KT(KOREA)	$7	None	$14 before 2GB	$7 before 500MB
			$0.017/MB(=$17/GB) After 2GB	$0.034/MB(=$34/GB) after 500MB
Clear(USA)	$10	$50	$40 before 2GB	$30 before 200MB
			$10/GB after 2GB	$10/GB after 200MB

Figure 19 Price Comparison (Clearwire, KT, SK, 2009)

Population patterns: **Population patterns**: Korea has unique population range. According the Korean National Statistical Office (2006) [50], Korea is the third highest population density (404/km²). 48.2% of the populations live in a metropolitan area (Seoul (20.8%), Kyungki-Do (22.0%), Incheon (5.4%)). Moreover, the population density of a metropolitan area (Seoul (16,181/km²), Kyungki-Do (1,028/km²), and Incheon (2,544/km²)) is 6,584 per square kilometer , whereas Portland population density is only 1,515 per square

kilometer [51]. Due to this unique distribution, most of Korean businesses focus on utilizing existing infrastructures in the metropolitan area, where it is easy to reach new customers. New technology is harder to adopt in rural areas, where new infrastructures are needed to offer WiMAX services.

(1 square mile = 2.6 km²)

	Korea					USA	
	National	Metropolitan area				National	Portland
		Total	Seoul	Gyeonggi-do	Incheon		
Population (,000)	47,254	22,767 (48.2%)	9,820 (20.8%)	10,415 (22.0%)	2,531 (5.4%)	281,424	529
population density(/km²)	404	6,584	16,181	1,028	2,544	31	1,515

Source: U.S. Census Bureau, "2000 Census of Population and Housing", United States Summary Washington, DC, 2004
Department of Census "Result of the 2005 Census of Population and Housing- Population unit", Korean National Statistical Office, May, 2006

Figure 20, Population and density of Korea and US

Technology familiarity: In Korea, consumers are already familiar with wireless broadband technologies. The United States is familiar with fixed network connection, but is now getting to know the role of wireless broadband connection in everyday life. According to the Monthly Factsheet of SK Telecom (2009), 94% among Korean people have cellular phones, and this percentage is still growing. Given that a large population is young, they are likely to become be familiar with internet technologies and applications. KT Corporation, the largest broadband provider in Korea (2009), reported 92% of people use Broadband.

7. Discussion

WiMAX is expected to have a profound impact on business productivity and in the way consumers interact and utilize the internet. Consumers have welcomed this innovation into all aspects of everyday life. The results of this paper will provide practitioners and researchers a basis for understanding the diffusion of WiMAX not only in the context of technology, but also in consideration of culture and economic factors. This paper is a good benchmark for future studies performed in the area of wireless communications when disparities between countries exist.

There are also some limitations to the results of this project. The model was built on the use of previous analogous products to forecast the diffusion rate of WiMAX. Therefore, the forecasting model is susceptible to the subjective process of product selection. A more robust model could result from adding actual WiMAX data as it becomes available.

8. Conclusion

WiMAX has gained a lot of attention in the market and media. Its technology intends to positively affect everyday life of citizens around the world. Although competing against incumbent fixed and wireless technologies, WiMAX promises to deliver a higher speed and a more cost-effective solution. WiMAX adoption rate is expected to accelerate as it attracts more consumers before competing technologies can catch up.

Its diffusion has received some attention, but there remain many opportunities to expand in this area. This paper provides a forecast for the diffusion of WiMAX and expands on the disparities of the diffusion curves in the United States and Korea. The model showed that WiMAX will diffuse in Korea at a faster rate due to high response from imitators. Culture, economic, and technologic factors in each country were identified to support the difference in behavior observed in the diffusion curves.

In conclusion, WiMAX in Korea is expected to reach maturity faster than it will in the United States. Imitators dominate in Korea, whereas, innovators play a significant role in the technology adoption in the United States. According to the forecasting results presented in this paper, innovators will take a major role in making WiMAX a success in the United States.

Appendix

1. Parameter Estimation Details

Scenario 1			Estimated Scores		
			Market Structure	Observability of Benefits	Relative Technology Advantage
Product (Period of Analysis)	**p**	**q**	w_1= 0.25	w2= 0.40	w3= 0.35
Cellular Telephone (1986-1996)	0.008	0.421	9	9	9
Home PC (1982-1988)	0.121	0.281	6	7	7
Radio (1922-1934)	0.027	0.435	9	9	9

Scenario 2			Estimated Scores		
			Market Structure	Observability of Benefits	Relative Technology Advantage
Product (Period of Analysis)	**p**	**q**	w_1= 0.25	w2= 0.40	w3= 0.35
Mainframe Computers (1955-1978)	0.021	0.234	9	9	9
DRAM (1974-1998)	0.020	0.510	5	7	6
Wireless Telephone (1984-2002)	0.001	1.232	6	7	7

Figure 201 US Based Scenario Details [47]

Scenario 3			Estimated Scores		
			Market Structure	Observability of Benefits	Technology Advantage
Product (Period of Analysis)	**p**	**q**	w_1= 0.25	w2= 0.40	w3= 0.35
Online Storage	0.003	1.673	2	7	7
Online Database	0.001	0.762	8	7	8
WebHost	0.001	0.762	9	8	9

Scenario 4			Estimated Scores		
			Market Structure	Observability of Benefits	Relative Technology Advantage
Product (Period of Analysis)	**p**	**q**	w_1= 0.25	w2= 0.40	w3= 0.35
FAX	0.000	0.358	8	9	9
Pager	0.000	0.869	9	7	9
PC Communication	0.000	1.301	9	7	8

Figure 212 Korea Based Scenario Details [46]

2. Wireless Terminology Used

Access Point: A device that transports data between a wireless network and a wired network infrastructure. Also referred as base station.

Bluetooth: a technology specification for small form factor, low-cost, short-range wireless links between mobile PCs, mobile phones, and other portable handheld devices, and connectivity to the Internet.

Broadband: Also called wideband. Transmission facility whose bandwidth is greater than that available on voice-grade facilities.

CDMA: Code Division Multiple Access. CDMA differs from GSM and TDMA by its use of spread spectrum techniques for transmitting voice or data over the air. Available in either 800 or 1900 MHz frequencies.

IEEE: Institute for Electrical and Electronics Engineers. A membership organization that includes engineers, scientists and students in electronics and allied fields.

3. *WiMAX Providers*

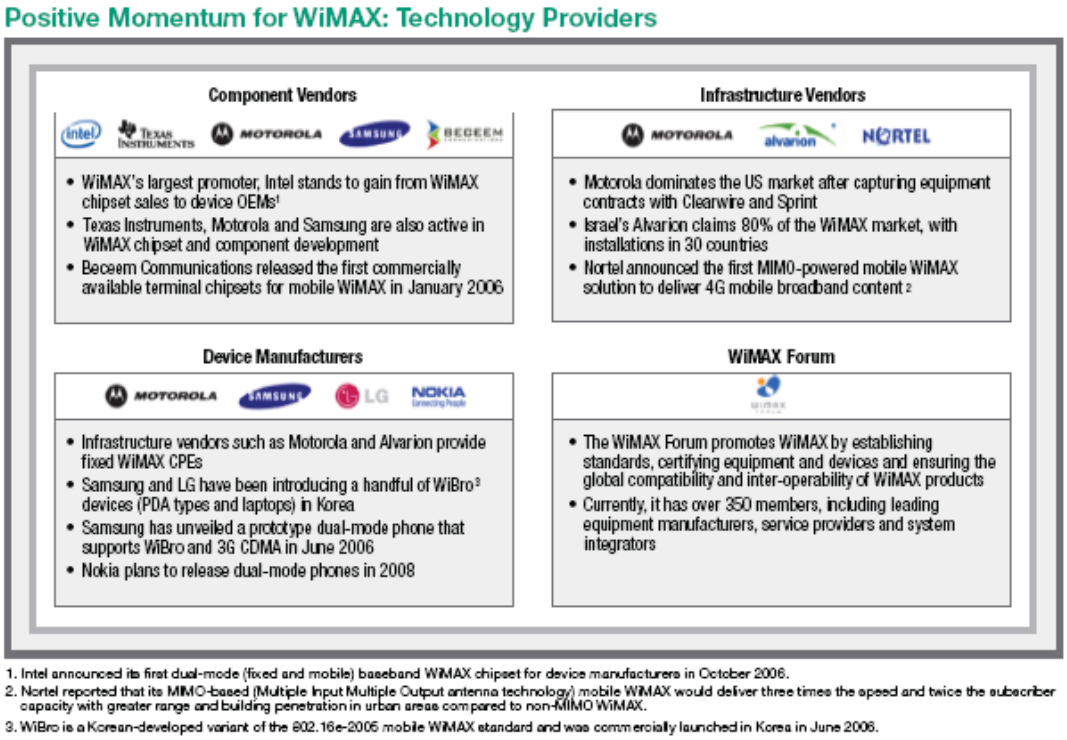


Figure 223 WiMAX service providers [50]

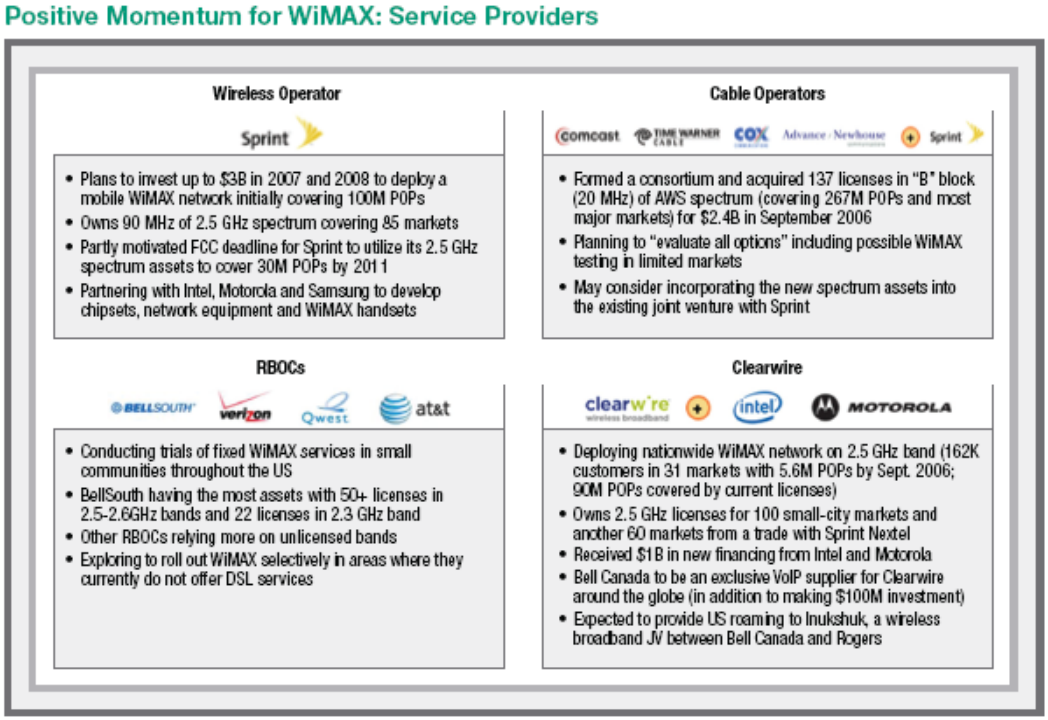


Figure 234 Growing Participants in the WiMAX Ecosystem [50]

4. WiMAX Shareholders

Figure 245 Subscriber Market Investors
Source: packetdata.wordpress.com/

5. WiMAX New Markets

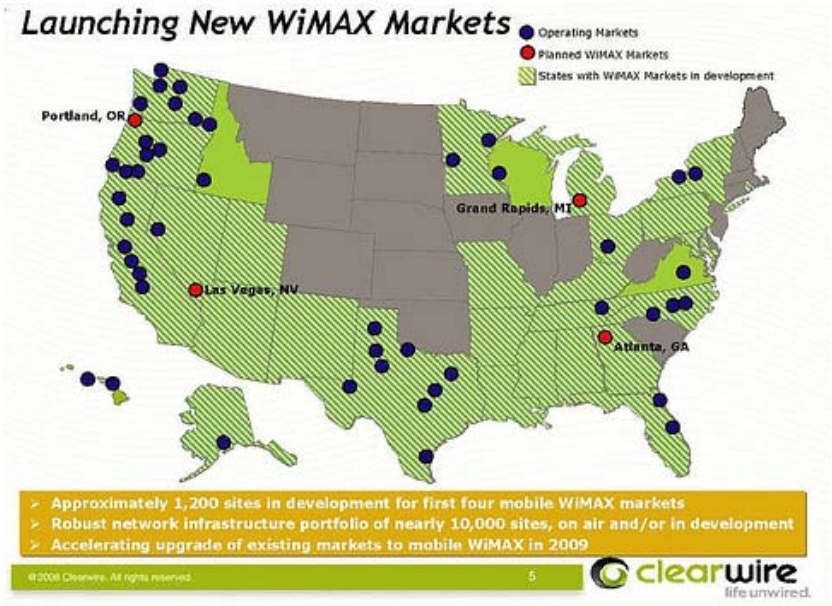


Figure 256 Potential WiMAX Markets
Source: www.clear.com

6. KT Telecom Fact Sheet - Korea

Broadband	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09
Broadband Subs	**6,352,542**	**6,382,446**	**6,413,395**	**6,449,729**	**6,492,321**	**6,515,008**	**6,522,631**	**6,512,848**	**6,511,779**	**6,522,080**	**6,520,022**	**6,513,293**	**6,515,541**	**6,518,821**	**6,555,162**	**6,627,175**	**6,648,047**	**6,684,230**	**6,687,147**	**6,741,946**	**6,811,107**	**6,754,027**	**6,793,156**	**6,771,374**	**6,711,538**	**6,683,979**
Net Addition	**4,817**	**29,904**	**30,949**	**36,334**	**42,592**	**22,687**	**7,623**	**-9,783**	**-1,069**	**10,301**	**-2,058**	**-6,729**	**2,248**	**3,280**	**36,341**	**72,013**	**20,872**	**36,183**	**2,917**	**54,799**	**69,161**	**-57,080**	**39,129**	**-21,782**	**-59,836**	**-27,559**
o Megapass Lite	4,937,187	5,585,070	5,629,537	5,686,454	5,682,919	5,699,599	5,694,737	5,671,453	5,653,174	5,639,452	5,618,010	5,592,588	5,573,114	5,554,600	5,565,964	5,599,970	5,600,582	5,613,366	5,596,844	5,629,828	5,662,337	5,611,047	5,624,066	5,600,155	5,552,393	5,518,916
o Megapass Premium	604,485																									
o Megapass Special	8,204	797,376	783,858	763,275	809,402	815,409	827,894	841,395	858,605	882,628	902,012	920,705	942,427	964,221	989,198	1,027,205	1,047,465	1,070,864	1,090,303	1,112,118	1,148,770	1,142,980	1,169,090	1,171,219	1,159,145	1,165,063
o Megapass Ntopia	802,666																									
Broadband M/S																										
KT	45.2%	45.3%	45.3%	45.3%	45.4%	45.4%	45.2%	45.0%	44.8%	44.7%	44.5%	44.3%	44.3%	44.1%	44.2%	44.3%	44.2%	44.4%	44.4%	44.7%	44.7%	44.2%	44.1%	43.8%	43.8%	
Hanaro	25.7%	25.8%	25.7%	25.6%	25.5%	25.5%	25.5%	25.5%	25.4%	25.3%	25.2%	25.1%	24.9%	24.8%	24.6%	24.2%	24.0%	23.5%	23.0%	22.4%	21.9%	22.6%	22.7%	22.7%	22.7%	
Powercomm	8.6%	8.8%	9.0%	9.3%	9.8%	10.1%	10.3%	10.5%	10.7%	10.9%	11.1%	11.4%	11.7%	11.9%	12.0%	12.2%	12.3%	12.5%	12.8%	13.2%	13.6%	13.4%	13.5%	13.8%	13.8%	
Dacom	0.8%	0.8%	0.7%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%	0.5%	0.5%	0.5%	0.5%	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	
SO	16.6%	16.8%	16.8%	17.0%	17.0%	17.1%	17.2%	17.2%	17.3%	17.4%	17.5%	17.6%	17.5%	17.6%	17.7%	17.8%	17.9%	18.2%	18.4%	18.6%	18.4%	18.5%	18.4%	18.4%	18.4%	
Others	3.0%	2.6%	2.3%	2.0%	1.7%	1.3%	1.2%	1.2%	1.2%	1.2%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.0%	1.0%	0.9%	1.1%	1.0%	1.0%	1.0%	1.0%	

Wireless	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09
Nespot	**470,855**	**465,262**	**459,221**	**450,147**	**447,858**	**446,719**	**432,068**	**422,315**	**421,020**	**419,228**	**411,653**	**406,475**	**401,831**	**398,743**	**395,395**	**391,921**	**388,506**	**389,393**	**387,193**	**379,663**	**376,860**	**370,764**	**363,214**	**359,465**	**351,869**	**347,694**
WiBRO		**1,011**	**1,153**	**1,224**	**4,508**	**6,532**	**19,887**	**27,962**	**38,425**	**64,361**	**80,431**	**102,475**	**106,153**	**115,917**	**120,443**	**145,290**	**158,190**	**197,496**	**201,903**	**187,601**	**177,611**	**172,048**	**175,194**	**176,157**	**160,422**	**164,472**
KT Resale	**2,704,112**	**2,733,691**	**2,782,811**	**2,806,610**	**2,838,079**	**2,888,641**	**2,944,658**	**2,952,185**	**2,920,531**	**2,916,277**	**2,870,464**	**2,873,989**	**2,927,201**	**2,943,999**	**2,919,223**	**2,938,583**	**2,959,223**	**2,901,544**	**2,905,973**	**2,898,953**	**2,894,718**	**2,860,213**	**2,874,966**	**2,861,746**	**2,833,751**	**2,815,794**
- KTF Resale Activation		**123,945**	**117,882**	**128,225**	**126,837**	**152,355**	**144,705**	**138,761**	**73,791**	**86,110**	**73,883**	**118,077**	**180,659**	**135,652**	**132,058**	**195,159**	**150,140**	**93,935**	**166,982**	**151,074**	**108,058**	**81,109**	**133,066**	**83,316**	**83,224**	**92,910**
- KTF Resale Deactivation		**94,366**	**68,762**	**104,426**	**95,368**	**101,793**	**88,688**	**131,235**	**105,444**	**90,365**	**119,696**	**114,552**	**127,447**	**118,854**	**156,834**	**175,799**	**129,500**	**151,614**	**162,553**	**158,094**	**112,293**	**115,614**	**118,313**	**96,536**	**111,219**	**110,867**
- Internal Migration		**0**	**0**	**0**	**0**	**19**	**20**	**89**	**159**	**193**	**8,920**	**2,259**	**6,745**	**3,634**	**28,495**	**4,912**	**3,800**	**4,813**	**7,852**	**16,115**	**8,391**	**7,240**	**15,567**	**7,276**	**16,862**	**16,479**
- Net Addition		**29,579**	**49,120**	**23,799**	**31,469**	**50,562**	**56,017**	**7,527**	**-31,654**	**-4,254**	**-45,813**	**3,525**	**53,212**	**16,798**	**-24,776**	**19,360**	**20,640**	**-57,679**	**4,429**	**-7,020**	**-4,235**	**-34,505**	**14,753**	**-13,220**	**-27,995**	**-17,957**
- Churn Rate		**3.5%**	**2.5%**	**3.7%**	**3.4%**	**3.6%**	**3.0%**	**4.5%**	**3.6%**	**3.1%**	**4.1%**	**4.0%**	**4.4%**	**4.0%**	**5.3%**	**6.0%**	**4.4%**	**5.2%**	**5.6%**	**5.4%**	**3.9%**	**4.0%**	**4.1%**	**3.4%**	**3.9%**	**3.9%**

※ Both the 'activation' and 'deactivation' numbers above include 'internal migration'(2G→3G).

Mega-TV	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09
Mega-TV	**12,090**	**25,921**	**35,790**	**38,765**	**39,463**	**42,511**	**55,254**	**65,221**	**74,999**	**148,354**	**233,809**	**296,912**	**324,609**	**390,027**	**495,913**	**567,230**	**608,734**	**636,536**	**705,856**	**722,857**	**766,058**	**808,101**	**846,651**	**825,760**	**773,109**	**712,131**

Fixed-line	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09
Telephony ('000)	**21,289**	**21,283**	**21,263**	**21,263**	**21,259**	**21,262**	**21,238**	**21,208**	**21,191**	**21,184**	**21,139**	**21,103**	**20,919**	**20,882**	**20,842**	**20,818**	**20,779**	**20,762**	**20,741**	**20,695**	**20,673**	**20,621**	**20,573**	**20,491**	**19,866**	**19,749**
Household ('000)	**958**	**20,316**	**20,284**	**20,281**	**20,266**	**20,259**	**20,219**	**20,180**	**20,153**	**20,117**	**20,064**	**20,018**	**19,980**	**19,936**	**19,894**	**19,861**	**19,817**	**19,796**	**19,768**	**19,719**	**19,689**	**19,635**	**19,579**	**19,496**	**18,883**	**18,766**
Business ('000)	**958**	**967**	**979**	**982**	**993**	**1,003**	**1,019**	**1,028**	**1,037**	**1,067**	**1,075**	**1,085**	**938**	**946**	**948**	**958**	**962**	**966**	**974**	**976**	**984**	**986**	**994**	**996**	**983**	**983**
Domestic Long Distance ('000)	**18,688**	**18,687**	**18,682**	**18,713**	**18,725**	**18,749**	**18,740**	**18,730**	**18,719**	**18,697**	**18,658**	**18,599**	**18,571**	**18,563**	**18,532**	**18,512**	**18,512**	**18,466**	**18,440**	**18,397**	**18,371**	**18,321**	**18,272**	**18,197**	**17,634**	**17,528**
* Ann ('000)	1,747	1,799	1,842	1,882	1,958	2,020	2,095	2,126	2,171	2,214	2,252	2,282	2,308	2,348	2,387	2,433	2,461	2,480	2,532	2,540	2,552	2,584	2,596	2,603	2,611	2,619
* Ringo ('000)	3,766	3,784	3,794	3,809	3,664	3,785	3,779	3,791	3,774	3,783	3,610	3,605	3,843	3,830	3,817	3,821	3,813	3,819	3,815	3,805	3,794	3,773	3,754	3,716	3,685	3,640
* Caller ID Users ('000)	5,315	5,331	5,355	5,403	5,438	5,478	5,503	5,510	5,525	5,538	5,538	5,532	5,538	5,548	5,553	5,569	5,582	5,599	5,599	5,591	5,590	5,586	5,579	5,561	5,535	5,506
* My Style(Local) ('000)	335	421	498	671	775	834	928	1,007	1,053	1,075	1,060	1,044	1,022	1,013	1,005	985	966	950	933	916	902	887	871	856	839	824
* My Style(DLD) ('000)	312	391	464	614	707	757	834	898	931	951	936	920	897	885	877	858	839	823	808	792	780	767	751	738	723	710
Fixed-line M/S																										
Local M/S (subscriber base)	92.2%	92.0%	91.9%	91.7%	91.6%	91.5%	91.4%	91.3%	91.1%	91.0%	90.8%	90.6%	90.4%	90.3%	90.2%	90.1%	90.1%	90.1%	90.1%	90.1%	90.1%	90.0%	89.9%	89.9%	89.8%	
DLD (revenue base)	85.6%	85.5%	85.5%	85.6%	85.6%	85.7%	85.7%	85.7%	85.6%	85.6%	85.5%	85.4%	85.4%	85.4%	85.4%	85.3%	85.3%	85.3%	85.5%	85.6%	85.7%	85.5%	85.3%	85.4%	85.3%	

Reference Data	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09
Population ('000)	**48,378**	**48,391**	**48,405**	**48,418**	**48,431**	**48,444**	**48,457**	**48,457**	**48,457**	**48,457**	**48,457**	**48,457**	**48,457**	**48,444**	**48,481**	**48,494**	**48,507**	**48,519**	**48,532**	**48,544**	**48,557**	**48,569**	**48,582**	**48,594**	**48,618**	**48,630**
Number of Household ('000)	**15,989**	**16,194**	**16,194**	**16,194**	**16,194**	**16,194**	**16,194**	**16,194**	**16,194**	**16,194**	**16,194**	**16,194**	**16,194**	**16,194**	**16,673**	**16,673**	**16,673**	**16,673**	**16,673**	**16,673**	**16,673**	**16,673**	**16,673**	**16,673**	**16,673**	

※ Broadband

- Reorganized service lineup into 2 price packages- Lite and Special in May 19, 2008. Previous Lite, Premium→Lite(50M), Special, Ntopia→Special(100M)

※ Fixed-line

- Telephony : From Jan.2008, number of business line subscribers will be included in Telephony, pursuant to the reporting rules of KCC

- Household : Formerly 'Local' subscribers

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