기술혁신학회지 제6권 제2호
2003년 8월 pp.213-227

Forecasting of ADSL vs VDSL; by Using Lotka-Volterra Competition (LVC) Model

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〈CONTENTS〉

요 약

초고속 인터넷 서비스는 사용자수의 증가와 더불어 고객의 다양한 욕구 즉 인터넷 방송, 주문형비디오(VOD) 서비스, 원격교육, 고화질 TV 등 대용량의 멀티미디어 서비스에 대한 욕구가 폭발적으로 증가하고 있다. 이러한 욕구를 충족하기 위해서는 현재의 초고속 인터넷서비스로서는 속도에 대한 한계에 부딪치게 되어 통신사업자들은 새로운 기술 또는 여러 가지 기술적 대안들을 추구하고 있다.

2002년부터 시작하여 2003년 이후에는 멀티미디어 수요의 증가에 따라 ADSL을 대체하는 기술로 VDSL이 등장하여 매년 꾸준한 신규가입자 수요가 발생하고 있으나, 통신사업자들은 각각의 망 특성, 시장위치, 전략적 필요성 등에 의해 상용화를 적극 검토, 추진하고 있으나 각각 전개하는 방식은 조금씩 다르다.

따라서 본 연구에서는 통신사업자들의 가입자망 진화 전략에 대해 살펴 본 다음 Lotka-Volterra Competition (LVC) 모델을 이용 ADSL 과 VDSL 두 기술간의 상호 경쟁 및 대체를 통해 어떻게 진화 되어가는지를 살펴보았다. 대표적인 통신사업자인 KT는 막강한 자금력을 바탕으로 시장 확대 및 경쟁사와의 차별화를 위해 VDSL 서비스 조기도입을 서두르고 있고, 하나로는 자금의 열세로 인한 ADSL 투자비를 회수 할 때까지 VDSL 서비스를 연기하고 있는 실정이다. ADSL 과 VDSL 두 기술의 관계는 Lotka-Volterra Competition (LVC) 모델을 이용한 시뮬레이션 결과를 통해 빠른 속도와 비슷한 가격대의 VDSL이 침략자(predator)로 기존 시장 지배자인 ADSL을 사냥감(prey)으로 빠른 속도로 대체해 나가는 것을 알 수 있었다.

Key Words: LVC Model, Access network, Evolution Strategies, Forecasting, ADSL, VDSL
핵심어: LVC 모델, 가입자망, 기술예측, ADSL, VDSL

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Ⅰ. Introduction

The broadband Internet service market has reached its peak in less than three years with its subscribers having attained a level of saturation. A mere 370,000 households subscribed to high-speed Internet in 1999; this number grew to over 4 million in late 2000. In December 2002, the number of domestic high-speed Internet subscribers was registered at 10 million.

In the context of rapidly changing Internet service environments driven by high-speed Internet services, customers are showing themselves ever more desirous of more convenient and fast communication media. The increasing need is further for a post-ADSL Internet service that can enable large-volume multimedia services such as Internet broadcasting, video-on-demand (VOD), on-line education, high definition TV, and other nascent large-volume content services. From the viewpoint of the Internet service providers, the creation of new demand, quality enhancement and subscriber network optimization have become new competitiveness issues in the face of intensifying competition to switch over subscribers among the companies of the Internet service providers.

The pressing questions are what is the next stage of high-speed Internet and how development strategies of Telcos will evolve in preparation for the next ADSL age. While it is still difficult to predict whether VDSL will actually replace ADSL as the next generation broadband Internet service, it is certain that it has come to count as one of the major technologies soon to be implemented. KT and Hanaro Telecom have been focusing on VDSL service instead of ADSL service. Heightened consumer also interest in video-streaming services since the start of digital TV service is expected to create high demand for VDSL.

In this manner, anyhow, the migration toward the VDSL market is to take place; in other words, the current subscribers to ADSL are to migrate to the VDSL service. However, it is still very difficult to predict when, to what extent, and how fast this migration will take place. Hence, in this article, we shall first analyze the environment of high-speed Internet service, and then proceed to an examination of the Telcos' strategies for transforming subscriber networks. Finally we will attempt to technology forecasting by projecting as to ADSL vs VDSL subscribers by using Lotka-Volterra Competition (LVC) Model.

Ⅱ. Environment of the Broadband Internet Market

According to the results of the surveys, carried out by the Korea Network Information Center (KRNIC), the number of Internet users surpassed 10 million in December 1999, and 24 million in 2001[8]. This explosive trend brought the total to 26 million in December 2002. However, the rate of increase is gradually slowing down. The number of Internet users, reaching 28 million by the end of 2003, is forecasted to arrive at a saturation point. This means in other words that potential demand for high-speed Internet

〈Table 1〉 High-Speed Internet Service Market Structure

(Unit:10 Thousand)

	Dec. 2000	June 2001	Dec.2001	June 2002	Dec. 2002
KT	173	310	385	433	492
Hanaro	110	157	207	243	287
Thrunet	76	105	130	130	130
Others	46	79	59	66	131
Total	405	652	780	872	1,041

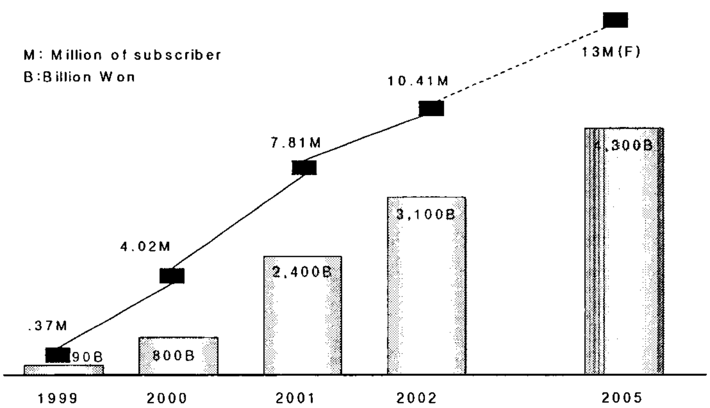
subscription becomes zero.

<Figure 1> shows the increase of domestic high-speed Internet subscribers from 1999 to 2002. As can be seen in this figure, a mere 370,000 households subscribed to high-speed Internet in 1999; this number grew to over 4 million in late 2000. In December 2002, the number of domestic high-speed Internet subscribers was registered at 10 million.

Among these subscribers, ADSL subscribers account for 54.4% of the total high-speed Internet subscriptions, in other words, over 5.7 million; cable network subscribers 34.2%, or 3.5 million. In addition, subscribers to LAN and satellite represent about 11% or 1.1 million.

This explosive increase was brought about in only three years by the sudden growth in the number of customers, to an extent no one predicted. However, as the number of subscribers rises from 10 million to 11 million toward the end of 2002, this number will gradually near its point of saturation, making further growth unlikely. From the point of view of the providers, this means the exhaustion of the potential demand, and points to the need to put forth efforts to create new demand, and to switch over other compa-

〈Figure 1〉 Overview of High-speed Internet Service Subscribers and Market Volume



nies' customers while maintaining existing demand.

As we look at the market structure of the domestic Internet, as shown in Table 1, KT currently (December 2002) serves 47.6% (4,920,000) of the total subscribers, followed by Hanaro Telecom, with 27.6% or 2,870,000, and Thrunet with 1,300,000 subscribers (or 12.5%)[11]. As table 1 shows, the broadband Internet service is taken market share of 72% of total market by two major providers, KT and Hanaro. Nevertheless, as has been mentioned above, the exhaustion of potential demand in high-speed Internet is likely to trigger a fierce competition for larger market shares between two companies in the industry.

Ⅲ. Telcos' Access Local Loop Evolution Strategies

Along with the growing number of subscribers to the broadband Internet, a dramatic increase is noted in customer demand for various large-volume multimedia services such as Internet broadcasting, VOD services, online education, and HDTV. Continuous expansion of cable networks, Ethernet-based concentrated residential area networking, and WLL, the fastest developing of all, are three noteworthy post-ADSL alternatives under consideration, each with its own advantages.

In particular, one of the new types of services provided, named 'Cyber Apartment Service,' takes into account specifics of the domestic housing infrastructure, dominated by collective residences (apartment complexes). Cyber Apartment Service is a broadband/Ethernet service that is connected to each apartment complex through trunks of 45M, 155M, 1G or E depending on the size of the complex. Fiber-optic cables connect each building with the LAN switch in the complex's communication office, and UTP cables connect each apartment to the building.

However, the most noteworthy technological alternative at present remains VDSL. While it is still difficult to predict whether VDSL will actually replace ADSL as the next generation broadband Internet service, it is certain that it has come to count as one of the major technologies soon to be implemented. Korea Telecom has started pilot installations of VDSL in Mokdong Housing Development #10. Hanaro Telecom started pilot services in Seoul residential areas including Dogok-dong using VDSL equipment from NLC and Space Cyberlink. Demand for VDSL is likely to be higher in newly developed residential areas, in particular new apartment complexes, which are equipped with broadband-Internet-ready infrastructures, and whose residents have relatively higher buying power[5].

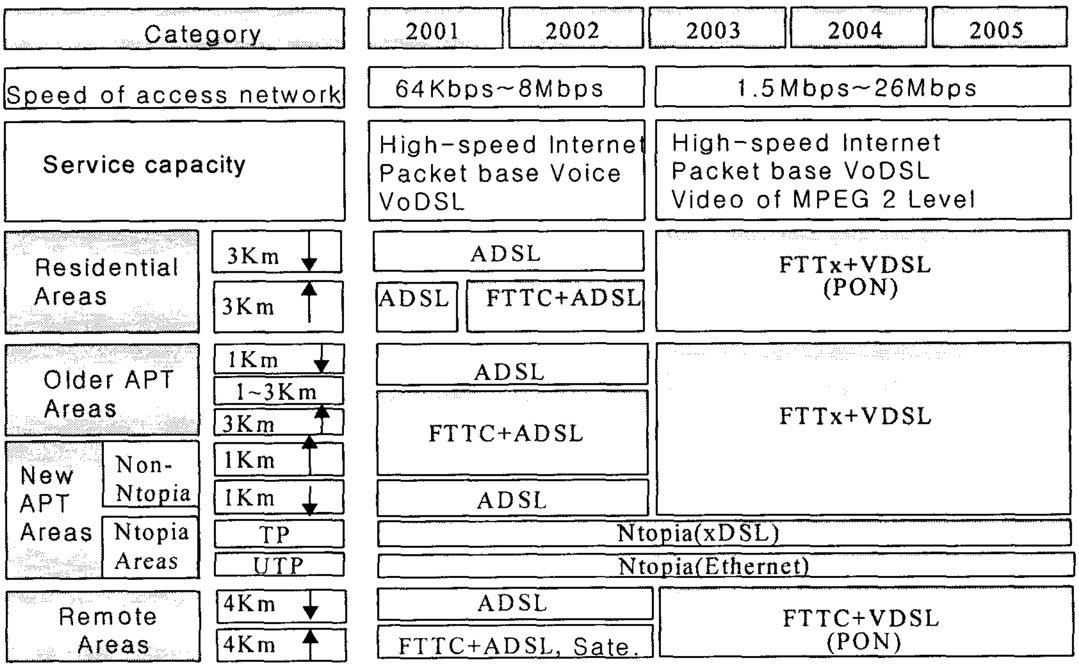
As, following the rise in multimedia subscriber numbers, VDSL emerged as next technology after ADSL, it has been experiencing steady increase in subscriber numbers since 2003 after its start in 2002, and communication companies are actively examining its implementation, according to their individual networking characteristics, locations of their markets, and their strategic necessities. However, each company deploys different development strategies.

1. KT's Migration Strategies of Subscriber Network

For KT, raising the connection speed is the top priority in its access network migration policy[4]. Paying heed to the large number of customers whose main concern is higher speed, KT is developing strategies for ensuring variable bandwidth of minimum 2M (per individual) and 10M (per household). In order to diversify and subdivide bandwidth ranges offered, KT has set as its goal, in the long term, to build a FTTH (Fiber To The Home) subscriber network boasting a two-digit Mbps level; in the medium term, a 26Mbps speed level network using VDSL and FTTC; in the short term, a broadband network via ADSL and LAN. Among KT's broadband access network migration plans, one that centers on general residential areas is summed up in Figure 2.

Apartments account for 45% of domestic housing, and this type of demographically-dense housing is expected to be further in demand in the future also. The government, with a broadband certification system for apartments geared to encourage installation of UTP (Unshielded Twister Pair) cable at the initial stage of construction, has contributed to preparing apartment complexes for easy Internet connections. In this circumstance, KT launched Cyber Dream Town, and offered a product-line called 'Ntopia', that aims to provide high-quality Internet access services, targeting high-population residential areas including apartment

〈Figure 2〉 KT's Network Migration Plans for Residential Areas



complexes, and also other applied Internet services.

Ntopia service for access services can be divided into two different types according to access methods. FTTC-LAN (Fiber to the Curb-Local Area Network), Ntopia's main line of business at present, provides 2M to 10M speed access to collective residential complexes; FTTC-xDSL (Fiber to the Curb-Digital Subscriber Line) provides SDSL and VDSL broadband access to housing complexes without UTP cable using phone lines[3]. These access methods reflect cost efficiency and availability of services to individual housing complexes, and specifics associated with different complexes.

2. Hanaro Telecom's Migration Strategies of Subscriber Network

Thanks to its high brand recognition level and quality services, Hanaro Telecom has maintained its market share at 27% in 2000, 27.6% in 2002. Furthermore, 76% of its sales profit comes from broadband Internet, followed by 17% from telephone/VoIP, and 6% from network solutions. Hanaro is also affected by the saturation of the broadband Internet market, and is striving to create new markets within the intermediary services market. Their challenge is also to enhance quality and optimize subscriber network in the face of intensifying competition for switching over subscribers. Figure 3 summarizes Hanaro Telecom's projection for the developmental direction of broadband subscribers' networks according to types of users[15].

Hanaro Telecom, with 2,700,000 home subscribers and 3,000,000 business subscribers, is currently planning to offer additional services such as VODSL and VOIP in order to increase its profitability level, and is

〈Figure 3〉 Hanaro's Strategy for Subscriber Network Migration

Category	Home Subscribers		Business Subscribers Including Buildings
	APT complex	Residential Areas	
Present	ADSL	HFC	FTTO : (SDH, PDH base)
↓	↓	↓	↓
Present + Future	VDSL	HFC Upgrade	FTTO : (SDH, PDH, PON base)
↓	↓	↓	↓
Future	FTTH (such as PON)	FTTH (such as PON)	FTTO : (MSPP base)

expected to offer these new services using methods such as VDSL, electronic communication, satellite, and next Hanaro's strategies in detail can be divided in two large categories. The first consists in providing NVOD services that upgrade ADSL functions and DSLAM trunks in order to provide ADSL based streaming, of which pilot services are scheduled. This category also includes plans to offer ATM based video streaming services.

The second strategy consists in maximizing existing infrastructure of FTTC in order to build a VDSL network capable of high quality video streaming services (HDTV). In other words, they will try to provide VDSL services (network compounded by ADSL and VDSL) by upgrading functions of DSLAM. As transmission distance must be within a certain range in order to provide stable real time video streaming, the company will maintain FTTx+VDSL network structure, and is planning to offer multi channel video streaming services.

While Hanaro is likely to introduce VDSL as a transitional step in the evolution toward FTTH for its apartment residing subscribers' post ADSL broadband service, the company estimates that it will take some time before VDSL replaces ADSL, pointing out that there are to date no real international standards for VDSL, and that VDSL requires a broadband equipped subscribers' network more than ADSL does; finally, that there is not yet an adequate amount of multimedia services or content providers. However, the biggest reason why Hanaro is delaying their switching to VDSL is in reality that they have not yet collected their investments in ADSL, and that it will take at least 5 to 6 years to reach the break even point. This is why, although they have verified the advantages offered by VDSL through their pilot service run in Dogok in July 2000, they will try to delay the switching over as long as possible until they reach the break even point.

3. Thrunet's and Dreamline's Migration Strategies of Subscriber Network

Thrunet, the first communication company to introduce high speed Internet service to the Korean market in 1998, held market share of 49% in late 1999. This share has since been eroded by the market entrance of KT and Hanaro Telecom, dwindling to 19% toward the end of 2000. Although the official annual report is not yet available, Thrunet's market share in late 2002 is estimated at 11%. Thrunet first entered the market by providing high speed Internet access both through TV cable networks, and ADSL access using phone lines. While Thrunet possesses a strong cable TV network infrastructure with comprehensive diversified technologies, it is handicapped by the fact that over 50% (figures from late 2001) of its customers are businesses. Thrunet is striving to develop differentiated product lines suiting different types of customers. Thrunet aims to become the second largest provider in the Internet access market by taking over Dreamline with their acquired capital.

Dreamline's market share fell from 7% in 1999 to

3% in late 2002. Shrinking market share leading to a diminished profit, the company has not built a high speed Internet infrastructure. It shifted its strategic focus from broadband Internet and DreamX (multimedia portal) to leased line service targeting small and medium businesses. In order to enhance its financial structure, it is deploying active efforts to draw in foreign capital. In the goal of securing profitability and improve the company's image, it has entrusted its communication network business to a specialized technology firm, and is in the process of preparing a self rescue plan, attempting a rebirth as company specialized in Internet services. Dreamline has now decided to undergo a whole sale conversion of its business structure by becoming a specialized service firm focusing only on Internet services development, network planning and architecturing.

Ⅳ. Access Network Technology Forecasting

When a given technology begins to mature(i.e., as improvements become increasingly difficult and expensive), a new technology will often emerge that can accomplish the required function in a more effective and economic manner. In its early stages, the new technology is usually inferior to the old in almost all of the standards by which technologies are traditionally measured. However, the new technology will often have certain properties that give it special advantages in a small segment of the market. Thus, technology changes through a process of successive substitution.

A new technology replaces an older technology because the newer one is better than the old one in some ways, e.g., performance, cost, appearance, etc. Since most new technologies progress on the basis of a large number of continuous incremental changes and basically through the recombination of existing know how, empirical studies show that growth pattern of the figure of merit of a technology follows an S shape. Thus, the technological change process over considerable period represents a series of sequential substitutions, each following S shaped growth curve.

Over the years, a number of mathematical models have been proposed to represent the time pattern of the substitution process, that is, the process by which the adoption of a technology spreads and grows to replaces an existing technology. There have been published numerous research papers exploring different technological growth curves[1], and most of these studies resulted in deterministic interpretation of the time dependent aspects of the S shaped substitution process. The underlying behavior theory of S shaped different technological growth model is that the substitution is an imitation process[4]. The process, in general, is described by following differential equation:

1) For more detail, see Technological Growth Curves(Peg Young, 1993) Technological Forecasting and Social Change 44 (1993) 375-38

$$\frac{df}{dt} = bf(F-f)$$

where f is the market share of a product at time t, F is the upper limit of the market share, and the parameter b is the coefficient of imitation or internal influence. The solution of above equation yields the S shaped depiction of the substitution process[2].

In the analysis of an ecosystem, the analysis of the dynamic equilibrium of predator-prey systems is one of the fundamental subjects and Lotka-Volterra equations are prevalently used for this dynamic equilibrium[3]

After Lotka and Volterra working simultaneously but independently, generalized growth model of interaction of biological species competing for the same resources, the Lotka Volterra competition (LVC) equations is analyzed for the special case of dominant competitor at equilibrium being replaced after the introduction of a small population of an invading competitor with a competitive advantage. Several researchers have used the LVC equations to forecast the new technology with competitiveness where the dominant competitor is at market saturation[14]. Porter et al[13] examine the LVC equations in detail, discussing the physical meaning of the model parameters and showing that many types of behavior such as liner, exponential, confined exponetial, logistic and Gompertz can be related to the LVC equations at different limitimg values of model parameters. Bhargava[1] uses time-varying parameters to show that LVC equations can approximate the time response. Farrell[6] shows that LVC equations are fitted to modeling the long-term evolutionary growth of technology by using lead-free cans replacing soldered cans, turfted carpets replacing woolen carpets and ball point pens replacing fountain pens.

The advantage of LVC equations to other substitution models is while LVC equations can indeed mimic the Bass, NSRL, Gompertz and Sharif-Kabir curves, they can not achive arbitrarily close fits to these curves, especially at arbitrarily small initial conditions. This is beacause the asymtotic behavior of the LVC equations differs from other substitution equations. The another advantage of LVC equations is that the method of modeling substitution with coupled differential equations are quite powerful and allow the use of data from both the invading technology and declining technology to obtain better forecasts.

1. Driving the LVC equations

The simplest differential equation describing technology growth is:

$$\frac{dX}{dt} = rX \qquad (1)$$

where X is the population of technology at time t, and r is a constant. X, the population of technology,

2) Mansfield model, Blackman model, and Fisher and Pry model have been served on the basis of this equation. For more detail, see Easingwood, Mahajan, and Muller(1981)

3) Hofbander, J., Sigmund, K., The theory of Evolution and Dynamical System. Cambridge University Press, Cambridge.

can be expressed several ways, e.g., rate of units sold, volume of market share, etc. The analytical solution of equation (1) is:

$$X = X_0 e^{rt} \tag{2}$$

where X0 represents initial conditions, that is the density at time t=0. Such a model can be successfully used for description of the growth of a technology. Equation (1) can hold only for a limited period of time. Ultimately an increasing population will exhaust its resource. Thus an equation, which is often used to describe the technology growth, is the logistic equation:

$$\frac{dX}{dt} = rX\left(1-\frac{X}{K}\right) \tag{3}$$

or

$$\frac{dX}{dt} = aX - bX^2 \tag{4}$$

The justification for this equation is that it is the simplest differential equation with two features: (i) when X is small, the equation reduces to equation (1), and the growth is exponential, and (ii) as t increases, X approaches a steady value without oscillations.

In equation (3) r is referred to as the intrinsic rate of increase and K as the carrying capacity. The term 'carrying capacity' refers equilibrium market size of technology in the absence of competition.

The technology or product will grow in an exponential growth due to the capability of multiply. The more products sold and the more attractive they are, the higher the rate of sales will be. Thus, depending on its attractiveness, every product sold will bring new customers. As a result, we can define, attractiveness = ea, Where a is the constant.

In equation (4), The first bend of S curve comes from the first term. The coefficient b expresses the strength of internal competition between members of the same technologies or products. It means that the percent rate of growth is also proportional to the still empty space in the market niche. The second bend of the S curve comes from the second term in equation.

The solution of this equation is the ubiquitous S shaped curve that enters extensively into every technology growth. The origin of competition is due to competition of the same technology in a crowed niche. If more then one technology comes out, the S curve law would not generally apply due to the competition between technologies. Whenever there is more than one competitor in the same niche, we must consider the interaction between them.

The usual analysis of competition between two technologies, going back to Lotka(1925) and Volterra(1926). By using the Lotka Volterra model, two competitor systems are:

$$\frac{dX}{dt} = a_x X - b_x X^2 + c_{xy} XY \tag{5}$$

$$\frac{dY}{dt} = a_y Y - b_y Y^2 + c_{yx} YX \tag{6}$$

〈Table 2〉 Six ways in Which Two Competitors can Influence Each Other's Growth rate

MODE	DEFINITION	Coupling Parameters	
		X	Y
Pure competition	Both species suffer from each other's existence.		
Predator Prey	One serves as food for the other.	+	
Mutualism	Symbiosis: a win win situation.	+	+
Commensalism	A parasitic type of relationship in which one species benefits from the existence of the other, which nevertheless.	+	o
Amensalism	One species suffers from the existence of the other, which remains impervious to what is happening.	-	o
Neutralism	No interaction whatsoever	o	o

where c_{xy}, and c_{yx} are coefficients of technologies X and Y. The coefficients can be considered the number of units of the competing technology that is inhibited from existing by the existence of one unit of technology.

For the computational convenience, the discrete forms of equations, which using the notation of Modis[10], are

$$X(t+1) = \frac{\lambda_x X(t)}{1+\beta_x X(t) - D\beta_x Y(t)}$$

$$Y(t+1) = \frac{\lambda_y Y(t)}{1+\beta_y Y(t) - D\beta_y X(t)}$$

where $\lambda_i = e^{a}{}_{i},,$

and $\beta_i = \dfrac{b_i(e_i^{a}-1)}{a_i}$ for $i = x, y$

and $A = \dfrac{C_{xy}}{\beta_x}$

$D = \dfrac{c_{xy}}{\beta_y}$

Assuming that X is the incumbent and Y the attacker, we can define A as the attackers' advantage and D as the defender's counterattack. For technologic species competition these parameters quantify the extant to which the defender can prevent from stealing market. According to the study of Cooper and Kleinscmidt[2], the most statistically significant parameter determining gain in market share was a "superior product that delivered unique benefits to the user." This and price considerations are the largest component of the attacker's advantage quantified by the parameter A. Under attack, the defender redoubles its own effect to maintain or improve its position. A high value for D implies more effective counter attack.

Modis[10] distinguished and labeled six ways in which two competitor can influence each other growth rate according to the sign of the two coupling parameters involved. The following table is examples of dynamic shifting of the relation between two technologies from one type of interaction to another.

2. The Simulation Results

To see the migration process from ADSL service to VDSL service, we adopt the LVC model. ADSL service as a defender dominates subscriber network but having attained a level of saturation. As the customer demands for various large volume services such as Internet broadcasting, VOD services, online education, and HDTV, The broadband Internet service providers have launched VDSL service in August 2002. VDSL can provide up to 13Mbps transmission speed within the range of 300m to 1.6km from the central office, and in the case of non symmetric services, up to 52 Mbps data transmission speed. As VDSL service can handle large volume multimedia services and the price of usage are as low as much that of ADSL service, we assumed that VDSL service is an attacker in LVC model.

The raw data we need is the number of subscribers of each subscriber network technology[4]. The principal information needed by the model is an assessment of how the defender and attacker would have grown in the absence of each other. The LVC model is a question of solving a pair of simultaneous differential equations[5] This establishes both sets of parameters a and b and hence β and λ in eqs. (7) and (8). These equations can then be computed to find the attacker's advantage, A and the defender's counterattack, D. In our study, we assumed that defender's counterattack is 0 because the major ADSL service provider, KT and Hanaro Telecom do not want to deploy ADSL subscriber network any more. They are focusing on VDSL service as a post ADSL subscriber network. The parameters estimated by using Lotka Volterra equations are shown in Table 3.

The simulation results of LVC show that ADSL service had reached its saturation point at the level of

⟨Table 3⟩ Summary of Lotka Volterra Model Parameters

	Parameters						
	a	b	β	λ	r	D	A
Defender (ADSL Service)	4.86			0.82	0.88	0	
Attacker (VDSL Service)	13.4	0.25		1.28	0.84	–	0.26

Once the parameters have been established, the number of subscriber data can be fitted to stepwise enumeration of eqs. (7) and (8). The results are shown in Table 4 and Figure 4.

4) The official data of ADSL subscribers is published by Ministr of Information and Communication(MIC) every month, but the number of VDSL subscribers is not published officially. The data of VDSL subscribers were collected from KT and Hanaro Telecom. The data we used as the number of subscribers are monthly data from July of 1999 to March of 2003 for ADSL service, from March of 2001 to March of 2003 for VDSL service, respectively.

5) For more detail, reffer Farrell(1993). He showed how to solve LVC equations practically.

6.3 millions of subscribers by the end of 2002. Until the early of 2004, the number of ADSL service subscribers is stagnated, and is decreasing onward. VDSL service, which was started in the early of 2001, begins to emerge in earnest and reached 1.5 million in 2003. Ultimately, VDSL service subscribers surpass the number of ADSL service in early 2005.

V. Conclusion

The basic goal of this paper was to examine the Telcos' evolution strategies of local loop and to forecast migration process form ADSL to VDSL. As the broadband Internet service market has reached its peak with its subscribers having attained a level of saturation, and the customers want to more convenient and fast broadband Internet service the pressing questions are what is the next stage of high speed Internet and how development strategies of Telcos will evolve. VDSL is receiving attention as an alternative technology because VDSL can provide up to 13Mbps transmission speed within the range of 300m to 1.6km from the central office, and in the case of non symmetric services, up to 52 Mbps data transmission speed. In particular, VDSL can handle large volume multimedia services

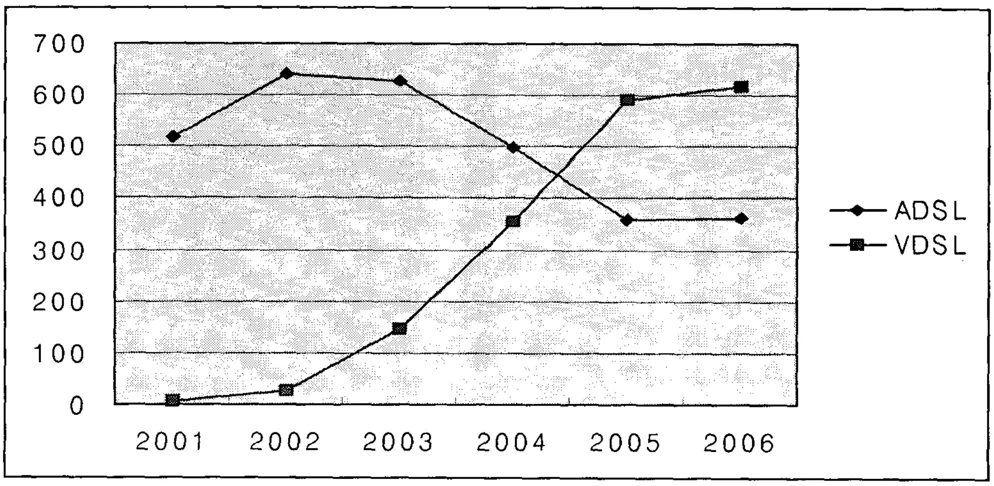
〈Table 4〉 The Results of the Lotka Volterra Model

(Unit: 10 Thousand)

	2001	2002	2003	2004	2005	2006
ADSL	518	639	628	499	359	360
VDSL	6	25	147	356	592	616
Total	524	664	775	854	951	978

〈Figure 4〉 ADSL vs VDSL Subscriber Forecasting: By Using LVC Model

(Unit: 10 Thousand)



such as Internet broadcasting, VOD, online education, HDTV.

For these reasons, we have analyzed the migration process from ADSL to VDSL by using LVC model. The origin of LVC model is generalized growth model of interaction of biological species competing for the same resources. But in this article, we introduced the Lotka Volterra competition (LVC) equations as the special case of dominant competitor at equilibrium being replaced after the introduction of a small population of an invading competitor with a competitive advantage. we adopt the LVC model with ADSL service as a defender and VDSL service, an attacker.

The simulation results of LVC show that ADSL service had reached its saturation point at the level of 6.3 millions of subscribers by the end of 2002. Starting from early 2004, the number of subscribers of ADSL is decreasing due to VDSL service subscribers will begin to emerge in earnest in 2003. Ultimately, VDSL service subscribers surpass the number of ADSL service in early 2005.

From our simulation results, the migration process from ADSL to VDSL is very fast. This is driven not only by customers need for 'more fast'; and 'more large volue of multimedia' but also by Telcos strategies for 'create new demand' and 'enhancement of competitiviness'. Under these circumstance, the government need to clear cut what is the next stage of high-speed Internet and what is the next generation network (NGN) implementation policy, especially on broadband Internet service. And also showing definite vision and roadmap of FTTH(Fiber to the Home) is very important as soon as possible.

From our study, 2 areas are remaining for further research. We have shown the evolution strategies of local access network from ADSL to VDSL but we need further studies the evolution path of FTTH(fiber to the home) ultimately. Everyone says that FTTH is the ultimate technology of local access network but no one say that how development of FTTH will evolve. Our study did not mentioned, either. Another remaining part for further research is the model. The Lotka Volterra model in our research describes interactions between two technologies, ADSL and VDSL. In the local access network, HFC(Hybrid Fiber Coax) is one of the major technology. The subscribers of HFC among the local access network account for 34.2%, or 3.5 million in 2002. Thus, the Lotka Volterra model with two technologies needs to extend to with three technologies model.

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