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Case study

Understanding the impact of convergence on broadband industry regulation: a case study of the United States

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Abstract

Convergence is a dominant trend in the telecommunications and information industries, driven by the market demands for broadband service and promoted by competition and deregulation. This paper examines the impact of convergence in technology, business, and market on broadband services regulation by investigating the distinct features of the emerging broadband technologies and networks, comparing the differences between the narrowband network and broadband network in several dimensions, and elaborating on the implications of these differences for the regulation of the broadband services. It is argued that the advanced broadband networks, as a brand-new facility, should be treated differently in regulation compared to the existing narrowband telecom industry.

1. Introduction

The history of the telecommunications industry demonstrates that the progress of communications technology does have an impact on the regulatory principles and the regulatory plans (Crandall, 1996). [1] Currently, the development of communications technology has reached the stage in which it is leading to the convergence of

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[1] For a survey about the impact of technology on the proliferation of telecommunications networks, see Hausman (1996).

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communications networks and services and dramatically pushing the network evolution from the existing narrowband designed for voice communication to the broadband networks dominated by data communication. As a consequence, convergence gives rise to challenges to existing regulatory institutions (Clements, 1998, p. 197). This paper contributes to understanding convergence and its impact on broadband service regulation by systematically elaborating on the distinct features embedded in the advanced broadband networks from the aspects of broadband technologies, the pace of innovation, investment risk, market structure, etc. The main finding is that these distinct features question the rationales of equally imposing the existing telephone regulatory principles without any modification to the broadband networks and require that regulation on broadband services, if any, should be tailored to the specific features.

This paper proceeds as follows. In Section 2, convergence as a kind of dominant movement in the communication industries is studied. In Section 3, the paper surveys the alternative broadband technologies and network structures. In Section 4, the specific distinctions between the advanced broadband networks and existing narrowband networks are analyzed. Section 5 explores the impact of these differentiations on broadband network policy and regulation. Section 6 concludes the paper.

2. Convergence

Convergence can be traced back to the 1970s when the computer technologies gradually meld into the telecommunications industry (Parsons and Frieden, 1998, p. 11). However, not until the 1990s, did convergence become an overwhelming trend due to the digitalization from technological progress and competition from deregulation. The digitalization in telecommunications makes it possible that different services can be delivered through different networks, which were traditionally dedicated for specific services. On the other hand, competition and deregulation, promoted by the Telecommunications Act of 1996 (the Act of 1996), removed the legal barriers prohibiting cross-ownerships over different communication networks. As a consequence, telephone companies and cable companies can now compete in both telephone and cable services at the same time.

Convergence means communication services previously restricted to separate networks can now be provided by any of the network operators (EC, 1997; Katz, 1996; Parsons and Frieden, 1998). Apart from the technological implication, convergence also exercises an impact on business and regulation. As a response to convergence in business strategy, telecommunications companies expand their service territories to other areas previously restricted to them. For instance, Ameritech enters into the cable service market by aggressively bidding franchises from local authorities. AT&T took over TCI and MediaOne and became the largest national cable operator. The merger between AOL and Time Warner will significantly boost AOL's Internet business by taking advantage of Time Warner's cable network. At the same time, cable companies such as Cox Communications, MediaOne, and Cablevision Systems also compete in telephone markets in the forms of resale, unbundling, and cable telephone. [2] Convergence driven by technological progress is "propelling all communications media towards a single, ubiquitous digital network" has been widely recognized (Crandall, 1996, p. 299). As expected, convergence brings about a blurring of the distinction between previously separate industries (Blackman, 1998, p. 164; Ramundo, 1996, p. 54).

In contrast to the impact on network development and business strategy, there is little consensus about the impact of convergence on regulation. On the one side, it is strongly argued that convergence will lead to regulatory change to keep up with the dynamic changes in communication technologies, networks, services, and business. Blackman (1998, p. 164) claims that "convergence requires re-examining the existing basis for regulation which has been based on different principals and with different objectives." While examining the impact of convergence on the role of state commission, Ramundo (1996, p. 49) concludes that "regulatory change surely will come – by policy, statute, or practicality." On the other side, however, some doubt whether convergence will exercise a major influence on the course of regulation. For instance, Michalis (1999) argues that technological convergence does not automatically imply regulatory convergence. In contrast, existing sector-specific will continue to exist.

In sum, convergence is a dominant trend in the telecommunications industry. Digitalization and new communication technology make this a technological feasibility. At the same time, competition and deregulation make convergence become a reality reflected in companies crossing the previous service boundaries and exploring new markets and business opportunities. The remainder of this paper will examine the impact of convergence on broadband service regulation by investigating the distinct features of the emerging broadband technologies and networks, comparing the differences between narrowband and broadband networks in several dimensions, and elaborating on the implications of these differences for the regulation of the broadband services.

3. Alternative broadband technologies

Historically, the telecommunications infrastructure is designed for the delivery of voice signal rather than data and video services (Hundt and Rosston, 1998). Although widespread application of optical fibers, asynchronous transfer mode (ATM), and packet-switched technologies has significantly improved the trunk transmission speeds and switching functions, the local loop section, i.e. from central office to the customer premises equipment (CPE), is still dominated by twisted-pair

[2] See more related information at http://www.ncta.com/yearend98_6html, (visited on 1 April 2000).

lines. [3] Currently, the development of the telecom network is asymmetric in terms of bandwidth. The backbones of interexchange carriers (IXCs) and Internet service providers (ISPs) can support speeds of transmission up to OC-192 10 Gbps (Gorman and Malecki, 2000). But the transmission speed in the local loop is still limited to 56 kbps with conventional technology (i.e. dial-up telephone modem) and not more than 128 kbps with ISDN, commonly regarded as the "last a mile" bottleneck to realizing end-to-end broadband communications (Maxwell, 1999, p. 21). Considering that the development of the communications technology is so dynamic, it is hard to claim with any certainty which kind of technology will be dominant in the prospective broadband network or infrastructure in the long run (Blair, 1999). However, there is less disagreement about the path of network evolution toward the broadband infrastructure and the technological solutions most likely employed in the short run.

3.1. The path of broadband infrastructure evolution

The rollout of broadband infrastructure depends on the specific services demanded by the market over time. The stronger the demand for broadband services, the quicker the pace of evolution. Because different services have specific requirements for the bandwidths, the practical evolution of the network toward broadband would be gradual and step-by-step.

According to Maxwell (1999), the network evolution typically consists of three phrases. In phase one, the driving force behind the network evolution toward broadband is from the high-speed Internet access. As of January 1999, it was reported that 65% of Internet users were still taking dial-up modem as a major solution to access the Internet with an average speed of 33 kbps (Lathen, 1999). The most promising technologies in this phrase are asymmetric digital subscriber line (ADSL) and cable modem. The downward speed with more than 1.5 Mbps can basically meet the cyber surf in the short run (Maxwell, 1999, p. 46).

In phrase two, the video-on-demand, home shopping, video games, and other entertainment services will become prevalent in broadband markets. The typical bandwidth required is around 10 Mbps. The alternative technologies could be very high data-rate digital subscriber line (VDSL), hybrid fiber/coax (HFC) and fiber-to-the-curb (FTTC). Finally, in phrase three, high definition television (HDTV) will be delivered over the full fiber network to sustain much higher bandwidth requirement. [4] The remainder of this section will discuss several promising technologies and network architectures in the foreseeable future.

[3] All of the large interexchange carriers (IXCs), including AT&T, MCI, Sprint, and WorldCom offer ATM service. In addition, ATM is also available from local exchange carriers (LECs). See Axner (1997).

[4] The actual bandwidth for HDTV depends on the number of channels. The typical rate for per HDTV channel is 19.3 Mbps (Maxwell, 1999, p. 42).

3.2. Integrated services digital network (ISDN)

As of 1998, there were 136 million access lines held by the RBOCs (FCC, 2000a). It would be the most economic and practical way to approach toward the broadband facility by upgrading the ordinary and ubiquitous access lines. As an alternative technology, ISDN is the most mature with the longest history. Since the first commercial installation of ISDN in the United States in 1986, there have been more than 108 million access lines equipped with ISDN function, accounting for 78.3% of the total RBOCs' access lines (Pooch et al., 1991, p. 436; FCC, 2000a, Table 18.2). [5]

The basic principle of ISDN is to upgrade the analog circuit to digital subscriber line (DSL) and support a range of services including voice and data communications (Maxwell, 1999, p. 222). There are two types of services in ISDN, working at basic rate and primary rate, respectively. Basic rate ISDN (BRI) provides end-to-end 2×64 plus 16 kbps (2B+D) transparent digital transmission. Primary rate ISDN (PRI) multiplexes B channels up to 23 (30B in European) (Pooch et al., 1991, pp. 435–444). For most residential customers, the basic rate of ISDN with 144 kbps ($2 \times 64 + 16$ kbps) is the most common choice for the Internet access, considering the cost and affordability. For the business customers, the primary rate ISDN can provide up to 1.544 Mbps high-speed digital link.

Even though ISDN can be regarded as the earliest effort made by RBOCs to modify the analog loop toward digital broadband, marketing has not been successful in terms of market penetration because of the wrong timing for technology adoption (Lutkowitz, 1998). In the 1980s, the market demand for broadband access lacked specific and strong services to stimulate market demands. Since the 1990s, the Internet access has experienced high demands. However, the basic rate ISDN (BRI) appears to be relatively weak to support high-speed Internet access. ISDN would be one of the solutions for the Internet access but hard to be the leading technology, especially in the circumstance that more cost-effective high-speed technologies are emerging.

3.3. xDSL [6]

ADSL is one of the line-upgrading technologies, called xDSL family, including ADSL, high data-rate digital subscriber line (HDSL), VDSL, etc. They are differentiated from each other in transmission rate, distance, and performance. Table 1 summarizes the main features of alternative xDSL technologies.

HDSL supports symmetric transmission speeds between upward and downward streams, up to 1.5 Mbps over 9000–12 000 feet contingent on the line quality. However, it requires two pairs of lines and cannot co-work with ordinary phone

[5] It is the proportion of access lines with the ISDN functions, not the penetration rate.

[6] "The acronym 'xDSL' refers to a general class of digital subscriber line technologies" (FCC, 2000b, Note 206).

Table 1
The specifications of xDSL[a]

xDSL	Transmission pattern	Downstream rate	Upstream rate	Distance	Co-work with POTS
ADSL	Asymmetric per pair	1.5–6 Mbps	64–640 kbps	9–18 Kft	Yes
HDSL	Symmetric (two pairs)	1.5 Mbps	1.5 Mbps	9–12 Kft	No
VDSL	Asymmetric per pair	12.96–52 Mbps	1.6–2.3 Mbps	1–4.5 Kft	Yes

[a] *Source*: Compiled from Kwok (1998).

service simultaneously. As a consequence, its application has been significantly dumped in the residential broadband market. But in the business market, it does demonstrate attractive advantages to compete with T1 (1.544 Mbps) high-speed link.

Comparatively, VDSL only requires one pair of ordinary phone lines and provides the highest speed access in the xDSL family, up to 52 Mbps. But the cost is to sacrifice transmission distance – not exceeding 4500 feet. Because of the restriction on transmission distance, it is generally used as a complementary technology with optical fiber to provide high-speed access, where the home is near the drop point of optical fiber (Cioffi et al., 1999).

In the xDSL family, the most promising technology for residential broadband access is ADSL. It is generally regarded as an effective solution for ILECs to defend against the aggressive competition from the cable companies equipped with cable modem technology (Allen, 1998). By splitting the line spectrum between ordinary phone service (POTS) and data transmission, ADSL typically uses the segment of 20–50 kbps for upstream transmission and 140–1100 kbps for the downstream delivery (Kwok, 1998, p. 298).

As the transmission of ADSL with 1.5 Mbps (downstream)/64 kbps (upstream) can reach up to 18 000 feet from the central office, about 75% of the customers fall into the service range (Kwok, 1998, p. 274). However, to upgrade the existing copper lines for ADSL function, a lot of engineering fieldwork is required, such as installation of ADSL multiplexer/demultiplexer (DSLAM), [7] line pre-qualification testing (no load coils acceptable), copper provisioning, and turning on the service (Allen, 1998; Aaron, 1999). In the upgraded public switched telephone network (PSTN) architecture with ADSL function, the POTS and data transmission are separate and independent over the same pair of lines. In addition, the circuit resource is dedicated to each user rather than shared among a group of customers as in the case of cable modem discussed below. Because ADSL can potentially and effectively provide high-speed access for more than 75% of the telephone customers, it is generally regarded

[7] DSLAM is the abbreviation of "digital subscriber line access multiplexer". It multiplexes/demultiplexes data signals between the broadband backbone network and customers' terminals.

as the leading technology for telephony companies to compete with cable companies in data, video, and Internet services (Mollenauer, 1998, p. 24).

3.4. Cable modem

The cable system is the only existing hard-wired, broadband communication infrastructure that is already universally available in the United States (Owen, 1999, p. 135). Like the telecommunications network, it is believed to be the dominant information infrastructure for broadband services (FCC, 2000a).

Initially, the cable system, or community antenna television systems (CATV), was invented to improve the television signal for remote areas by deploying coaxial cable (Crandall and Furchtgott-Roth, 1996). After five decades of development, it has become a nationwide communication facility. As of the middle of 1999, cable subscribers reached 66.7 million and the basic cable penetration grew to 69.4% (FCC, 2000b at 20). Due to historical reasons, the basic cable system architecture was designed as a kind of one-way tree-and-branch structure (Parsons and Frieden, 1998, p. 87). As a practical action of defending against the threat from telephone companies, the cable industry has been aggressively upgrading its network to provide a two-way structure by deploying hybrid fiber/coax (HFC), an integrated multi-service communications platform (Masud, 1998; Maxwell, 1999, p. 248; FCC, 2000b, at 66).

Cable modem is crucial for cable companies to provide cable subscribers with high-speed data communication services such as the Internet access. As with ADSL, it supports upstream and downstream data transmission per channel (with standard 6 MHz bandwidth) by splitting the cable spectrum into specific segments. According to the Data Over Cable Service Interface Specification (DOCSIS) 1.1 standard issued by Cable Television Laboratories (CableLabs), cable modem supports downstream speeds of 27–38 Mbps and upstream speeds of 320 kbps to 10 Mbps (Masud, 1998).

Different from ADSL, cable modems share the transmission capacity with others using the same channel (Maxwell, 1999, p. 180). As a consequence, the actual access speeds are contingent on how many other customers are sharing the same capacity at the same time (Owen, 1999, p. 134). In other words, the cable system with HFC structure also encounters the transmission "bottleneck". In the short run, one solution is to have fewer subscribers at optical network unit (ONU) and another is to apply data compression technology to increase the system capacity for handling more traffic (Owen, 1999, p. 134). In the long run, the full optical structure (i.e. fiber-to-the-home (FTTH)) is expected to finally resolve the problem of speed-limitation and support duplex communication by deploying two-way amplifiers, and the ONU can share a number of users.

3.5. Wireless solutions

Different from wireline networks, i.e. telephone and cable networks, wireless access has competitive advantages in that it does not require huge sunk costs invested in local loop. In addition, it avoids the rights-of-way to access conduits and poles controlled by public utility companies (i.e. telephone, electricity, etc.). As a consequence, wireless solutions significantly reduce the barriers to entry and can quickly launch services. Currently there are several leading technologies in wireless access. First of all, personal communications service (PCS) with either time division multiple access (TDMA) or code division multiple access (CDMA) provides mobile communication and Internet access. As of the end of 1998, the number of subscribers reached 69.2 million, accounting for 26% of the national population in the United States (FCC, 1999a). However, the current mobile service can only support low-speed data access around 14.4 kbps (Knisely et al., 1998, p. 65). The prospective third-generation wireless system is expected to provide a broader range of services such as voice, Internet access, video conferencing, and multimedia at 2 Mbps (Knisely et al., 1998, p. 66; Mikkonen et al., 1998). [8]

Besides cellular phone technology, the emerging local multipoint distribution service (LMDS) and multichannel multipoint distribution system (MMDS) also have significant promise to compete in broadband market (Owen, 1999, p. 152). Moreover, the direct broadcast satellites (DBS) and low-earth orbit (LEO) satellites are well positioned to the quick and large-scale deployment of broadband services such as video delivery and high-rate data communications markets, especially for remote areas (Akyildiz and Jeong, 1997; Wittig, 1997).

In sum, in the emerging broadband market, there are diverse technologies available to be employed by competitors including, ILECs, cable companies, CLECs, ISPs, and other interested parties. The various wireline and wireless technologies should fiercely compete with each other in the broadband markets in the years to come. Typically at the present stage, ADSL and cable modem are the leading technologies used by ILECs and cable companies, respectively.

4. Comparison between the narrowband and broadband networks

Based on the brief survey of alternative technologies in the broadband infrastructure discussed above, I turn to investigate the distinctions between the existing telecommunications networks and the emerging broadband networks. Accordingly, I will use the findings to elaborate on one of the hypotheses of the dissertation, i.e., that the advanced broadband networks, as a brand-new facility, should be treated differently in regulation compared to the existing narrowband telecom industry.

[8] The first generation of mobile service was introduced in the late 1970s with analog communication technology. Current wireless systems fall into the second generation with digital technology (TDMA and CDMA). The third-generation (3G) wireless systems will support circuit- and packet-based network access with much higher rate for broader communications services. As a result, 3G wireless will most likely become an effective competitor for broadband wireline networks. See Knisely et al. (1998) and Wang et al. (1998).

4.1. Speeds

The broadband networks, as the name suggests, support much higher-rate applications than the existing narrowband networks. Even though there is no general consensus about the minimum speed of the broadband, 1.5 Mbps in the US and 2 Mbps in Europe are generally regarded as the dividing points for the broadband (Maxwell, 1999, p. 30). [9] The existing telecommunications network, however, is not designed to support such high rates of service, as mentioned earlier. Clearly, the telecommunications carriers face a serious and challenging task to modernize their low-speed networks.

4.2. Switching and transmission

The broadband networks will finally change the traditional switching and transmission mechanism dominated by the circuit-switched and dedicated transmission modes. The packet-switched and routers will gradually play a more important role in the future to handle the explosive growth of data communication traffic. As Masud (1999, p. 22) indicated, "[T]here is a certain inexorable logic in shifting voice traffic away from TDM (i.e. *TDMA, noted by the author*) networks to a more bandwidth-efficient, packet-based infrastructure because data is growing at rates several times faster than voice. Such a move would also shift the huge revenues derived from voice to the public data networks." As a consequence, the evolution toward data-dominated networks would be inevitable. Specifically, the Internet will be a main representative of the prospective broadband networks, a global data network that is highly accepted as a multimedia information platform (Schoen et al., 1998, p. 42).

4.3. Risky and uncertain investment

The fast pace of technological innovation gives rise to a new challenge for telecommunications carriers: the investment is risky and its return is uncertain, dramatically contrary to the case of existing telecommunications under either rate-of-return or price cap regulation.

The distinct and interesting issue in the pursuit of high-speed communication facilities is that the common carriers, i.e. incumbent LECs, are not sole players as was the case in the age of narrowband. Also, the alternative technological solutions are so diverse that it is hard to safely forecast what technology will lead the trend in broadband, and moreover, the technologies compete with each other. As a consequence, the competition among the technologies speeds up innovation and

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[9] FCC defined the minimum speed of broadband as 200 kbps. However, it also claimed that the definition of broadband is an evolutionary concept. See FCC (1999b, p. 20).

the application of new services on the one hand; on the other hand, the life of technology is expected to shorten significantly in the circumstance of convergence compared with the technologies deployed in the narrowband network, such as copper twisted line in the local loop. For instance, considering the strong possibility of substitution from ADSL technology, a necessary strategy has to be taken to fight back the aggressive deployment of cable modem from cable companies, the ILECs would most likely forgo their most investments in ISDN in the forthcoming years. However, even though ADSL could be a killer application for ILECS, it is uncertain how long ADSL will last because, in the long run, the bandwidth provided by ADSL is still far less than satisfactory for some broadband services such as HDTV. Clearly, the case of ADSL shows that investments in the broadband networks and services are uncertain and risky. As mentioned, this is one of the important features of broadband networks, which differs from the existing narrowband network.

4.4. Deployment of technology

Recalling the history of xDSL technologies, we can find that they did not get enough attention from local telephone companies (telcos) when they were invented in the late 1980s by Bellcore (Kwok, 1998, p. 286). In contrast, telcos pay more attention to HFC and FTTC architectures, which would be extremely time-consuming and expensive (Kwok, 1998, p. 286). Another important reason for telecos to intentionally slow the deployment of xDSL is that they feared that these new technologies would dramatically slash their profits from lucrative businesses such as T1 (1.5 Mbps) service, which could be substituted by xDSL (FCC, 1999c, note 73).

As a result, xDSL technologies generally stayed at field trial only, and there was no large-scale deployment until teleocs faced the threat of competition. As a direct result of the Telecommunications Act of 1996, aggressive competition from the cable companies forced telecos to rethink xDSL technologies and made the quick deployment of xDSL technologies a top priority. According to FCC (1999c), it was reported that "there were approximately 160 000 DSL lines in service at the end of the second quarter 1999. This represents a 300% increase since the fourth quarter 1998 and a 100% increase since the first quarter 1999". Most recently, the number of DSL served by telecos (ILECs) reached 563 000 at the end of first quarter 2000, an increase of 252% in nine months. [10]

The development of xDSL demonstrates that it is the market forces and consumer demands that drive the deployment of technology in the broadband market rather than the monopolistic carriers as in the narrowband market. This constitutes another distinct feature differentiating the broadband market from the narrow market.

[10] See http://www.xdsl.com/content/resources/deployment_info.asp (visited on 2 June 2000).

4.5. Services

The broadband network supports diverse applications from voice to video and from low-speed to high-speed services. It is an open and integrated communications platform for all residential and business customers. In contrast, the services on the existing narrowband network are rather limited, mainly voice-grade communications, such as POTS, facsimile, and low-speed data communications.

After more than 100 years of development, telephone service is nearly "universal" in the United States. As of November 1999, the penetration of telephone reached 94% (FCC, 2000c). Nevertheless, the provision of broadband services is only at the infant stage. A rough estimation shows that the number of high-speed access of the Internet in the forms of xDSL and cable modem reached 910 000 in the middle of 1999, accounting for 0.87% only. [11] Clearly, to meet Section 706 of 1996 Act, i.e. providing advanced telecommunications capacity to "all Americans", there is a long way to go. It raises a serious problem for public policy: how to implement universal service obligation for the broadband services. Because the precondition of universal service is universal access, discovering how to speed up the deployment of broadband networks is crucial. Going a step further, deciding what public policy will encourage investment, which is mainly from private sector, would play a large role in influencing the progress of broadband services as recognized by the regulator (FCC, 1999c).

In the pure competitive circumstance without government intervention, the expansion of broadband services will follow the model of "broadband islands" as illustrated in Fig. 1. The broadband services will be most likely deployed first at metropolitan, urban, and populous areas characterized by low-cost and high demands. In each island, competition would stimulate investment and drive the growth of services. With the expansion of the networks, it is expected that more and more areas will be served and the separate broadband islands will tend to overlap, merge, and ultimately cover the areas to the extent justified by economics. However, relying on competition alone will leave the rural and high cost areas ("blind areas" in Fig. 1) behind in the deployment of broadband services, and such a "digital divide" would hurt the people in those areas, and giving rise to debates about fairness in the availability of universal broadband service. Like basic telephone service, depending solely on market forces will not result in universal service (Parker, 2000). The universal service obligation imposed by regulators in the case of basic telephone service will likely be extended to the case of broadband services (Blackman, 1998, p. 168; Ramundo, 1996, p. 60).

[11] It is calculated based on the following sources (as the middle of 1999). ADSL: 160 000 (FCC, 1999c), cable modem: 750 000 (FCC, 1999c; Gillett and Lehr, 1999, Table 10), and households: 105 100 000 (FCC, 2000c). Penetration $= (160000 + 750000)/105100000 = 0.87\%$. It should be noted that I assume all the subscribers are residential. Clearly it is not accurate. Here is just to present a rough sketch about the current development of broadband services.

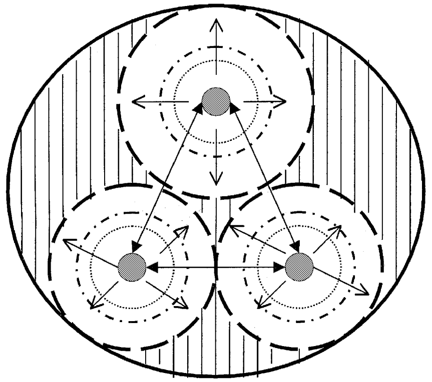

Fig. 1. The expansion of broadband services. (*Source*: Constructed by the author.)

4.6. Industrial structure

Traditionally, the telecommunications industry was organized as a form of vertical integration. The tenets of economies of scale, economies of scope, and positive network externalities not only justified one operator monopolizing a telephone service market but also the spread of monopoly over other non-basic telephone services. At the same time, to safeguard the public interests and prevent the monopolist from abusing market power, comprehensive financial and service regulation was imposed on the telecommunications industry. Now the technological progress and deregulation have fiercely shaken this monopolistic foundation since the 1980s and especially in the last decade – a period dominated by competition and relaxed oversight (Sidak and Spulber, 1997). As a result, the barriers to entry have been significantly reduced (Sidak and Spulber, 1997). Deregulation with a mandatory requirement of interconnection between incumbent LECs and competitors allows the new entrants to make use of the incumbent's ubiquitous telecommunications networks. [12] Therefore, the technologies and competition are changing the traditional telecommunications industrial structure from one of the vertical integration to the decentralized and "competitive/co-operative" model (Melody, 2000, p. 279).

Melody's competitive/co-operative model fits well in describing the emerging broadband industry. First, the broadband market is competitive. Players equipped with different kinds of technologies compete in high-speed Internet access, video delivery, and other broadband services. As mentioned before, the ILECs, IXCs, CLECs, cable carriers, and other competitors pick the most suitable technologies for

[12] Interconnection obligation is addressed in Section 251, Telecommunications Act of 1996. It is further detailed in the FCC's interconnection order. See Telecommunications Act (1996) and FCC (1996).

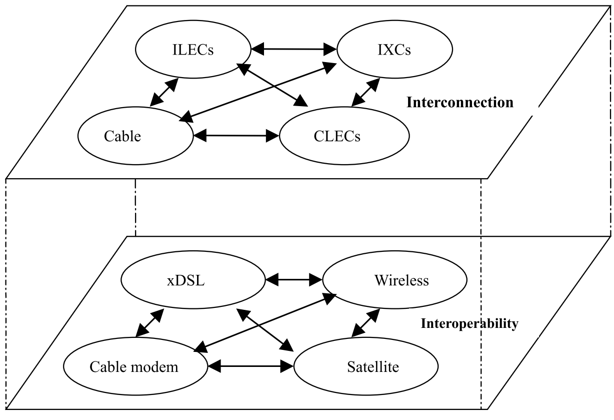

Fig. 2. Broadband networks interconnection and interoperability. (*Source*: Constructed by the author.)

them, such as ISDN, DSL, wireless, cable modem, satellite, etc. and dramatically stimulate the development of broadband services. Second and most importantly, current competition in broadband markets is not chaotic but cooperative on the grounds of network interconnection and standard interoperability. See Fig. 2. At the present infant stage, each player has a strong incentive to cooperate and interconnect with each other because there does not exist dominant market power.

4.7. Market structure

Even though market forces and competition will promote the deployment of broadband networks, the market structure should not be expected to be equally divided among the competitors. In addition, the deployment of technologies would vary with competitors and territories. In fact, the development of broadband networks will reveal a pattern of "path dependence".

As broadband services have to depend on existing communications infrastructure (mainly including telecommunications and cable networks), the market power and competitive advantages of network scope, expertise in network management and marketing, human resources, and research and development (R&D) will extend to the broadband services competition. As a result, the dominant players in their own markets tend to take significant shares of the broadband services market. Such a phenomenon, i.e. path dependence, reflects the inner relationships between existing networks and the prospective broadband networks in terms of production inputs identified earlier.

For instance, as discussed earlier, xDSL is a kind of technology enhancing twisted lines capacity by working in high frequency segments to support high-speed downstream and upstream transmissions. In fact, xDSL has no differences from existing narrowband local loop transmission in terms of transmission medium, i.e. twisted-

Table 2
Market shares of access lines and xDSL between ILECs and CLECs[a]

Market share	ILECs	CLECs
Narrowband access lines (as of the end of 1998)	98.1%	1.9%
Broadband xDSL (as of the end of March 2000)	74.6	25.4

[a] *Source*: Access lines data are from FCC (1999d) and xDSL data are derived from xDSL.com web site by the author.

pair copper lines. Because ILECs control more than 98% of the national access lines, [13] it is expected that ILECs will have an advantage over other competitors in xDSL deployment. In fact, the empirical data support this judgment. Table 2 shows that ILECs have an undisputable lead over CLECs in the xDSL market in the short run. By the same token, cable companies will have significant advantages in broadband access markets with cable modem technology. Even in the long run, as generally believed, when optical fiber will finally replace all copper lines and the local loop will be of end-to-end digital optical transmission, the ILECs and cable companies are still expected to be the main suppliers. This is because of the fact that both have aggressively deployed optical fibers between central offices (headends for cable network) and network interface units.

Based on the above analysis, the market structure in broadband services market will show different styles compared to the narrowband telecommunications markets. In the narrowband telephone market, ILECs dominate the market and many small companies compete with the incumbents, a market characterized by the "dominant-fringe" model (Rosenberg and Clements, 2000). However, the competition in the broadband market is across the traditional industrial boundaries and there are several dominant-fringe clusters competing head-to-head. In this end, the broadband market is competitive across industries (clusters) differentiated in the employed broadband technologies. As Clements (1998, p. 205) pointed out, "as convergence takes hold, what was dominance or even *de facto* monopoly in one sector will become competitive provision in the converged environment as other avenues of distribution, dominated by other players, become available". Specifically, ILECs and cable companies are widely expected to be two major contenders in the broadband service markets (Crandall, 1996, p. 304; Katz and Woroch, 1997).

4.8. Externalities

A fundamental property of network industries, including telecommunications, is "externalities", defined by the statement that "the value to an individual of access to a network depends on the size and composition of the group that also has access"

[13] According to FCC (1999d, Tables 3.1 and 3.3), as of the end of 1998, CLECs retained 0.2% access lines by unbundling and 1.7% by total service resale (TSR).

(Willig, 1979, p. 109). The source of network externalities comes from the complementarity between the components of a network (Economides, 1996, p. 679). Network externalities can be further categorized into direct externalities for two-way network and for indirect network for one-way network (Economides, 1996; Economides and White, 1996). The network carriers with significant market power tend to be against network compatibility, a necessary condition for network complementarity (Katz and Shapiro, 1985, p. 425; Economides, 1996, p. 676). As a consequence, the incumbents have incentives to refuse interconnection with competitors even though it would increase welfare as indicated by Katz and Shapiro (1985). For this reason, it is necessary that mandatory interconnection be imposed on the incumbents with market power over two-way telephone networks, as the 1996 Act required. However, some argue that the broadband services, especially high-speed Internet access, are characterized as indirect externalities (Speta, 2000, p. 83). Because the major application of the Internet access is for one-way information browse at its initial developmental stage, indirect externalities should be the dominant feature for the broadband networks. This distinction will have significant implications for regulatory policy toward the broadband networks as discussed later.

In the end, Table 3 summarizes the distinct features between narrowband and broadband networks. The next section will examine the implications of these differences for regulatory policy about the broadband networks.

Table 3
Comparison between narrowband and broadband networks

Features	Narrowband Network	Broadband Network
Speed	$\leqslant$ 56 kbps[a]	$\geqslant$ 2 Mbps[b]
Switching and transmission	Circuit-switched and dedicated transmission	Mainly packet-switched and routers
Services	Voice and low-rate data	Integrated (voice, data, static and moving pictures, video, etc.)
Pace of innovation	Slow	Fast
Risk of investment	Low	High
Deployment of technology	Carriers pick	Market driven
Status of development	Mature[c]	Infant[d]
Market structure	Dominant-fringe model	Competitive (multiple dominant-fringe structures in different service segments)
Externalities	Direct	Indirect

Source: Constructed by the author.
[a] With phone modem.
[b] Contingent on technologies, demands, and line conditions.
[c] Penetration more than 94% as of November 1999.
[d] Penetration less than 0.74% as of June 1999.

5. Implications for broadband services regulation

Broadband networks make necessary a re-examination of the regulatory principles and methods in the context of convergence. There are many important questions related to this issue. For instance, what are the rationales, if any, to regulate broadband networks? Should the broadband networks require different regulations because of the distinct features identified above? What kind of regulation would be needed to meet the broadband networks? It would be beyond the scope of this paper to fully research the broadband networks regulation and design a complete regulatory framework for broadband networks from political, legal, economic, and social aspects. Instead, in this section, I center the attention on the implications of the distinct features of broadband networks for the regulation and intend to answer the question whether the broadband network requires different regulatory approaches.

Telecommunications regulation rooted in the public-interest theory. [14] Regulation serves as a substitution for the market mechanism to protect consumers from the abuse of market power resulting from the natural monopoly (Posner, 1974; Bolter, 1979; Reagan, 1987; Strick, 1994). The "market failure" theory assumes that the firms with market power would not efficiently meet consumer's demands and also accomplish prescribed social goals. Regulatory intervention in telecommunications has a twofold purpose. On the one hand, regulation makes telephone services available and affordable to all citizens at reasonable price and quality. On the other hand, regulation protects the regulated firms from competition and grants them reasonable (average) rates of return from their investment and network operation. However, rate of return regulation has been criticized as encouraging inefficient investment because any expenditure, subject to regulator's scrutiny, can be recovered (Averch and Johnson, 1962). Most recently, price caps as an alternative incentive regulation have gradually replaced rate-of-return regulation to give the regulated firms more freedom in pricing (Abel and Clements, 1998). No matter what kind of regulatory method taken in telecommunications, either rate of return or price cap, the basic regulatory goals remains the same.

Nevertheless, it is problematic to fully apply the existing telephone regulatory framework which lasted nearly a century to the broadband services. In fact, the analysis of differences between the basic telephone network and broadband networks presented earlier constitutes a framework for re-examining the justification and nature of regulation on broadband networks.

[14] Philips presents four models of regulatory theories: public interest theory, capture theory, interest groups theory, and equity-stability theory (Phillips, 1988, pp. 174–179). However, the public interest theory is much more influential and most often used as doctrine for the FCC in its regulation of the telecommunications industry.

5.1. Convergence of technology, network and business

As discussed earlier, the fast pace of technological innovation and the overwhelming convergence of communications networks constitute significant differences compared with the basic telephone service. As a direct result of convergence in telecommunications, computing, audio and video industry, the current sector-specific regulation with different regulatory principles and objectives cannot keep up with industrial developments. Telecommunications policy is recognized as "fragmented" (Bauer, 1999). For instance, incumbent telephone companies are regulated under Title II as common carriers and cable television under Title VI in the Act of 1996. It would be expected to cause distortions when a telephone company (or a cable company) enters into a cable (or telephone) market because it raises the question as to what type of regulation should be appropriately applied. If service-sector regulations are imposed simultaneously to one firm doing business across regulatory boundaries, some behaviors such as cross-subsidy between the business activities will raise issues of efficiency and fairness.

In addition to the fragmentation in legislation, telecommunications regulatory authorities are divided among federal, state, and local government (Phillips, 1988). In the telephone industry, the FCC is mainly responsible for interstate regulation and state public utility commissions are in charge of local telephone regulation. Contrary to telephone regulation, in the case of cable TV business, local authorities generally play a dominant role in the form of franchise regulation.

Clearly, current regulation is characterized as a narrowband-oriented, network-isolated, service-specific, and policy-differentiated regulatory framework. Such an institutional arrangement causes distortions in the setting of convergence. As argued by Benkler, "communications infrastructure regulation should be focused on accentuating those attributes of digital information technology" (Benkler, 1998, p. 183). Changes in technology, a driving force behind convergence, will finally reshape the traditional industrial operations and change the market structure. As a consequence, regulation should respond to these changes and make necessary adjustments, even though the changes will take time because of the inertia of regulatory lag.

5.2. Multiple clusters of dominant-fringe market structure

As discussed earlier, the broadband services markets are identified as several dominant players plus multiple competitive fringes. Specifically, ILECs and cable carriers (multiple system operators, MSO) are dominant in broadband markets posited in telecommunications network and cable networks equipped with xDSL and cable modem, respectively. This unique market structure is significantly different from the traditional monopoly market structure before deregulation and convergence. The basic characteristic is that the fierce competition in the same broadband service market exists between the major competitors in different industries employing different technologies. This demonstrates the force of market convergence, and as a result, the overall broadband market is competitive. As observed by Baldwin et al. (1996, p. 4):

> The convergence of telephone and cable industry functions has been *accelerated* by the threat of competition in developing integrated broadband systems.. . . . . If the telephone company fails to rebuild and expand to a broadband network, it could be superseded by a cable industry that offers an integrated service including voice communication. If the cable industry does not anticipate the telephone industry conversion to broadband service, and stands pat with a one-way, video-only service, it could experience the same fate.

In fact, competition in the broadband service market is not just a theoretical possibility, but has happened in reality, as noted in last section. [15] This competitive market casts strong doubt to justify the application of "market failure"-oriented regulatory framework into the broadband market. There is no evidence that either the ILECs, or MSO, or any other competitors have enough market power to perform anti-competition such as price-fix, limiting output, and impeding the technological innovation. In other words, the current broadband market generally, if not totally, [16] demonstrates the desired competitive feature regarded as the most efficient by most economists. Therefore, through the lens of market structure, there is little ground to exercise tight regulation designed to overcome the market failure problem as in the telephone market.

5.3. Uncertain return of investment

Uncertainty of investment is the most distinct feature of broadband services compared to basic telephone service. Historically, average industry rates of return in the telephone industry were safeguarded through regulation. However, competition provides no such safety of investment.

The uncertainty of investment mainly comes from two aspects. First, the technology is dynamic, and the pace of innovation is exceptionally fast. As mentioned in Section 6, the currently deployed technologies such as xDSL, cable modem, terrestrial wireless, and satellite are just temporary solutions for the broadband networks. Strictly speaking, these prevalent technologies do not support full applications of broadband services, especially not for video-switching services. In other words, all of these technologies support simplex (i.e. one-way and downward stream) broadband communication) only rather than duplex (i.e. two-way and both downward streams).

[15] For the description of competitive status of broadband services, see FCC (1999c).

[16] As discussed later, competition will result in the concern of universal service, a non-economic but important political issue.

The quick technological progress will outdate the current broadband solutions and it is uncertain how long they will be in use and whether the investment will be fully recovered. But one thing is clear: that competition will accelerate technological innovation and bring about further uncertainty of investment.

Another important source of uncertainty is from the dynamic and unfathomable market demands. Even though the general demand for high-speed access is certain, the demands for more specific accesses and most importantly, the services (i.e. information, content, video-programming, and other complementary services) delivered upon the broadband networks are diverse and hard to foresee. In other words, indirect externalities impose more complexity and ambiguity in market demands compared to the basic telephone services.

Finally, the uncertainty from government regulation also constitutes a risk for investment. As a brand-new industry, there is no clear legislative direction for regulation about broadband services yet. In fact, currently there exist contradictory opinions about regulation of broadband services in terms of necessity and approach. As argued here, it is very questionable whether existing regulatory frameworks should be extended to broadband services. Specifically, whether the xDSL platform and cable modem system should be required to open for competition in the form of unbundling as imposed on incumbent local exchange carriers, and how to price the unbundling network elements are highly controversial and hotly debated. [17]

In sum, the uncertainties associated with the deployment of the broadband services cast substantial risks on recovery of the investment. Considering the development of broadband networks is still at an infant stage, how to encourage private investment that has a reasonable chance of recovery is an important issue of public policy.

5.4. Dilemma of universal service

Considering the fundamental role of information services and infrastructure, it seems clear that the universal service obligation should be extended from the basic telephone service to broadband service (Blackman, 1998). The Act of 1996 significantly expands the scope of universal service package from dial-tone phone service to "advanced telecommunication capacity" defined as "high-speed, *switched*, broadband telecommunications capacity that enables users to *originate and receive* high-quality voice, data, graphics, and video telecommunications using any technology" (the Act of 1996, Section 706 (c) (1), emphasis added by the author). In addition, it is required that "the deployment on a reasonable and timely basis of advanced telecommunications capacity to *all American* (including, in particular, elementary and

[17] For debate on opening advanced broadband networks, see FCC (1999c), Speta (2000), and Ridder (2000). For debate on pricing unbundling network elements, see Baumol and Sidak (1994), Sidak and Teece (2000), and Economides and White (1995).

secondary schools and classrooms)" (the Act of 1996, Section 706 (a), emphasis added by the author). However, it is not clear what mechanism should be taken for implementing this obligation. For instance, when should the universal service obligation be implemented? Who should be eligible for the obligation? And how is the obligation going to be financed? Even though there are mounting questions around the issue of universal broadband services, one thing is clear that regulatory intervention in the development of broadband service in the name of promoting universal service is politically inevitable. In this sense, devising a regulatory policy to promote the proliferation of broadband services through investment incentive and other means is crucial.

6. Conclusion

Convergence is a dominant trend in telecommunications and information industry, driven by the market demand of broadband services and promoted by competition and deregulation. As a brand-new movement, it challenges the theoretical rationales of regulation imposed on the narrowband telecommunications industry.

From the aspects of technology, service, investment, and market, this paper identifies and examines the distinct features associated with the broadband networks. In addition, the implications of these distinct features are investigated. It is found that competition characterizes the functioning of current broadband networks, and there is little justification to extend traditional regulation to the broadband industries, at least at the current stage. Further, it is warned that competition is not effective to implement universal service obligation related to the provision of broadband services and some extent of regulatory intervention is expected to step in as long as the universal broadband service is singled out and stressed as a "public interest".

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