Broadband Access in Korea: Experience and Future Perspective

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ABSTRACT

With the growing popularity of the Internet, Korea has been successful in providing broadband Internet services to the level of universal service. More than 70 percent of households have high-speed Internet connection, and their lives have been changed dramatically. The cutting edge technology of broadband Internet has a profound impact on many aspects of the economy, education, entertainment, and social culture. This article addresses the experiences and future perspectives of KT (formerly Korea Telecom) in providing the broadband network and services in Korea. We present our experiences in the deployment of the world's largest ADSL network, and our ongoing deployment of VDSL and WLAN. Based on the accomplishments in broadband access, we will also provide a forecast on the next generation of broadband services and the corresponding technologies required to support these services.

INTRODUCTION

According to the Korea Network Information Center (KRNIC), the number of high-speed Internet connections, based mainly on digital subscriber line (xDSL) and cable (CATV), surpassed 10 million by the end of 2002 [1]. This corresponds to more than 70 percent of households and almost coincides with the 80 percent penetration of personal computers. Out of these 10 million users , 6.1 million subscribe to xDSL services. KT alone has 5.4 million xDSL subscribers, including 0.8 million users subscribing to very high-data-rate DSL (VDSL) services. The large number of xDSL users can be attributed to the preinstalled copper pairs for plain old telephone service (POTS) that cover the entire country with no additional cable installation required. CATV is the second popular solution, with 3.7 million subscribers. These statistics are remarkable considering the current stagnation of the telecommunications industry worldwide.

The widespread availability of broadband Internet is now affecting every aspect of daily life. A significant portion of offline activities have shifted to online networks. Nearly all transactions of banking, finance, tax payment, and stock trading are available at home, and Internet shopping has already grown to 10 percent of the total retail market. The successful deployment of broadband Internet is the result of harmonization of network infrastructure, public policy, demographic profiles, and other factors. From the policy side, regulators strongly encourage controlled competition in the marketplace. This enables the normal user to get high-quality service at a low price. The service providers, in turn, are constantly striving to keep the cost low while increasing the quality of services. This has resulted in a wide range of service portfolios based not only on ADSL but also on other advanced technologies such as VDSL, Ethernet, and wireless LAN. To offer a glimpse of current service offerings, Table 1 shows the broadband service portfolio of KT under the umbrella brand Megapass. The service consists of several subcategories according to data speed and technology used, all with a monthly flat rate. A whopping two-thirds of subscribers selected *Megapass Lite* rather than *Megapass Premium* because of its relatively high speed and reasonable price. On the other hand, *Megapass Special* and *NESPOT* users are fast growing because of the significantly higher speed and wireless access, respectively, of these two services.

Another reason for this success is the high population density in the distinctive residential segments in Korea. Two distinctive segments are the apartment area and non-apartment area, which hereafter we call housing areas. The apartment area, where nearly 40 percent of the total population lives, is especially suitable for providing economical fiber-based services. High population density and a distinctive residential environment contribute to shortening the copper loop length. Accordingly, half of the subscribers are within 2 km of the central office (CO) and 80 percent within 3 km. The average distance from CO to subscriber is around 2.5 km. These factors enabled cost-effective broadband deployment.

KT, now serving almost 50 percent of the Korean broadband market, has been in a pivotal position in the introduction and expansion of broadband services in Korea. This article describes KT's experiences and future perspec-

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tive on next-generation services and networks. We will first give a description of the current broadband access network, the asymmetric DSL (ADSL) network. This will be followed by descriptions on newly emerging broadband network services based on VDSL, Ethernet, and wireless LAN technology. Finally, we provide our vision of the evolution of our future broadband network and services.

The Current Broadband Access Network

The decrease of local and long distance call traffic, mainly resulting from the introduction of cellular services, forced traditional service providers to look for new growth engines beyond telephone services. KT started by introducing Internet access service, which was initially based on ISDN with a speed of 128 kb/s. The service, however, proved insufficient for multimedia purposes and could not satisfy customer demand. Accordingly, ADSL was chosen as the broadband Internet technology, and intensive investment took place in 1999. ADSL is now a mature technology, and other enhanced services based on new technologies are emerging. Nevertheless, ADSL-based access service still occupies the largest portion of the current broadband access market.

Figure 1 shows two kinds of ADSL networks. The first one is ADSL directly from the CO, called CO-ADSL. In this scheme, DSL access multiplexers (DSLAMs) are located in the CO, and subscribers are directly connected to DSLAMs only through twisted pairs. About 90 percent of installed ADSL lines are CO-ADSL, mainly provided for housing areas. CO-ADSL, however, may not be effective for remote subscribers more than 3 km away from the CO. About 20 percent of all subscribers fall into this category, and they are the first candidates to be connected by fiber-based broadband access.

Megapass	Main technology	Max. speed (down/up, b/s)	Main target area
Lite	ADSL	2 M/640 k	Housing areas
Premium	ADSL, VDSL	8 M/640 k	Housing areas
Special	VDSL	13 M/13 M 25 M/3 M 50 M/7 M	Apartment complexes
Ntopia	Ethernet	10 M	Newly built apartment complexes
NESPOT	Wireless LAN	11 M	Home, SOHO, hotspot (combined with wired access)

Table 1. *The umbrella brand of KT's broadband services.*

The second type of ADSL is based on fiber to the curb (FTTC). FTTC-ADSL mainly serves subscribers in apartment areas or, to avoid degradation of ADSL quality, in housing areas where the loop length is 3 km or more away from the CO. In this scheme, the optical line termination (OLT) is placed in the CO, and the optical network unit (ONU) in the apartment area. So far, current access networks are based on asynchronous transfer mode (ATM) and ADSL. On the contrary, emerging broadband access networks are based on IP, Ethernet, and VDSL.

The successful deployment of an ADSL network depends heavily on the provisioning and maintenance capabilities of the service. For the provisioning side, shortening the delay between service request and actual provisioning becomes a key issue. On the maintenance side, timely and/or proactive service quality maintenance activity are crucial. For this purpose, KT has implemented an integrated management system. The system is divided into three components with respect to the subscription process. Before subscription, customers can get service availability information and network quality with the help

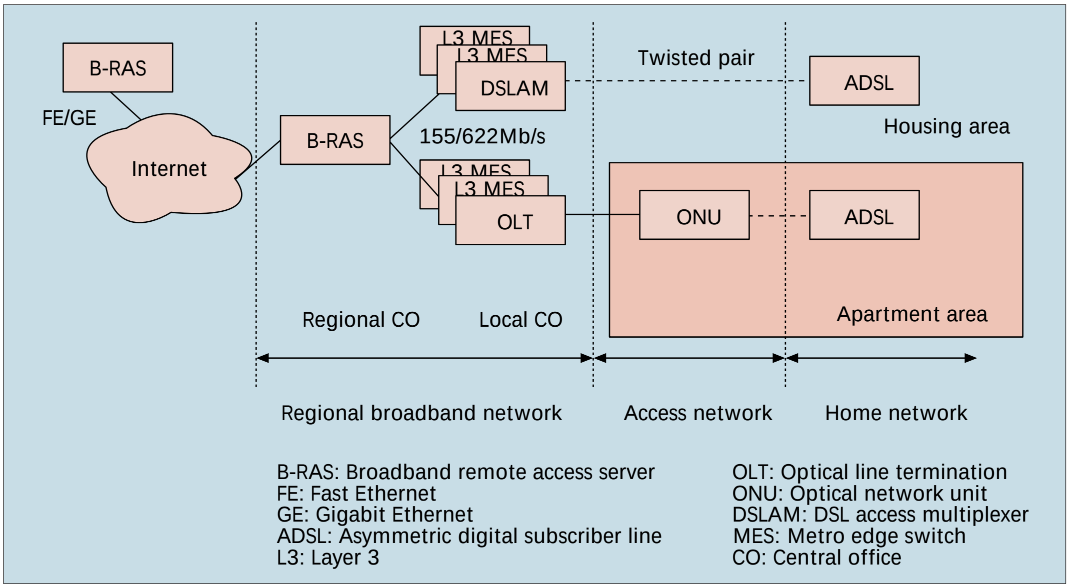

Figure 1. *The ADSL access network of KT.*

For proper maintenance of the service, interoperability between devices from diverse vendors is crucial. Lack of interoperability can incur unnecessary cost when a device needs to be replaced.

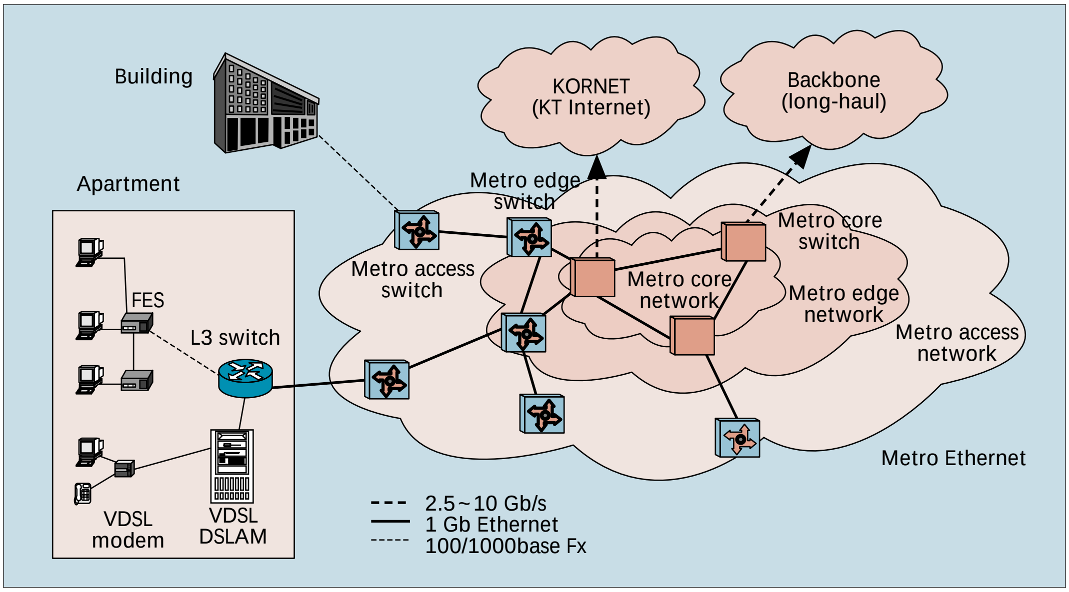

Figure 2. *IP-VDSL, Ethernet, and metro Ethernet network.*

of the ADSL Transmission Line Analysis System (ATLAS). Once the customer requests a subscription, the Subscriber Data Management System (SDMS) enables prompt network setup by managing a collection of various network management systems. After subscription, the Access Network Support and Warranty for End Resources System (ANSWERS) provides network diagnosis and after-sale services.

For proper maintenance of the service, interoperability between devices from diverse vendors is crucial. Lack of interoperability can incur unnecessary cost when a device needs to be replaced. The customer PC is another source of maintenance cost. Statistics show that a significant portion of customer requests for after-sale service come from malfunctions of customer PCs rather than problems related to Internet access functions. Since this incurs unnecessary cost, remote maintenance of customer PCs becomes an important approach for reducing service cost.

Emerging Broadband Access Networks

Despite the widespread of broadband Internet services, the future success of the broadband access business in Korea is not ensured. With the market largely saturated, growth of new subscribers is leveling off, and broadband Internet service providers now face two challenges: competition in the market and new sources of growth. In terms of competition, consumers have been asking for faster and faster speeds, and providers are always looking for the most cost-effective way to increase bandwidth. For new sources of growth, the service providers are expanding their business area to include not only wired services but also wireless Internet services. Termed *post-ADSL*, various newly emerging technologies are now being deployed to provide more advanced services in a cost-effective manner. This section describes post-ADSL technologies, including VDSL, Ethernet to the home, and metro Ethernet. Also described is the emerging wireless LAN service targeted to expand the broadband Internet service market.

VDSL

Ongoing VDSL deployment: In order to overcome sluggish growth, create new revenue sources utilizing existing copper, and maintain initiatives in the future broadband market, KT started to deploy VDSL in areas where churn is very heavy. Using VDSL means shortening the copper portion and moving the fiber closer to the neighborhood. This way we can expand our coverage and provide DSL in new areas. In July 2002, KT launched 13 Mb/s symmetric VDSL for the first time in Korea and also announced 25 Mb/s asymmetric VDSL in the first half of 2003. 50 Mb/s asymmetric VDSL service was launched in the second half of 2003.

Services: The VDSL down and upstream bandwidth enables telcos to provide triple play service of digital TV, video on demand, and higher-speed Internet and telephone service. Newly approved ITU-T Recommendation H.610 of the FS-VDSL Focus Group defines triple play service using DSL technologies and makes it possible for telcos to provide video-centric full service [2]. To be successful as a triple play operator, the network should support multimedia content and communication services that require bandwidth and quality management along the end-to-end path of the session. To exploit the most out of the increased bandwidth at the access network, and to avoid the quality problem associated with the backbone/peering traffic, the multimedia services are best provided at the edge of the core network. For content services, KT has launched *HomeMedia* service that provides on-demand content service through a content delivery network comprising 10 regional server farms. For communication services, the quality control and management capability at the edge becomes crucial for delivering commercial level services.

Interferences: While preparing for VDSL deployment in 2002, we found that the interference between VDSL and existing broadband access TLAN was severe. TLAN is one of the initial types of broadband Internet access that uses time-division duplexing LAN technology. As one of the early techniques, TLAN was based on proprietary technology and did not consider spectrum regulatory issues. Unfortunately, the spectrum of TLAN overlapped significantly with that of the newly deployed VDSL, and until it was fixed, it was the main cause of performance degradation. Another problem was the use of VDSL technology that was not standardized at deployment time. Mainly driven by the need to jumpstart the market, this approach was helpful in maintaining leadership in a fast changing broadband market. In return, additional efforts were made to upgrade the nonstandard VDSL to prevent potential frequency interference with standard VDSL.

IP-VDSL: International Telecommunication Union — Telecommunication Standardization Sector (ITU-T) VDSL Recommendation G.993.1 specifies that the transfer mode of VDSL should be either ATM with transmission convergence (ATM-TC) or plesiochronous transfer mode with TC (PTM-TC) [3]. This means that while ADSL was based on ATM or synchronous transfer mode (STM), VDSL can use ATM or Ethernet. PTM-TC VDSL can be called simply Ethernet over VDSL. KT chose Ethernet as the next broadband protocol because of its wider availability, cost effectiveness, IP conformance, and expected future-proofing. Thus, IP-VDSL was named in accordance with this viewpoint and represents Ethernet-based VDSL for an IP-converged broadband network.

Ethernet to the Home

Besides VDSL, another post-ADSL solution is *Ethernet to the home*. In Korea, UTP cables are already installed in some newly built apartments that enabled service providers to use pure Ethernet solutions to those residential areas. By using Ethernet technology directly to the home, we can connect at an up to 100 Mb/s line rate to customers while the speed of service is limited to 10 Mb/s by provision. This service is characterized as *Megapass Ntopia* in Table 1. Figure 2 shows IP-VDSL and Ethernet to the home for apartments. Both IP-VDSL and Ethernet to the home have the same network topology, except the VDSL DSLAM is substituted by a fast Ethernet switch. Both of them use a metro Ethernet network as the regional broadband network.

Metro Ethernet

Figure 2 shows the overall architecture of IP-VDSL in accordance with the metro Ethernet network. To overcome the limitation of loop length, the layer 3 switch and DSLAM are placed in the apartment complex. It is a simple but effective deployment because 40 percent of the total population in Korea live in apartment complexes where one apartment complex normally has more than 1000 households. The DSLAM terminates the VDSL and implements Ethernet switching, IGMP snooping, prioritized traffic handling, and so on. An L3 switch aggregates tens of DSLAMs and works as a gateway to the Internet. it implements L3 and L2 protocols including default routing, DHCP server/relay, multicasting, and 802.1p/Q. The metro access switch, metro edge switch, and metro core switch are all L3 Ethernet switches and hierarchically constitute the metro Ethernet network. A metro access switch is located in every local CO and aggregates tens of L3 switches via Gigabit Ethernet. The hierarchical position of ADSL DSLAM in Fig. 1 corresponds to the metro access switch in Fig. 2. The metro edge switch is located in the regional CO and aggregates several metro access switches via Gigabit Ethernet. The metro edge switch corresponds to B-RAS in Fig. 1.

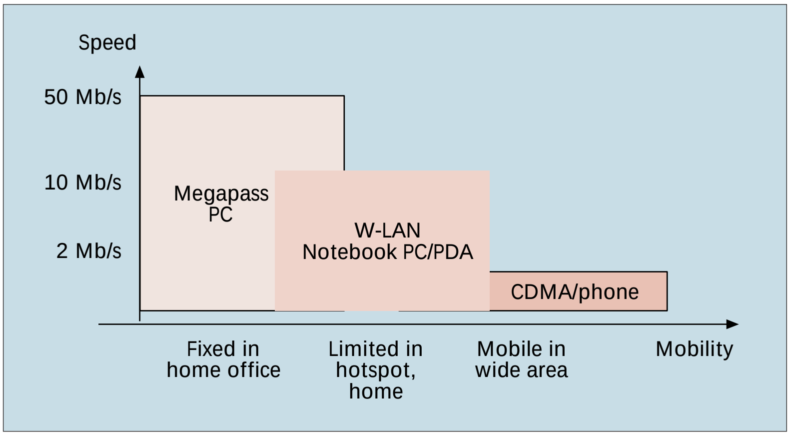

Figure 3. *WLAN positioning.*

Growing Wireless LAN Service

So far, we have only covered wired broadband access networks. Considering the increasing popularity of wireless information terminals, wireless LAN (WLAN) becomes another important post-ADSL solution for new growth. KT started public nationwide WLAN service in early 2002, and the customer base is expected to grow to a half mllion users by the end of 2003. The service, called NESPOT, is currently based on the IEEE 802.11b standard, and it will evolve to 802.11a or 802.11g for enhanced services. Figure 3 shows the position of WLAN in the service spectrum from wired to mobile services. Wired broadband service such as ADSL/VDSL provides very high-speed Internet connection but does not support mobility. 3G CDMA service enables relatively low data rates, but supports mobility in wide areas. The position of WLAN is located between the two, and the service enables easy and high-speed Internet access through a notebook PC or PDA with restricted mobility in hotspot areas.

Besides public WLAN, it is noteworthy that home WLAN service is very promising because Korea has a sufficient number of homes wired to high-speed Internet. With growing numbers of homes having multiple PCs and notebooks, the home WLAN market is emerging as a strong potential market combined with existing wired access. Using access points integrated in ADSL or VDSL modems, home WLAN provides a wireless home network that enables multi-PC

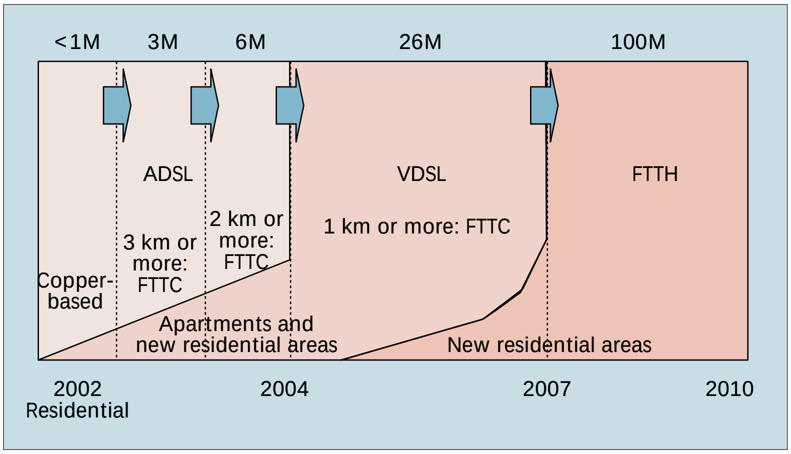

Figure 4. *Broadband access evolution and timeframe of KT.*

connection while using one wired access line of ADSL/VDSL. The service is available to existing customers for a small additional charge.

Current WLAN service has several drawbacks such as short coverage, limited number of hotspots, and radio frequency (RF) interference in the industrial, scientific, and medical (ISM) band. It also has to overcome such problems as ease of use, security, mobility, and network management [4, 5]. However, with advances in wireless communication technology along with integration with other fixed and mobile technologies, the wireless broadband Internet market is believed to be another major market in the long term.

PERSPECTIVE ON NEXT-GENERATION BROADBAND INTERNET

Spurred by the enthusiasm of Internet savvys and youngsters, broadband Internet service in Korea has penetrated into the daily lives of normal people [6]. A recent survey of Internet usage patterns shows that users are now spending around 2 h/day on Internet applications [1], which is comparable to the average daily TV viewing time. Although encouraging, the survey also shows that the main Internet applications in Korea are still Web surfing, email, games, and chatting using PCs at home. This shows that even though broadband Internet connectivity is becoming nearly universal in every household in Korea, applications are still limited to sending and receiving traditional text, image, and control information through the Internet, only at faster speeds. This is in contrast to the predictions of wide penetration of multimedia entertainment and communication applications such as Internet broadcasting, video on demand (VoD), voice over IP (VoIP), and multimedia conferencing. That users are mainly using PCs at home also means limitations on location, time of day, and terminals in using the Internet. The next natural step for the evolution of broadband Internet therefore will be in overcoming these limitations and positioning the IP network at the core and other aspects of everyday life and work activities. This section touches on technical issues to enable the realization of the next-generation broadband Internet as described above. Issues covered are bandwidth, quality of service (QoS), and wireless/mobile Internet.

BANDWIDTH

Bandwidth demand is expected to grow rapidly as high-quality multimedia applications begin to be used in daily life. A typical service configuration for the home includes several high-quality video streams for broadcast and VoD sessions, a number of multimedia communication sessions, high-bandwidth peer-to-peer (p2p) sessions, and normal Web surfing. The bandwidth required for this service set can range from tens of megabits per second to 100 Mb/s depending on the quality requirements for multimedia streams. To provide users with a multimedia experience comparable or superior to the current TV experience, it is envisioned that Internet-based multimedia streaming service will support high-definition TV quality for media broadcasting and VoD, and standard TV quality for multimedia communication sessions. Considering that the typical high-definition media stream requires up to 20 Mb/s, access network bandwidth of 50–100 Mb/s is considered adequate to accommodate future broadband Internet traffic.

To provide the required bandwidth as a universal service, service providers need to upgrade their access network. KT is taking a phased approach to providing bandwidth for next-generation applications — FTTC-based VDSL and fiber to the home (FTTH). VDSL has already achieved 50 Mb/s at 300 m, and since fiber is available for apartment complexes, VDSL service is currently applicable to apartment areas. Apartment complexes currently under construction are also equipped with UTP CAT 5 that enables 100 Mb/s Fast Ethernet speed. Moreover, upcoming apartments are expected to have optical fiber as basic cables, and every home in those optical apartments will have optical connection. This means that FTTH can be provided to apartment complexes in the near future.

For non-apartment areas (i.e., housing areas), VDSL deployment makes use of broadband access nodes that will be placed on the street, on a wall, on a pole, or somewhere near the houses. The broadband access node is connected by fiber from the CO and will be of varying size in accordance with location. Each house is connected to the broadband access node through VDSL technology. In the near term, it accommodates VDSL DSLAMs or access switches. VDSL or Ethernet on CAT 5 will serve as a pre-FTTH solution in short range for the time being. In the long term, the broadband access node will ultimately be responsible for FTTH. Regarding FTTH access technologies, passive optical network (PON) is considered at present the best candidate for an FTTH solution enabling point-to-multipoint fiber connection. While point-to-point fiber connection for FTTH requires as many optical ports as the number of subscribers, PON has an advantage in reducing this cost as well as cutting down fiber installation cost. Eventually, wavelength-division multiplexing PON (WDM-PON) is expected to provide a dedicated 100 Mb/s fiber connection to houses (Fig. 4).

QoS

Compared to the current practice of providing multimedia services over a best effort network, providing high-quality media services requires the network to meet the specific QoS requirements of applications. For example, high-quality interactive communication requires one-way delay of less than 150 ms and less than 1 percent loss. On the other hand, a distributive streaming session (e.g., VoD) has less stringent delay requirements. From the service provider's standpoint, QoS provisioning implies building a managed IP network that can transfer the media information in a managed way. Also, the end-to-end nature of QoS requires quality handling not only at the access network but also at other parts of the end-to-end path, including the core IP network, the premise network, and even at the terminal itself. The control mechanism should be able to track the location/status of customer terminals and manage network resources for guaranteed performance. Considering that broadband Internet business until now has mainly focused on the access network part of the end-to-end path, this approach means a significant change of direction for traditional broadband Internet service providers.

Providing QoS at the network and premises sites has been a major technical issue for network service providers seeking revenue sources other than network connectivity services [7, 8]. KT's effort to meet future service requirements involves the buildup of a premium network, as shown in Fig. 5. The network consists of three parts: access, edge, and core networks. The access network is responsible for delivering information between customer equipment and edge nodes. For economic reasons, the network is shared between managed service traffic and best effort traffic, requiring differentiated traffic handling at the access network. The differentiation mechanisms at the access network range from simple priority handling to more sophisticated ones such as virtual tunnels supporting QoS and security. The managed core network will consist of a set of MPLS tunnels that provides simple but high-throughput transport of packets between edge nodes. The edge network contains service intelligence in that it performs the mapping of QoS requirements between the access network and the managed core network, and different route control for best effort and managed service traffic. This requires the most sophisticated processing in edge nodes in that each of the incoming packets from the access network should be mapped to the proper tunnel in the core and vice versa, based on the QoS marking and destination address. Added to the complexity is the requirement to process each packet to identify source address, application type, destination address, and other information elements to perform proper routing and traffic management functions. The edge network also contains value-added service features that are best provided at the edge locations (e.g., managed security, content filtering).

Equally important is the QoS at the terminal where media encoding/decoding is performed. Terminals with less processing capability may

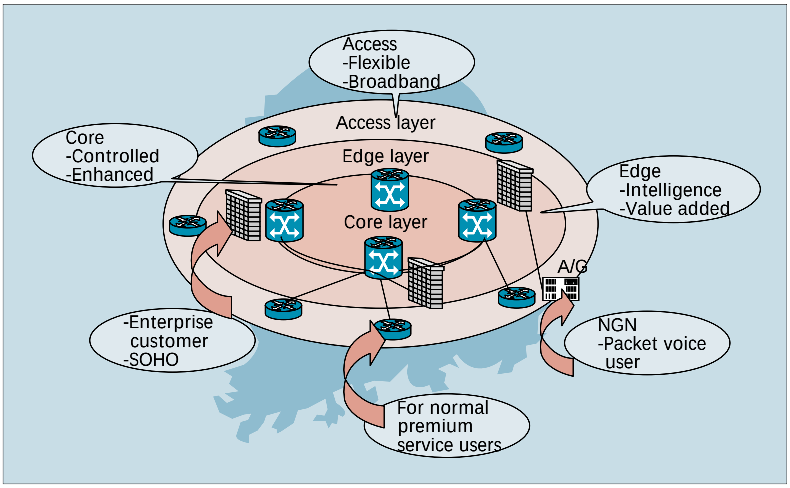

Figure 5. *A conceptual view of the premium network for next-generation services.*

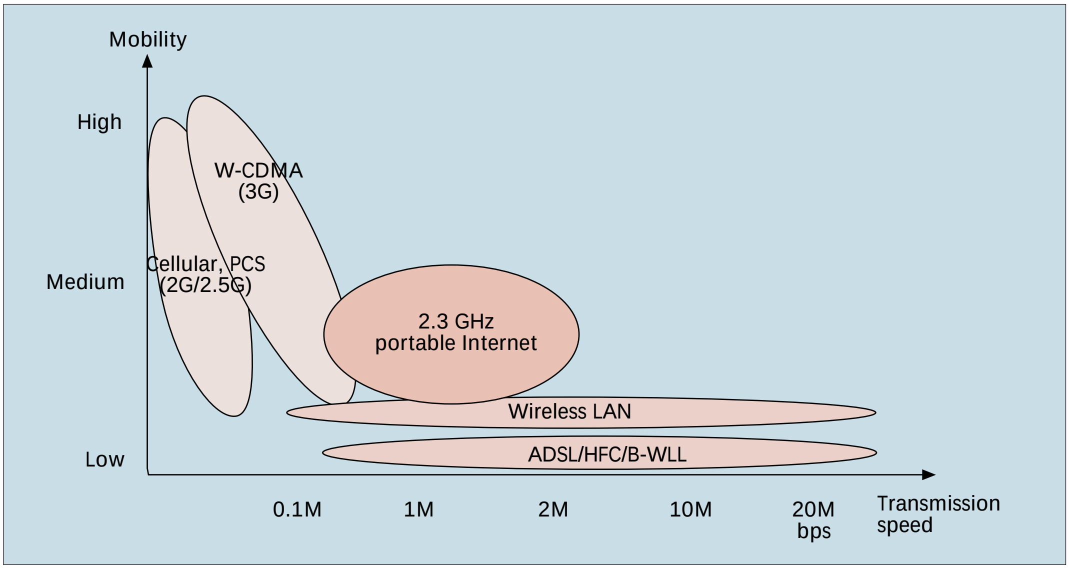

Figure 6. *Portable Internet technology providing universal wireless Internet connectivity.*

Under the name *portable Internet*, the 2.3 GHz-based wireless Internet service aims to provide broadband connectivity to wireless devices in metropolitan areas at an affordable price rate.

not deliver satisfactory quality to end users even though the network quality is above the required level. A typical problem arises when performing multimedia conferencing using a PC where the processing delay at the terminal is often more than 200 ms (compared to a 150 ms one-way delay requirement for a high-quality interactive session). This calls for highly efficient software codecs or cost-effective implementation of hardware codecs at the terminal side. From the service provider's point of view, providing a high-quality media application can include controlling not only the network, but also equipment at customer premises.

WIRELESS/MOBILE INTERNET

The vision of ubiquity of Internet access is another hurdle to overcome for widespread deployment of Internet-based services. Currently, users are restricted to homes/offices for using the Internet; additional freedom is given through the use of WiFi-based WLAN service at hotspots and homes/offices. For wider area mobility, customers rely on cellular communications technology (e.g., CDMA1x EVDO or 3G). However, the relatively low data rate and higher pricing structure for cellular technology have been the obstacles to widespread use of mobile Internet. On the other hand, WiFi technology using the ISM band covers only a small region while providing higher speed at an affordable price. This calls for another technology that can fill the gap between cellular and WLAN services. Figure 6 shows KT's approach in introducing a bridge between fixed/WLAN Internet and cellular data service.

Under the name *portable Internet*, the 2.3 GHz-based wireless Internet service aims to provide broadband connectivity to wireless devices in metropolitan areas at an affordable price rate. The service is in its field trial, where a number of relevant technologies are being evaluated [9]. Considering that the service will be commercially available in two years, the performance of the commercial service (i.e., the average bandwidth per user, service area size, and mobility) is expected to be comparable to that of current wired broadband Internet service as the relevant technologies and standards mature. We expect introduction of the service will change the way the Internet is used, especially in that the broadband Internet is always available through a handy terminal at a moderate cost — the concept of anytime, anywhere connectivity.

SUMMARY

This article describes KT's view of previous experiences and future perspectives on broadband Internet. Following the massive deployment of ADSL-based broadband Internet service, new technologies are aggressively deployed to provide better access services in the competitive and nearly saturated broadband market in Korea. It is envisioned that the next phase of the broadband Internet will provide high quality and ubiquitous services. This calls for upgrades in bandwidth, deployment of QoS mechanisms, and provisioning of wireless mobility over wide areas.

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BIOGRAPHIES

YONG-KYUNG LEE (ykl@kt.co.kr) has been serving as president and CEO of KT Corporation (Korea Telecom) as of August 2002. Prior to that, he served three years as CEO of KTF, the highly profitable wireless subsidiary of KT. He joined Korea Telecom in 1991 as a senior managing director of the Outside Plant Technology Laboratory, and has held similar positions in the Software Laboratory, Telecommunications Systems Laboratory, and Wireless Technology Laboratory. His notable career experience includes six years in the KT R&D Group, including four years as executive vice president and 12 years as a senior researcher for AT&T Bell Laboratories, where he was engaged in semiconductor laser development and optical communications research. His other experience includes two years as a senior researcher at Exxon Enterprises Inc. and an assistant professorship at the University of Illinois. He received B.S. and Ph.D. degrees in electronics engineering from Seoul National University and the University of California at Berkeley in 1964 and 1975, respectively. His research accomplishments are in such areas as thin film and finer optics, semi-conductor laser and optical interconnections, R&D management and planning of telecommunications technologies covering network planning and operation management, high-speed transmission, access networks, various multimedia services, and wireless communications.

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