Journal of Asia-Pacific Studies (Waseda University) No. 23 (June 2014)

Optical Fiber Unbundling and NGN Interconnection in Japan: Policy Advancement and Impediments to the Deployment in a Competitive Environment

Hitoshi Mitomo[†]

1. Introduction

This paper presents a policy perspective on the deployment of optical fiber and NGN in Japan, and discusses the effects of policies to unbundle them and impediments to their progress in a competitive environment. Japan has become one of the most advanced countries in the deployment of optical fiber networks, with household coverage now exceeding 90%, whereas in many other countries optical fiber networks are still at an initial or growing stage (Ministry of Internal Affairs and Communications (MIC), 2010). The Next Generation Network (NGN) is expected to provide a variety of services through packet-based optical fiber networks. NTT East and West,[1] the incumbent network service providers in Japan, started commercial NGN services in March 2008, and the number of subscribers reached 3.3 million in September 2010. ITU defines NGN as "a packet-based network able to provide services including telecommunication services and able to make use of multiple broadband, Quality-of-Service (QoS)-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies." Although NGN has somewhat different designs according to operators' business strategies, it focuses on separating the transport and service layers. NTT's NGN service, however, emphasizes on service characteristics such as QoS, security, reliability and open interface rather than on the separation of layers and service integration on the network.

Unbundling is a regulatory framework for creating a competitive environment by ensuring interconnections of networks between operators, in which when an operator requests to use a specific part of a facility or function of the network of another operator, the request shall be permitted. Initially, it was considered that the same regulatory framework as Public Switched Telephone Network (PSTN) unbundling should be applied to the unbundling of physical components of optical fiber networks.

In December 1996, the MIC's Advisory Council recommended the Minister of MIC to introduce unbundling of PSTN to promote the diffusion of the Internet. The Telecommunications Business

[†] Professor, Graduate School of Asia-Pacific Studies
Director, Waseda Institute for Digital Society, Waseda University
E-mail: mitomo@waseda.jp

[1] NTT was split up into two regional companies, NTT East and NTT West, in 1999. In this paper, NTT means the two companies unless otherwise noted.

Law was amended in June 1997 to encompass the unbundling of telecommunications services. Since then, Japan has made the most of service-based competition through unbundling and co-location. Facility-based competition or a combination of two competition regulations such as the ladder-of-investment approach (Cave, 2006, 2010) can be applied in the developing stage. However, once the network has been rolled out nationwide by the incumbent, their applications seem no longer effective for promoting competition.

In addition, MIC introduced unbundling of the inter-office dark fiber and subscriber dark fiber of NTT East/West in September 2001 reflecting the fact that the demand for interconnection of optical fibers was growing and optical fiber was expected to dominate communications in the future, and that MIC considered that the same competitive field should be provided for optical fiber as in the case of PSTN. However, NTT's technological setting of line sharing has caused difficulties of optical fiber unbundling of local loops at the household level (NTT East, 2007b). An optical subscriber line from an NTT East/West building is split into up to eight end users with the passive optical network (PON) arrangement and any split end-user lines cannot be unbundled due to technical difficulties.

Regarding PSTN and optical fiber unbundling, network facilities to be unbundled can be uniquely specified, but this is not the case for NGN unbundling since even for an unbundled network or services, it is required to accommodate the functions of NGN such as secured network capacities. NGN unbundling is therefore regarded as interconnection arrangements or simply network service provision rather than the physical detachment of network facilities. Actually, for the commercial NGN network, NTT provides interconnections at various levels of the network and imposes interconnection charges on users of unbundled NGN services. The charges are calculated based on the forward-looking method and should be calculated for each unbundled unit but further elaboration is necessary.

Technologies for optical fiber communications are still progressing and excessive enforcement of unbundling may diminish incentives for R&D and investment in optical fiber networks and facilities. However, without such a regulatory arrangement, the incumbent will dominate the market. To ensure a competitive environment in the age of NGN without impeding the progress of optical fiber and NGN, carefully balanced policies are necessary. This paper reviews Japan's experience and offers suggestions based on it.

This paper is organized as follows. In Section 2, some basic principles of unbundling are explained. Section 3 describes the first unbundling policy applied for ADSL expansion. Sections 4 and 5 show competition policies for optical fiber and NGN, while Section 6 highlights difficulties in optical fiber and NGN unbundling. Some implications and conclusions are given in Section 7.

2. Unbundling Policies in Japan

Prior to 2000, Japan lagged behind many other developed countries in terms of broadband diffusion. According to statistics published by the Ministry of Public Affairs, Home Management, Posts and Telecommunications (hereinafter, MPHPT)[2] (2002), the number of DSL and other broadband users was

almost zero while that of Internet stood at 27.0 million by the end of 1999. The deployment of broadband networks was therefore a high-priority issue for the MPHPT.

The Japanese government and the MPHPT released a series of policy strategies from 2000. The e-Japan Strategy (2001), which was the first ICT strategy, was extended to e-Japan II (2003) and u-Japan (2004). In all its strategies, the government aimed to develop nationwide ultra-high-speed Internet access networks at affordable prices, to promote advanced applications, and to establish a ubiquitous society.

Prior to the strategies, the MPHPT's Advisory Council recommended its Minister to introduce unbundling in December 1996 to promote the diffusion of the Internet, and offered a definition and concept of unbundling. In the recommendation, unbundling was defined as an interconnection of networks between operators in which a requested operator allows a requesting operator to use specific parts of the facilities or functions of its network.

In order to introduce unbundling in telecommunications service, the Telecommunications Business Law was amended in June 1997. Under the law, operators who install "Designated Category 1 Telecommunications Facilities" are required to do the following:

(1) to establish interconnection charges for each unbundling facility/function;
(2) to publicly announce the "Articles of Agreement Concerning Interconnection" which stipulates interconnection charges; and
(3) to obtain the Minister's approval for the Articles.

To date, NTT East and West are the only telecommunications operators entitled to install Designated Category 1 Telecommunications Facilities.

The law contains the inherent principle that unbundling should be promoted if there are needs from other operators, because unbundling enhances various kinds of interconnections among operators. Any operator having Designated Category 1 Telecommunications Facilities cannot refuse other operators' requests to use unbundled units. The network facilities and functions that a requesting operator wishes to use should be unbundled provided it is technically feasible. Furthermore, unbundling of facilities or functions should be regarded as technically feasible if the requested operator cannot demonstrate otherwise within a certain period. As a consequence of the unbundling regulation, competing service providers started to provide DSL services by using NTT's local loops.

3. Promotion of Service-Based Competition for DSL Diffusion

Among the huge number of Internet users, many still used narrowband for Internet access such as dial-up through an analog or digital subscriber line. There were two reasons why NTT was not positive toward DSL. Firstly, NTT promoted the digital subscriber network called Integrated Services Digital

[2] Softbank's "Yahoo!BB" started FTTH service in October 2004 using its own optical fiber network. However, it ceased the service in March 2010 and continues to provide FTTH service by using NTT's network.

Network (ISDN) as the next-generation network technology in Japan. Secondly, DSL was based on copper cable networks and was not compatible with optical fiber. NTT had a vision that ISDN could provide both voice and data services during the transition phase from copper to optical fiber. Since local loops had been exclusively supplied by NTT, a bottleneck monopoly emerged in the supply of Internet access: other providers were required to lease local loops from NTT, but NTT itself was also a DSL service provider. Other operators claimed that NTT erected a barrier by setting high line fees that hindered fair competition.

The tariff for data communication at the time also seemed to hinder broadband diffusion. Only a metered rate had been applied for dial-up connection and users paid by the seconds, minutes or hours of usage for data communication. Until a flat rate was introduced in the mid 2000, the U.S. Department of Commerce (1999), citing DSA Analytics, pointed out that "most Japanese Internet users note that the cost of local phone calls is a major disincentive to greater use."

The Japanese government considered that the dominance of NTT had impeded broadband diffusion and that service-based competition by unbundling the local loop could be an efficient policy instrument for the rapid deployment of broadband. Even after the liberalization of the telecommunications industry, NTT has been controlled by government regulations. Facility-based competition is sometimes regarded as a more favorable alternative to service-based competition. However, it was almost impossible to expect an operator to construct an alternative nationwide broadband network within a few years. In Japan, the construction of networks is left to the private sector and the government is unlikely to invest directly. Consequently, facility-based competition was substantially the only measure for the rapid deployment of broadband and DSL was considered to be the appropriate immediately-available technology.

In addition to unbundling regulations, the government introduced co-location regulations to allow competitors to install their facilities in NTT's telephone offices. Co-location regulations made it easier to provide competitive services by reducing the burden for an operator of building its own facilities near NTT's telephone offices.

As a result of the unbundling and co-location regulations, competing providers started to provide broadband Internet access. These services were very attractive for Internet users since the line speed was much faster than ISDN and a lower flat rate was offered. In addition, providers supplied the equipment for DSL connection such as ADSL modems free of charge. Packaged services with other applications such as free IP phones helped to attract more users. As a result, the number of DSL users increased drastically.

4. Optical Fiber Unbundling

NTT lagged behind other providers in ADSL provision. Its share of the ADSL market was 38.5% in March 2007, which is extremely low compared to its shares of other telecommunications markets. In order to revive the broadband market, NTT rapidly shifted its broadband service to optical fiber.

While ADSL is based on copper cable networks and can provide speeds of up to 50 Mbps, optical fiber is the next-generation technology and offers faster speeds with very low transmission loss: 100 M–1 Gbps for detached houses and 50–100 Mbps for apartments using VDSL technology. Thanks to continuous investment and managerial effort, NTT has become the dominant supplier of optical fiber access even though there are some competitors which possess their own optical fiber network. KDDI is the only competitor that provides a nationwide optical fiber service using both its own network and leased networks. There are also several local fiber service providers; these are mostly subsidiaries of local electric power corporations, which provide a commercial fiber service by using optical fiber that was originally constructed for monitoring their facilities.

Japan is the only country that imposes an obligation to unbundle optical fiber. Since demand for optical fiber was expected to grow among operators and optical fibers were expected to be the core technology for communications in the future, the MPHPT decided to introduce unbundling for the trunk optical dark fiber and subscriber optical dark fiber of NTT in September 2001. As data communication expands, higher network transmission capacity is required and the demand for interconnection increases. In some cases NTT was reluctant to accept the interconnection of optical fibers from other operators, and due to NTT's dominance, an agreement on interconnection could not always be negotiated successfully. The MPHPT's policy was that any measure intended to encourage competition that applied to copper networks should also apply even to optical fiber networks. Thus, both unbundling and co-location regulations have been applied. Since December 2000, NTT has been providing optical fiber interconnection by leasing unbundled interoffice and subscriber lines.

Regarding optical fiber networks, interconnection is substantially the same as unbundling for copper cable networks because packet transmission does not require physical unbundling of network components but can share them with other communications. There are two methods of calculating the interconnection charge: the forward-looking method and the historical cost method. The forward-looking method applies to a new service or a service that is expected to enjoy huge growth in demand, specifically, when there is a need to alleviate a sudden change in the interconnection charge. The historical cost method applies to relatively stable services or network components. The methods of calculating the interconnection charge are listed in Table 1.

The interconnection charge for inter-office dark fiber is calculated based on the historical cost method. Since the unbundling of inter-office dark fiber commenced in September 2001, NTT has received ministerial approval and has revised its Agreement Concerning Interconnection every year. For these network components, the interconnection charge is calculated based on the actual demand and cost of two years ago, because those data are the latest available at the time of each calculation. When the actual data for the base year for calculation become available, the difference between the calculated and actual interconnection charges is adjusted in setting the interconnection charge of two years later. On the other hand, the interconnection charge for subscriber dark fiber is calculated based on the forward-looking cost method. NTT received ministerial approval in September 2001 and set the inter-

Table 1 Methods of Calculating the Interconnection Charge

Calculation Method	Concept of Application	Applicable Services
Forward-looking Method	➢Applies to a new service or a service expected to enjoy huge growth in demand. ➢Applies when there is a need to alleviate a sudden change in interconnection charge.	➢Subscriber optical dark fiber ➢NGN
Historical Cost Method	➢Calculated based on the actual demand and cost of two years ago (at the time of calculation, data of two years ago is the latest data available). ➢When actual data for the calculation year becomes available, the difference in interconnection charge must be adjusted in the calculation of interconnection charge of two years later.	➢IP related facilities (GE-PON) ➢Local IP network ➢ Inter-office optical dark fiber ➢Telephone line (dry copper cable) ➢Public telephone

Source: MIC (2010)

connection charge for the seven years from 2001 to 2007, and received another ministerial approval in June 2008 and set the interconnection charge for the three years from 2008 to 2010.

Figure 1 shows the transition of the access charge and the cost per line for the single star access. The figure indicates that the charge will fall by 30% from ¥4,610 to ¥3,380 for NTT East in the three years from 2011. The charge is similarly calculated for NTT West, showing a decrease from ¥4,932 to ¥3,426. NTT East and West stress that the access charge for optical fiber subscriber line is continuously decreasing owing to their efforts to reduce cost, and that optical fiber is already in a competitive environment.

Two types of optical fiber access are provided in Japan: single star access and shared access. An optical fiber reaches each end user directly in the case of single star; this system is used mainly for condominium buildings and companies. In the case of shared access, an optical fiber is divided into several branches and each branch provides network access. For NTT East and West, an optical fiber line is divided into eight branch terminal lines and accommodates up to eight subscribers; this system is mainly used for detached houses. Shared access has an advantage of lower investment cost and that fiber service can be provided at lower cost as there are more end users per fiber line (Figure 2). Data transmitted to and from end users are multiplexed using the Gigabit Ethernet-Passive Optical Network (GE-PON). Using a splitter, an optical fiber line is split in the vicinity of end users. NTT uses this tech-

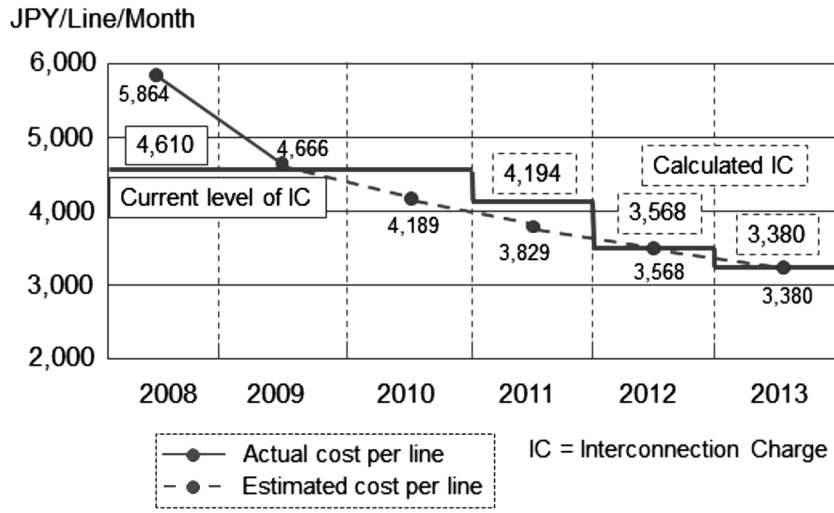

Figure 1 Current and Calculated Interconnection Charges for a Subscriber Line: The Case of NTT East
Source: NTT East (2010)

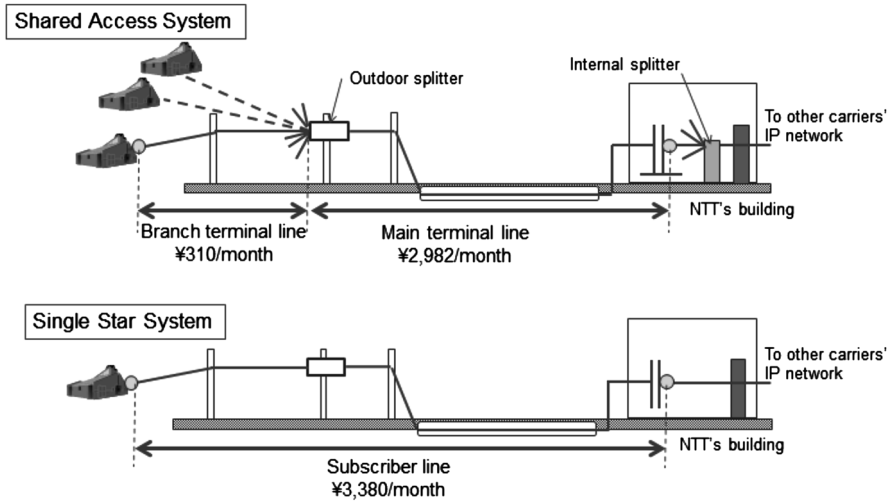

Figure 2 Shared Access and Single Star Systems: the Case of NTT East
Source: NTT East (2010)

nology to provide optical fiber access: a 1-Gbps optical fiber line can be shared by up to eight end users.

In the case of shared access, the reduction in access charge is more conspicuous because as the number of subscribers using one optical fiber line increases, the per-subscriber cost for the fiber line is reduced although the unit cost for a branch line is charged to each user. The historical cost approach is used to calculate the access charge for optical fiber subscriber lines, and in the calculation, it is allowed to adjust the difference between the estimated cost and actual revenue. For calculating the current

access charge (as of 2010), the estimated total cost was ¥382.2 billion and ¥376.2 billion for NTT East and West, respectively. Since the estimated numbers of subscribers were 2.48 million and 2.33 million, the unit access charges were ¥4,610 and ¥4,932, respectively. However, the actual revenue and the number of subscribers were ¥347.2 billion and 2.24 million for NTT East and ¥299.8 billion and 1.85 million for NTT West. Since the differences in revenue were ¥36.0 billion and ¥76.4 billion for NTT East and West, respectively, they added the difference between the actual revenue and cost, ¥12.4 billion and ¥42.2 billion, to the calculation of the access charge of two years later.

5. Competition Policies for NGN

The Next Generation Network (NGN) service in Japan has been solely provided by NTT East and West since March 2008. NGN is characterized by IP-based technologies through high-speed broadband networks, high security and reliability, quality of service (QoS) secured by end-to-end network control, and interconnectivity achieved by an open interface. The physical network structure is shown in Figure 3. NTT advocates that NGN achieves both i) the reliability and stability of general switched telephone networks and ii) convenience and economic efficiency of IP networks.

NGN is planned to be used for diverse services (see Figure 4). Various applications and content can be provided such as video communication, video delivery, distance learning, teleworking, education and healthcare. Along with optical fiber broadband service through NGN, customers can access a variety of services such as IP/video phone, content viewing, VPN, etc.

According to NTT (2008), NGN will reduce costs by consolidating relay transport networks through integrated offerings of multiple services, by realizing a scale merit by aggregating control equipment, and by introducing the latest technologies. It will also create opportunities for higher revenues by enabling the delivery of converged and partnership-based services and by offering high-capacity broadband services with QoS guarantee.

The interface conditions for interconnection have been disclosed to promote interconnection. In addition to the network-network interface (NNI) for interconnecting other operators' networks, the

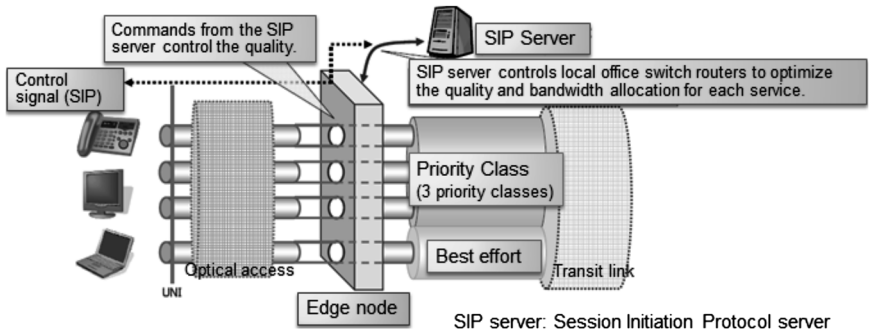

Figure 3 Physical Structure of NGN
Source: NTT East (2007a)

application server-network interface (SNI) is open to application providers and content providers, and the user-network interface (UNI) is available for NGN users. This means that NGN provided by NTT is just a packet-based network which can provide a variety of services for various providers and users.

The interconnection charges have been calculated for the following four types of interconnection: 1) IGS interconnection, 2) central office router interconnection, 3) gateway router interconnection, and 4) Ethernet interconnection. The interconnection points are displayed in Figure 5. These interconnection charges have been approved by a Council Meeting in MIC, and the respective charges

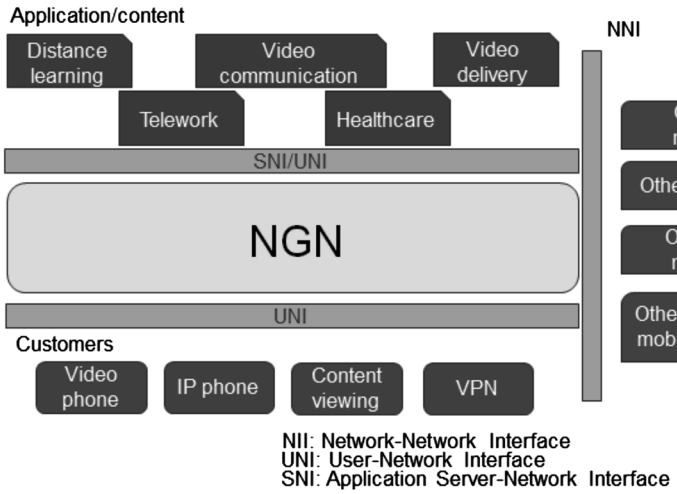

Figure 4 Service Structure of NGN
Source: NTT East (2007a)

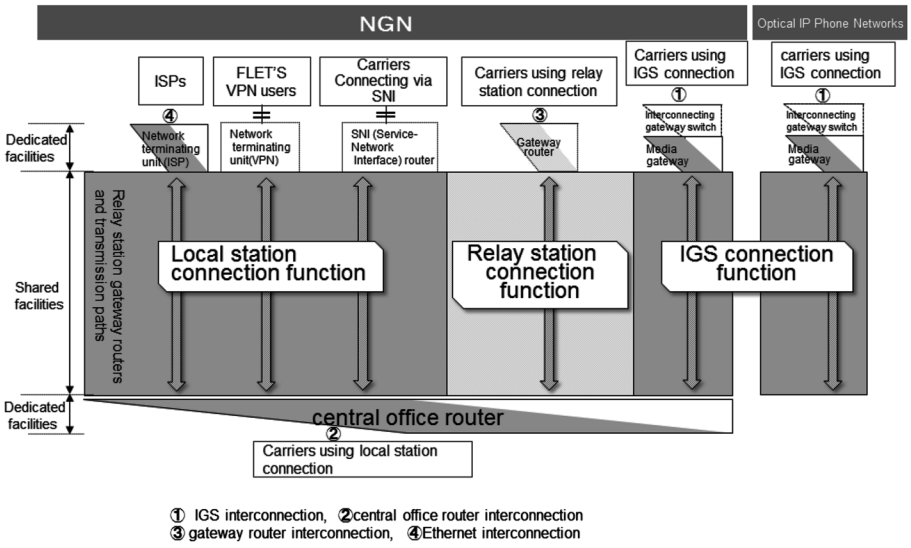

Figure 5 Interconnection Points of NGN
Source: NTT East (2007a)

approved for 2010 were ¥5.7/3 min, ¥2.16 million/unit・month, ¥6.34 million/10 Gport・month, and ¥1.70 million/1 G・month.

6. Difficulties in Optical Fiber Unbundling and NGN Interconnection

1) Optical Fiber

Since there are substantially very few competing suppliers having their own network and their market share is small compared with the incumbent, facility-based competition does not seem effective in the Japanese optical fiber access market. As described before, there are some optical fiber operators, but they have concentrated their service in densely populated local municipalities and do not offer nationwide coverage.

Since optical fibers have been unbundled and NGN has open interfaces currently with four interconnection points in the network, competition on NTT's network would appear to be possible. Service-based competition can be achieved in the same competitive environment as ADSL. For realizing optical fiber unbundling, technological standards should be fixed. Thus, unbundling may actually deter technological upgrades of the system and hence impede the progress of technology. Consequently, if the network is unbundled inappropriately, quality improvement and diversification of the service may be delayed.

NTT East and West have already introduced unbundling in both single star and shared access systems. Any operator wishing to lease unbundled lines is of course allowed in the fiber access market. However, the shared access system is not fully compatible with unbundling. Due to technological limitations, each branch cannot be unbundled, but each main terminal line or eight branches in a bunch can. It is difficult for competing suppliers to collect nearly eight users in close proximity. They want one or some branches to be unbundled, not all eight branches. NTT insists that each fiber line can be unbundled, but not one or some of the branches as otherwise conflicts or malfunctions may occur. As of May 2011, one conceivable way to deal with this problem would be to promote sharing of an optical fiber subscriber line among operators desiring fiber unbundling. Competing operators claim that this technological limitation impedes fair competition on the incumbent's network.

2) NGN

NGN is NTT's integrated fiber access network, so other operators are not able to provide NTT's fiber access to users with services using their own relay networks. Other operators cannot enable users of NTT's fiber access to bypass NTT's NGN and connect them to their own networks. Local routers that act as gateway routers do not have a function for diverting traffic to other networks. Routers in NGN are interactively connected and control traffic. As a result, local loop unbundling like a GC (Group unit Center) connection for PSTN has not been realized. Figure 6 compares PSTN and NGN unbundling. As of May 2011, no operator has used the unbundling service for NGN even though the network itself has an open access policy.

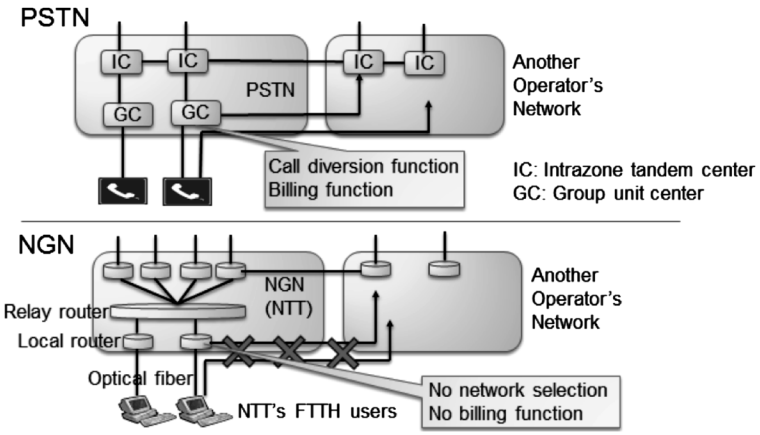

Figure 6 The Difference in Unbundling between PSTN and NGN
Source: NTT East (2007a)

7. Implications and Conclusions

Japan succeeded in the rapid diffusion of broadband in the early 2000s through unbundling and co-location regulations. The telephone network of NTT, the incumbent operator, was used by competing operators to provide ADSL service. In those days, Japan lagged behind other countries in the diffusion of broadband and there was high demand for it from Internet users. In the same way, people believed that unbundling and co-location regulation could create a competitive environment in the optical fiber access market. This was partly true and Japan has one of the most advanced optical fiber networks. However, the creation of a competitive environment has resulted in slightly different consequences with various difficulties.

These difficulties arise from both the degree of maturity of optical fiber technologies and the technological characteristics of IP networks. As is often said, unbundling of a network amid technological progress will not only reduce incentives to invest in facilities and R&D activities for both the incumbent and competitors, but also cause technological incompatibilities.

With strong political leadership, the MIC introduced optical fiber unbundling and open access to NGN from the outset and NTT accepted them. The rapid deployment of the nationwide optical fiber network in Japan has been achieved mainly thanks to the corporate efforts of NTT in line with the MIC's promotion policies. The existence of facility-based competing providers from the beginning also stimulated NTT's investment. However, once the dominance of NTT had been established, competition policies tended to rely more on service-based competition. Thus, the role of unbundling has become increasingly important.

The decrease in the number of optical fiber access providers in Japan suggests that the general theory in industrial organizations that a facility-based industry with large fixed, sunk or common costs can finally become a monopoly is also true in the optical fiber access market. The optical fiber access market is no exception. The MIC did not expect too much from facility-based competition. Rather, they

anticipated the failure of facility-based competition and promoted service-based competition as they had experienced the successful rapid diffusion of broadband in the ADSL market. In the US and UK markets, it was considered that facility-based competition is sounder and that service-based competition may leave room for political intervention and harm the healthy development of the industry. Therefore, ways to achieve gradual development utilizing facility-based competition or both types of competition were considered. On the other hand, Japanese policymakers rushed to construct a nationwide optical fiber network as they believed higher national coverage was a symbol of progress.

The rapid deployment of optical fiber was successful in Japan, but it has raised two problems. Firstly, as discussed above, service-based competition has faced incompatibilities with technological settings and development of the optical fiber network. Since the optical fiber network is fully IP-based, in some cases a network component cannot be unbundled physically due to the limitations of existing technology. Secondly, utilization of such an ultra-high-speed network has not advanced compared to the physical network development. In 2010, household coverage by the ultra-high-speed network exceeded 90%, yet merely 30% of households have subscribed. People have little incentive to join the network due to the lack of convenient applications or attractive content. The MIC is still looking for ways of efficient utilization and has set up committees to promote widespread utilization of the ultra-high-speed network in various aspects of life. Utilization of optical fiber networks is also expected to help revitalize local economies, but its effects are not yet visible.

To promote the use of optical fiber, it was discussed that the optical fiber IP phone service should be regarded as a universal service. So far, only PSTN has qualified as a universal service in Japan, and it is obvious that IP phones will never be a killer application for optical fiber.

The success of the optical fiber access market in Japan has been supported by continuous service-based competition and open access policies. These policies are sustained by the existence of an elephantine incumbent operator and regulatory intervention by the authorities. As far as this traditional industrial structure is maintained, service-based competition policies should be efficient. However, as seen in the NGN market, when physical separation faces difficulties, some functional separation should be considered. Nevertheless, due to technological constraints, it is difficult to achieve fair competition in the market. Evidently, there has been no operator that utilizes unbundled (functionally separated) NGN facilities in order to provide a competitive service. The real success of the market heavily depends on attractive services being provided by using the advantages of optical fiber and NGN, and on creating demand for such services.

References

Cave, M., 2006, "Encouraging infrastructure competition via the ladder of investment," Telecommunications Policy, 30(3–4), 223–237.

Cave, M., 2010, "Snakes and ladders: Unbundling in a next generation world," Telecommunications Policy, 34(1–2), 80–85.

ITU, 2007, "Telecommunication Development Symposium (TDS): Survey Analysis on Next-Generation Network 2007," available at http://www.itu.int/publ/S-TLC-WT.TDS.SURV-2007/en (Last accessed on March 20, 2014)

ITU, "NGN Working Definition," available at http://www.itu.int/ITU-T/studygroups/com13/ngn2004/working_definition.html (Last accessed on March 20, 2014)

Ministry of Internal Affairs and Communications (MIC), 2010, "Towards the Realization of 'Hikari no Michi' (a New Broadband Super Highway) Concept (in Japanese)," Dec. 14, 2010, available at http://www.soumu.go.jp/main_content/000092951.pdf (Last accessed on March 20, 2014)

MIC, "The Number of Broadband Subscribers (in Japanese)," available at http://www.soumu.go.jp/johotsusintokei/new/index.html (Last accessed on March 20, 2014)

Ministry of Public Affairs, Home Management, Posts and Telecommunications (MPHPT), 2002, "Number of Internet Users," available at http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Statistics/number_users021227.html (Last accessed on March 20, 2014)

NTT East, 2007a, "An Outline of the NGN Provided by NTT East (in Japanese)," Nov. 13, 2007, available at http://www.ntt-east.co.jp/aboutus/pdf/071113siryo.pdf (Last accessed on March 20, 2014)

NTT East, 2007b, "Opinion of NTT East on the Interconnection Charge of the NGN (in Japanese)," Nov. 16, 2007, available at http://www.ntt-east.co.jp/aboutus/pdf/071116siryo.pdf (Last accessed on March 20, 2014)

Taguchi, S., 2011, "Study of the Application of Quantitative Methods to the Evaluation of the Economic Effects Derived from Telecommunications Policies," PhD dissertation, Graduate School of Global Info-Communication Studies, Waseda University.

U.S. Department of Commerce, 1999, *The Emerging Digital Economy* II, p. 7, http://www.esa.doc.gov/Reports/emerging-digital-economy-ii. (Last accessed on March 20, 2014)

NTT East, 2010, "Adjustment of Subscriber Fiber Interconnection Fees (in Japanese)," available at http://www.ntt-east.co.jp/release/1101/pdf/110121b_1.pdf (Last accessed on March 20, 2014)

NTT West, 2010, "Adjustment of Subscriber Fiber Interconnection Fees (in Japanese)," available at http://www.ntt-west.co.jp/news/1101/pdf/110121b.pdf (Last accessed on March 20, 2014)