Broadband Communications

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Communications technologies that provide high-speed, always-on connections to the Internet for large numbers of residential and small-business subscribers are commonly referred to as "broadband" technologies. *High-speed* is an imprecise term—it simply means much faster than dial-up connections. A dial-up connection, using a 56-kbit/second modem, typically transfers data at about 40 Kb/s. The U.S. Federal Communications Commission (2000) defines high speed as a connection that provides at least 200 kb/s in one direction. Much higher speeds are generally available in modern digital subscriber line (DSL) or cable modem services.[1] *Always-on* refers to an Internet connection that is immediately available to the user and does not require that he (or she) log on to the service for each use. With an always-on or always-available connection, the delay from the time that a user goes to the computer and clicks on a web page icon to the time when the request for information is delivered to the remote server is measured in milliseconds.

In this chapter, I review the literature on the development of mass-market broadband services for residential and small-business subscribers. I specifically exclude any discussion of traditional high-speed services for medium and large businesses, such as DS-1 or DS-3 services, or various high-speed packet-switched services, such as frame relay. Nor do I include any discussion of "special access" or "leased lines" that are used by large businesses or long distance carriers to originate or terminate large numbers of voice/data calls.

1. The Technology

It is often asserted that broadband technologies have been available for as much as two decades, but that regulated telecommunications carriers were slow to deploy them. However, there was little demand for broadband connections until a large number of subscribers had access to the Internet. For example, as recently as 1994, less than one-fourth of U.S. households had a computer and far fewer had Internet access. In this environment there was not likely to be much demand for broadband connections at any price.

1.1. DSL

Telephone networks are typically constructed with a mix of fiber optics and copper wires. The copper wires typically extend from the central office to the subscriber's premises, but in areas of low population density or new development, fiber optics may radiate out from the central office to remote terminals from which copper wire is extended to the subscriber. Digital subscriber line modems are used to transmit data over these copper wires at far higher rates than is possible over voice-grade connections because they can take advantage of capacity in the copper wire that is not used for voice

[1] The FCC retains its current definition for advanced telecommunications capability as infrastructure capable of delivering a speed of 200 Kb/s in each direction. In Japan and Korea, broadband services are often delivered at speeds of 4Mb/s to 12 Mb/s.

communications. There are a number of different DSL technologies available that may be employed by telephone companies under various conditions. These technologies, shown in Table 1, offer a variety of speeds for the downstream and upstream paths.

Table 1
The Varieties of Digital Subscriber Line (DSL) Service

DSL Type	Description	Data Rate	Distance Limit	Application
IDSL	ISDN Digital Subscriber Line	128 Kbps	18,000 feet on 24 gauge wire	Similar to the ISDN BRI service but data only (no voice on the same line)
CDSL	Consumer DSL from Rockwell	1 Mbps downstream; less upstream	18,000 feet on 24 gauge wire	Home and small business service not requiring a splitter; similar to DSL Lite.
G.Lite or DSL Lite	"Splitterless" DSL without the "truck roll"	From 1.544 Mbps to 6 Mpbs , depending on the subscribed service	18,000 feet on 24 gauge wire	The standard ADSL; sacrifices speed for not having to install a splitter at the user's home or business
HDSL	High bit-rate Digital Subscriber Line	1.544 Mbps duplex on two twisted-pair lines; 2.048 Mbps duplex on three twisted-pair lines	12,000 feet on 24 gauge wire	T1/E1 service between server and phone company or within a company; WAN, LAN, server access
SDSL	Single-line DSL	1.544 Mbps to 2.048 Mbps downstream and upstream on a single duplex line	12,000 feet on 24 gauge wire	Same as for HDSL but requiring only one line of twisted-pair
ADSL	Asymmetric Digital Subscriber Line	1.544 to 6.1 Mbps downstream; 16 to 640 Kbps upstream	From 1.544 Mbps at 18,000 feet to 8.448 Mbps at 9,000 feet	Used for Internet and Web access, motion video, video on demand, remote LAN access
RADSL	Rate-Adaptive DSL from Westell	640 Kbps to 2.2 Mbps downstream; 272 Kbps to 1.088 Mbps upstream	Not provided	Similar to ADSL
VDSL	Very high Digital Subscriber Line	12.9 to 52.8 Mbps downstream;1.5 to 2.3 Mbps upstream	12.96 Mbps at 4,500 feet to 51.84 Mbps at 1,000 feet	ATM networks; Fiber to the Neighborhood

Source: http://www.everythingdsl.com/types/index.shtml

The higher-speed services shown in Table 1 often require considerable installation expense at the customer's premises because "splitters" must be installed to divide the lower-frequency voice signal from the higher-frequency data signal or dedicated lines must be installed for the high-speed data connection. Even those not requiring such installations may require substantial network upgrades to be reach large numbers of subscribers.

Most DSL services are *asymmetric digital subscriber line* (ADSL) services, offering different transmission capacities for downstream and upstream communications. Higher speeds are offered for downloading information or even audio or video programming than for communicating upstream. ADSL is designed to share the copper loop used for ordinary telephone calls. By splitting the signals on the loop at the central office or remote terminal and routing the lower-frequency portion, generally from 0 to 4Khz, over the traditional voice network and the higher frequencies to a separate modem or *digital subscriber line access multiplexer* or *"DSLAM,"* a telephone company can deliver a high-speed access service for Internet connections over the same line as it delivers voice services.[2]

As Table 1 shows, DSL service is limited by the quality and length of the copper lines that extend to the subscriber's premises. DSL connections can be restricted or even made unworkable if the copper loop is impaired by various devices that are used to enhance the quality of voice communications, such as loading coils. Moreover, the ability of copper telephone loops to carry high-speed data signals declines with distance.

The various DSL services shown in Table 1 are designed for different uses, offering a variety of range and capacity alternatives as well as technical standards. Thus, the telephone industry lacks the simplicity of a single standard enjoyed by the cable industry. Typically, ADSL permits downstream speeds of from 500 kb/s to 8 Mb/s and upstream speeds of up to 640 Kb/s. The communications speed actually achieved depends on the quality and length of the copper line connecting the subscriber. ADSL modems adjust the operating rate to deliver the highest possible speed over a specific loop, but they do not operate reliably over copper loops longer than about three miles (5,000 meters).

As the Internet has grown, the cost of providing ADSL service has declined, in large part because of the declining cost of electronics. The cost of ADSL modems has fallen substantially as Figure 1 shows. In 1992, the cost of a modem was approximately $10,000; nine years later it was in the range of $100. This cost trend helps to explain why telephone companies were initially slow to deploy DSL. Faulhaber (2002a), for example, suggests that the incumbent U.S. telephone companies should have begun to deploy DSL before 1998, but the high cost of modems may have made such deployment uneconomic. Similar conclusions obviously apply for cable modems and for cable television company deployment of broadband.

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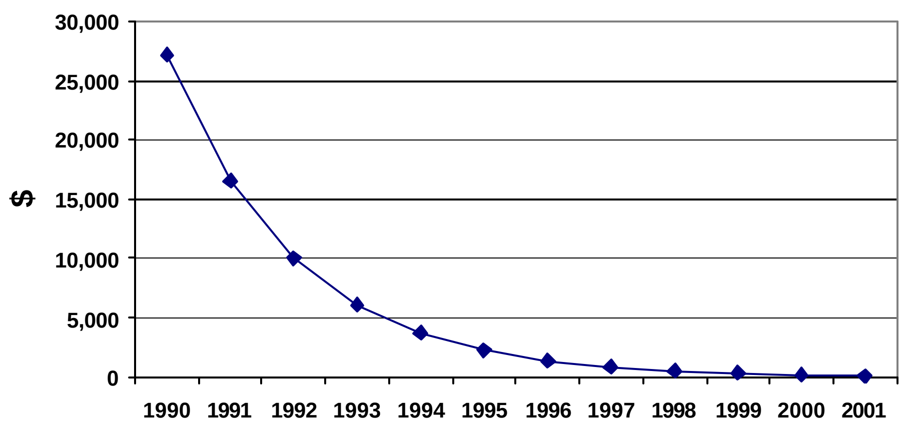
[2] For a more detailed exposition, see Jackson (2002)

Figure1
The Cost of an ADSL Modem



Source: Based on Jackson (2002)

1.2. Cable Modems

Broadband services can also be offered over traditional cable television networks that employ a *hybrid fiber-coaxial cable* (HFC) technology. In the 1990s, a cable industry research consortium, CableLabs, developed a standard for data communication over cable systems, Data Over Cable System Interface Specification, or DOCSIS.[3] DOCSIS has had a major impact on the cable modem market, allowing multiple manufacturers to compete in the supply of compatible equipment and reducing the risk to consumers of being saddled with orphaned equipment. More than 50 manufacturers now supply DOCSIS cable modems—including firms such as Motorola, Cisco, Toshiba and 3Com.[4]

Figure 2 provides a schematic diagram of a DOCSIS system. Each subscriber has a cable modem at its premises, and the cable company installs a cable modem termination system (CMTS) located at its head-end. The cable modems and the CMTS use the preexisting cable network much as a dial-up modems use the telephone network.

Figure 2

The Cable Labs DOCIS System

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[3] The DOCSIS project was renamed as the CableLabs® Certified™ Cable Modem project.
[4] See Jackson (2002) for details.

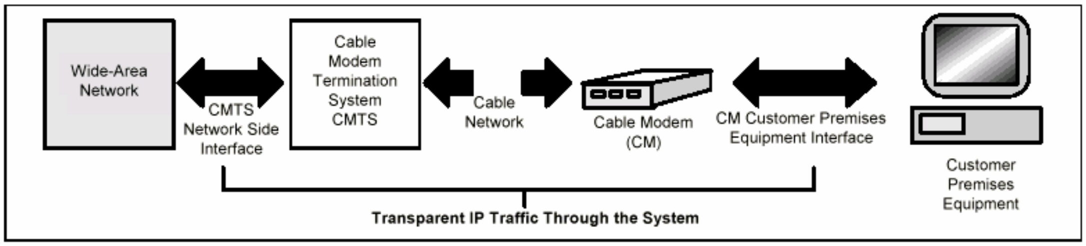

Figure 1-1. Transparent IP Traffic Through the Data-Over-Cable System

Source: CableLabs SP-RF1-106-010829 as reproduced by Jackson (2002)

Cable modems can receive data at speeds as high as 40 Mb\s and transmit at speeds up to 10 Mb\s. The next generation of cable modems may be able to transmit upstream at 30 million bits per second.[5]

To offer high-speed access, a cable television system must dedicate some of the system's capacity, typically the equivalent of a single TV channel, to the cable modem service. One TV channel provides about 40 Mb\s of downstream capacity that is shared by subscribers. This sharing of capacity creates a fundamental problem for cable systems. The downstream data from the headend to the subscriber is transmitted over the cable through its tree and branch architecture, much as a television signal is distributed over the system. DOCSIS includes an encryption element, the modern version of a secret codes, to prevent anyone other than the subscriber from reading the data in these broadcast packets. In a large cable system with 100,000 subscribers, a downstream capacity of 40 Mb\s would provide an average capacity of just 400 bits per second per subscriber if all subscribers were connected. If as many as 5 percent were connected, the capacity would still only be 8 Kb\s.

The solution to this network sharing problem is to provide different data streams to a number of remote neighborhood nodes. For example, if a cable system serves an average of 1,000 homes per fiber node and no more than 5 percent of homes are using the downstream capacity at one time, the average downstream capacity would be 800 Kb\s. per second, an acceptable speed for web-browsing service for most subscribers. The data capacity is not rigidly divided among the subscribers, but the capacity resides in a pool and is allocated dynamically as users need to communicate. Notice however, if many consumers choose to use the Web in a fashion that requires continuous transmission— say, downloading a host of music files – the shared capacity will quickly be exhausted. Improving system performance or speed will then require the allocation of additional capacity to the cable modem service.

1.3. Fiber to the Home

[5] This description is drawn from Jackson (2002).

The highest speed broadband connections are available through fiber to the home (FTTH) technology, which is now being installed in Japan and a variety of small communities in the United States. FTTH technology utilizes fiber optics to distribute signals from the telephone central office to the final subscriber and back again. The capacity of a single fiber is substantial; therefore, several FTTH architectures split the fiber so that 16 to 64 households share the capacity of a single fiber. If the splitting is accomplished at a "passive" network node which cannot vary the capacity allocation across subscribers, the network is described as a Passive Optical Network (PON). If the node at which the splitting occurs has electronics that permit the allocation to vary with network usage, the network is an Active Star Network. Each subscriber to these networks would be able to receive service at speeds of 10 Mb/s to 100Mb/s or even higher if demand warrants.

In Japan, NTT is offering a FTTH service to businesses and residences in dense areas at a monthly price of between U.S. $30 and $70. By August 2002, NTT had enrolled nearly 100,000 subscribers in this service, which offers speeds of up to 100 Mb/s, but most subscribers are businesses. (Tsuji, 2002) Nor is it clear that this service covers its costs at these low rates. Total worldwide subscribers to FTTH at end of 2002 were estimated to be 400,000.[6]

1.4 Wireless Access

A third form of broadband access is provided by various wireless technologies. The earliest of these technologies was fixed wireless, utilizing a central wireless transmission facility that radiates signals to dispersed customers with antennas. These services have been used to provide services to medium-sized and even large businesses, but with limited economic success. More recently, several U.S. companies have acquired spectrum in the MMDS and LMDS bands. These services are not yet very widely subscribed, nor is it clear that they are competitive with wire-based systems if they must pay auction-based spectrum license fees. A recent analysis by Wanichkorn and Sirbu (2002) suggests that they are only competitive with cable modems and DSL at very low population densities.

Satellite systems are the most widely used of the high-speed wireless options today. Two U.S. firms, DirecPC and StarBand, provide two-way satellite-based Internet access. These systems provide service at data rates of about 400 to 500 kilobits per second. Thus far, satellite firms appear to be targeting customers in rural areas who will not be offered DSL or cable-modem service. Because geostationary satellites have large footprints they are not well suited for delivering broadband services to large numbers of customers. The next generation of satellite systems will use spot beams to overcome this deficiency and,

[6] Jeff Baumgartner, "Fiber to the home blazes an evolutionary path," CED Magazine, February 2003, accessed April 10 at http://www.cedmagazine.com/ced/2003/0203/02a.htm

therefore, will be able to offer higher data rates to millions of customers due the greater system capacity afforded by spot beams.

The newest wireless technology that is gaining attention is the "WiFi" technology that uses unlicensed spectrum, the 2.4 GHz spectrum in the U.S., to reach wireless local area networks (LANs). Using an IEEE standard called 802.11,[7] users can access the Internet at thousands of low-power wireless network locations throughout the country, including university campuses, airports, coffee shops, hotels, and even their own homes. This technology supports data rates at up to 54 megabits per second, but it is shared access and no one user would typically be able to achieve this rate.[8] This technology is spreading rapidly, primarily to allow people to gain access from numerous locations through their lap-top or notebook computers or through other wireless appliances.

While WiFi solves the problem of distributing Internet services the last few yards to the subscriber, it is not a technology that can substitute for DSL or cable modem service unless high-speed connections are widely available from the wireless LAN to the Internet backbone. Users typically only need to sign up with a Wi-Fi service provider and deploy a Wi-Fi PC card on their laptop to surf the Web or access e-mail, but they must be in relatively close proximity to a "hot spot" to access the Wi-Fi network. Lehr and McKnight (2003) suggest that the current cellular service providers could integrate WiFi into their networks, either as a substitute for 3G or as a complement to it. This would allow ubiquitous WiFi service.

2. Broadband Diffusion

In its first few years, broadband grew rapidly in some countries, but not in others. Before examining the possible reasons for these differences, it is useful to provide data on the extent of broadband penetration in the developed world.

2.1 Cross Country Comparisons

Figure 3 shows the data compiled by the Organization for Economic Co-Operation and Development as of September 2002. Figure 4 shows that there is a weak relationship between income per capita and broadband penetration, with the obvious outliers being Korea, which deserves special attention, and Luxembourg. North America, Scandinavia, and the Benelux countries tend to have much higher broadband penetration than other OECD countries. The United Kingdom, Australia, and New Zealand lag badly despite their early liberalization of telecommunications and their obvious initial advantage in using the Internet because of their use of the English language.

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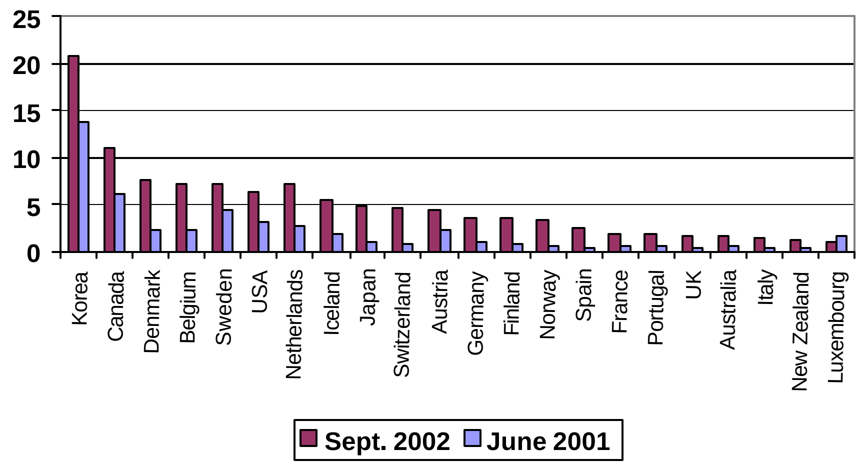
[7] 802.11 comes in 4 flavors—in chronological order they are: 802.11, 802.11b, 802.11a, and 802.11g.
[8] Even if they could, relatively few coffee shops install a 54 mbps or 11 mbps upstream connections to the Internet.

Figure 3
Broadband Subscribers per 100 Population, June 2001 and September 2002



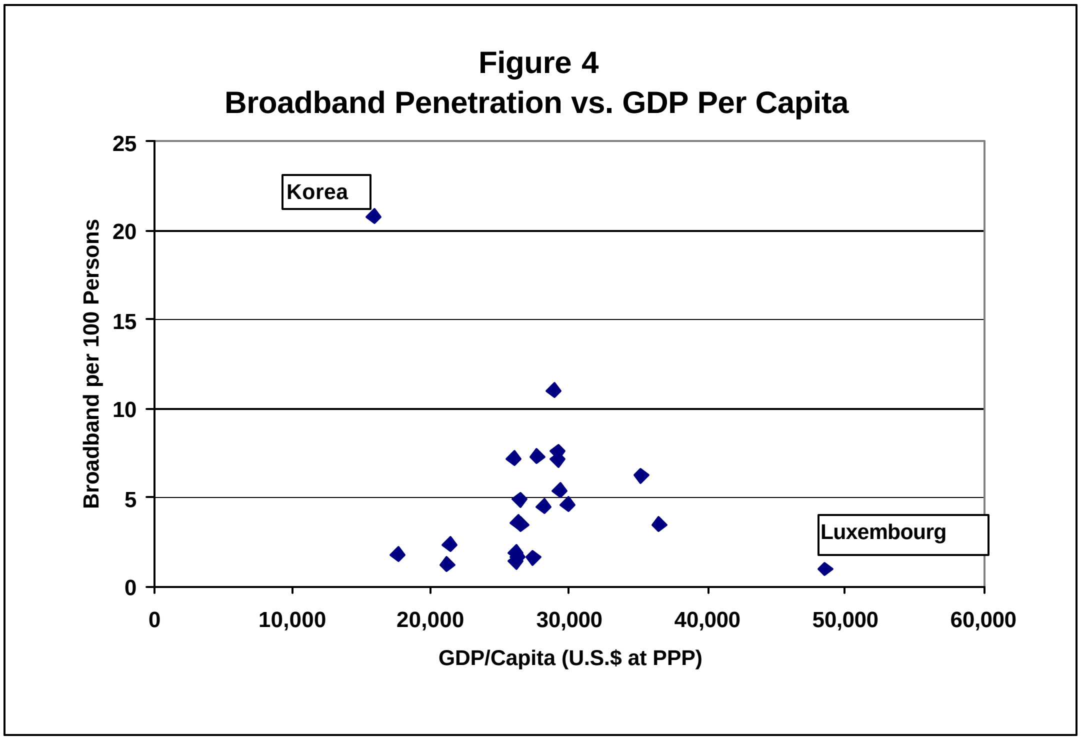
Source: OECD (2002)

It is also useful to array these countries' broadband penetration in terms of technology. Korea has the most aggressive policy of extending fiber optics to new residential buildings, particularly the large apartment complexes that have been built in recent years. About two-thirds of Korean subscribers use DSL and one-third use cable modems. Among the other countries with substantial broadband penetration, Canada, the United States, the Netherlands and Austria have a large share connected to cable modems. Countries with little cable television, such as France, Italy, New Zealand, and Spain tend to have much lower broadband penetration.[9]

Some economists contend that incumbent telephone companies have been reluctant to deploy DSL because this service "cannibalizes" the incumbents' highly profitable high-speed business services, such as DS-1. Although there is no empirical evidence to support this claim as yet, it is a plausible argument because of regulators' attempts to keep basic local residential telephone service rates low by allowing regulated incumbent carriers to charge supra-competitive prices in business markets.[10] This theory underlies much of the regulatory rationale for requiring "local loop unbundling" that is described below.

[9] Germany and the United Kingdom have substantial cable television penetration, but little cable modem subscription. In the U.K., the cable companies have performed badly and have recently been reorganized through merger into two large carriers. In Germany, Deutsche Telekom, the incumbent telephone company, owns most of the cable network and has been unwilling to pursue cable modem development.

[10] See Crandall and Waverman (2000).



2.2 Comparing Broadband Diffusion with Other "Breakthrough" Technologies

Given that the Internet has existed only since 1990[11] and that household Internet connections did not approach 25 percent in even the most developed countries until 1995 or later, the growth of broadband has been quite rapid. But how does its diffusion compare with the spread of earlier technological breakthroughs in consumer durables or services, such as radio, television, the VCR, or the home computer?

Economists and technologists often measure the speed at which new inventions or media spread throughout the population by calculating "diffusion curves." Owen (2002) measures the rate of diffusion for major new consumer technologies. His results are reproduced in Figure 5. The diffusion of consumer broadband services, shown in the lower right corner, occurred about as rapidly in its first few years as the diffusion of VCRs, the Internet ("Online"), and the VCR, and it spread more rapidly than cable television or personal computers. Only television gained consumer favor more rapidly than broadband in Owen's analysis.

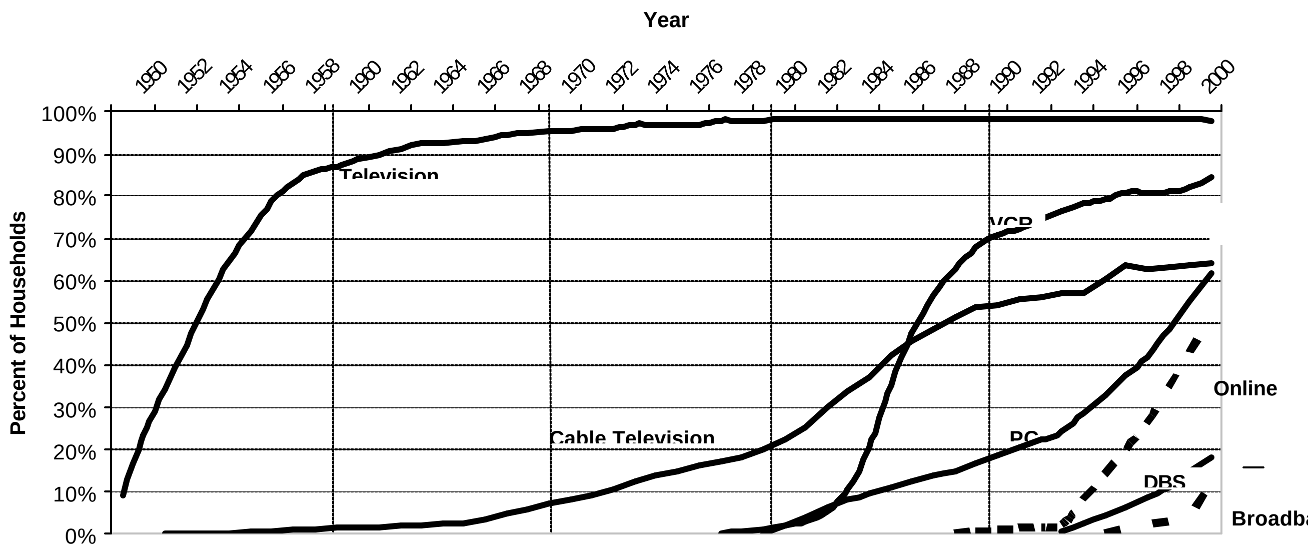
Faulhaber (2002) makes the same point in analyzing the barriers to broadband deployment. He finds that broadband diffusion has been as rapid as that of the VCR in its first few years and far outstrips the diffusion rate for wireless telephony. As a result, he

[11] Formally, the Internet was created on 1/1/83 when the arpanet split into the Arpanet and milnet.

doubts that regulatory policies had been a major impediment to widespread broadband penetration through 2002.

These comparisons of historical diffusion rates are somewhat misleading. When television sets were first introduced, they were quite expensive, as were the first wireless telephones. A new television set in 1948 would have represented a much larger share of a household's budget in 1948 than the purchase of a household computer or broadband service today.[12] I return to the diffusion issue in a later discussion of network and "bandwagon" effects.

Figure 5
Diffusion Curves for New Consumer Goods and Services



Source: Adapted from Owen (2002)

3. The Economics of Broadband Supply

The provision of broadband communications services is subject to many of the economies of scale, scope, and density generally observed in the telecommunications sector, particularly if the service is delivered over wires. Given these economies, what is the likely market structure of the broadband industry?

3.1 Cable Modems, DSL, and Fixed Wireless

[12] Faulhaber acknowledges this point *vis a vis* wireless telephony in his article. (Faulhaber (2002))

Faulhaber and Hogendorn (2000) have undertaken an analysis of the cost of building a hybrid fiber-coaxial cable system *de novo* and the likelihood of competitive entry into the delivery of broadband services over such networks. They conclude that such entry is feasible under certain conditions. Using a Cournot model of spatial competition, they analyze the likely deployment of new hybrid fiber coaxial cable networks to deliver broadband services to residences. (They assume that DSL is not a viable competitor.) They find that a second firm enters the market when the demand for broadband rises by 50 percent from its initial level of 15 percent at a $50 per month price. The third firm enters when demand rises to 85 percent above this level. Once broadband subscriptions rise to the level of current cable television subscription, their model predicts that 70 percent of households will have a choice of three facilities-based providers.

Jackson (2002) also examines the economics of offering broadband over DSL on an incumbent telephone company's network and via cable modem over a cable television network. He finds that the costs are relatively similar. However, Jackson does not analyze the effects of the necessary investment in modifying existing telephone networks or cable systems to deliver these new broadband services.

Wanichkorn and Sirbu (2002) have provided a detailed engineering analysis of the capital costs of delivering broadband over three platforms: fixed wireless, DSL, and cable television, using the results provided by Fryxell (2002) for cable modems and DSL. They conclude that cable modem service enjoys a cost advantage over DSL in every population density range, but that fixed wireless has an advantage over cable at extremely low population densities, *i.e.*, less than 100 lines per square mile. (See Table 2). Their costs exclude all operating costs, marketing costs and SG&A, and they also exclude the spectrum costs of the fixed wireless option. When spectrum costs are included, the cost advantage of fixed wireless diminishes and perhaps disappears for all but the areas with less than 5 lines per square mile.

Given the large customer-acquisition (marketing) costs involved in selling a new service, none of these studies provides an analysis of the full costs of delivering broadband services. In addition, they do not take into account the joint costs of marketing and operating a communications company, such as a cable television company or an incumbent telephone company that offers a variety of video, wireless telecommunications, and wireline telecommunications. If there are substantial joint economies in offering and marketing such services, the market for broadband services may evolve into one involving only platform competition from large, diversified carriers.

Table 2
Annual Cost per Line for Broadband over Three Platforms
($/line/year)

Density (lines/sq.mi.)	Fixed Wireless*	DSL	Cable Modem
0-5	250-336	707	646
5-100	248-308	364	292
100-200	230-304	274	189
200-650	233-287	228	136
650-850	227-302	212	121
850-2,250	217-270	202	113
2,250-5,000	212-259	195	109
5,000-10,000	207-258	199	114
>10,000	214-241	181	110
Average	225-286	236	151

* Excludes spectrum costs, which may add as much as $22.60/line/year. Wireless may also offer bandwidth (speed) that is different from typical cable modem or DSL bandwidth.
Source: Wanichkorn and Sirbu (2002).

3.2 FTTH

The costs of broadband delivered on a FTTH system are substantial because of the need to extend fiber farther into the network and to install a variety of equipment in the subscriber's premises to translate the optical signal into an electrical signal that existing household appliances can receive. Several U.S. communities are considering the construction of FTTH networks. Palo Alto, CA, has been investigating the economics of such a system for some time and has estimated that a system designed to serve the entire city would cost about $1,000 per home passed plus another $1,500 per home connected to the network. Thus, if 25 percent of homes subscribed, the network could cost as much as $5,500 per subscriber, or more than three times the cost of current cable or telephone networks.[13]

A more recent analysis of current and prospective FTTH technologies has been undertaken by a consortium led by Carnegie Mellon University (2002). It focuses principally on FTTH technologies. It provides a useful comparison of the costs of FTTH

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[13] See "FTTH Business Case" at http://www.pafiber.net/references/20021002-UAC-packet.htm.

versus other technologies based upon a study performed by Hopkins (2001) and summarized in Table 3.

Table 3
The Capital Cost per Subscriber of Alternative Broadband Technologies

Technology	Data Speed	Approximate Cost per Home Served
DSL	640 kb/s-8Mb/s	$500
Cable	500 kb/s +	$400
FTTH	20Mb/s +	$2,000-$6,000
MMDS	2 Mb/s +	$650
LMDS	2 Mb/s +	$1,300
Satellite	400 kb/s +	$1,000 + Earth Station

Source: Hopkins (2001) as reported in Carnegie Mellon University (2002).

However, according to the CMU analysis, the capital cost of FTTH systems could be much greater than the $2,000 to $6,000 shown in Table 3. The capital cost per home served using the PON architecture in an urban area rises from about $2,000 with 80% subscriber penetration to $5,000 with only 20 percent subscriber penetration. In small towns, such a system would cost about $3,500 per subscriber if 80 percent subscribed, but more than $10,000 if only 20 percent subscribed.

These costs make the widespread deployment of new FTTH networks uneconomic at present unless a large share of households subscribe and the cost of the subscriber equipment and installation declines substantially. The extension of current fiber-coaxial cable networks, owned by cable television companies, or fiber-copper systems, owned by telephone companies, would appear more economical, but even these extensions would be limited by the cost of customer premises equipment and its installation. However, as the cost of the electronic equipment required declines, even FTTH could evolve into an attractive option for subscribers desiring extremely fast network connections.

3.3 The Weak Dominance of Cable

The analyses summarized above suggest cable modem service currently enjoys a substantial advantage over DSL, particularly in areas where the cable infrastructure is already deployed and where the copper telephone plant requires substantial upgrading. This advantage may be mitigated by the degradation of speed that occurs when large numbers of subscribers are connected to the same cable node. Such performance degradation can be overcome, however, if cable operators devote more than 6 Mhz of their 750 Mhz of capacity to cable modem service or if fiber is extended farther out toward the subscriber. Why they do not do so at present is discussed below.

Fixed wireless and satellite systems are generally higher-cost technologies that dominate cable and DSL only in rural areas. Finally, the new FTTH systems are being deployed on an experimental basis in the United States, often with municipal government participation, and in Japan, a country with high population density. These systems have extremely high costs at the present and will only be economical as the cost of the required electronics declines and household demand for high speed outruns the speeds available via cable modems and DSL.

4. The Demand for Broadband

As with all new services or technologies, particularly those that feature network externalities, it is very difficult to predict the demand for mass-market broadband service. The nature of any new service may be evolving rapidly at first, or in the case of broadband, the potential use of the service may be changing rapidly. Some households may not be interested until others show them the value of adopting the service or provide them the opportunity to reap the benefits of consumption externalities generated by the service.

The first empirical studies to examine broadband adoption are Madden and Savage (1996) and Madden, Savage, and Simpson (1996). They utilized survey data from a sample of Australian households that asked participants to indicate their preferences for a broadband service that had not yet been deployed. They find that the interest in broadband is directly related to education, at least one member of the household originating from Europe or Asia, and age. Households were less interested in broadband if one or more people in the household was 65 years or older. They interpret their results as portending a danger of the creation of a class of "information poor." This danger seems to have receded since then as the real cost of personal computers and Internet subscriptions has fallen dramatically.

One of the earliest studies of the demand for high-speed connections in the United States was undertaken by Hal Varian and his colleagues in an experimental setting at the University of California, Berkeley. In 1998-99, 70 members of the Berkeley community were provided with various access speeds up to 128Kb/s at different prices, admitted a low ceiling by today's standards but not by the standards of 1998-99. Varian found that his sample of users exhibited a rather high price elasticity of demand for bandwidth. The own-price elasticities of demand for the higher speeds were in the range of -2.0 to -3.1. Moreover, the implied value of the time exhibited by these 70 participants was astoundingly low, generally in the range of 1 to 5 cents per minute. Varian attributes this low demand for bandwidth to the absence of applications requiring high speed and the ability of users to occupy their time productively in other pursuits while waiting for file downloads.

Obviously, Varian's results pre-date the development of Napster and the increased use of the Internet for downloading video or engaging in real-time electronic games. More current estimates of the demand for broadband are reflected in the work of Rappoport and associates. Their work addresses two related issues: (1) what are the own and cross price elasticities of demand for broadband and narrowband services? And (2) how different are the users and uses of broadband and narrowband Internet services?

Using a sample of 20,000 United States households that were surveyed in 2000, Rappoport, et.al., (2001a) estimate a nested logit model of Internet subscription and choice of narrowband or broadband access. Because cable modem service is available to some households in the United States where DSL is unavailable, DSL is available to others where cable modem service is unavailable, and both are available to yet others, the authors are afforded a rich set of possible choices to examine. They find that the own-price elasticity of demand for broadband service is much greater than the demand elasticity for narrowband. Rappoport, et.al, find that the own-price elasticity is in the range of -0.6 to -0.8 for cable modem service and -1.4 to -1.5 for ADSL service. In general, they find that dial-up service and broadband services are substitutes for each other, a result that conflicts with the results in Hausman (2002a). Hausman points out that narrowband and broadband services are not likely in the same market given that residential dial-up telephone rates vary substantially across states while broadband rates typically do not. As broadband diffuses throughout the economy, the degree of substitution between broadband and narrowband connections will surely decline even farther.

Using data from 2000-01, Crandall, Sidak, and Singer (2002) estimate a model similar to that used by Rappoport, et.al., and obtain own-price elasticities for both services equal to -1.2. In a later paper that uses August 2001 Internet user data, Rappoport, et.al. (2002) examine the intensity and nature of Internet use of households with narrowband or broadband connections. They show that the decision to use a broadband connection depends on the opportunity cost of time for the user and intensity of Internet use. Higher income households who use the Internet intensively are most likely to subscribe to broadband. Broadband subscribers tend to visit more Internet sites, particularly "entertainment" and "Internet services" sites and spend more time online. However, in this later paper, Rappoport, et. al., find that the demand for broadband is substantially less price elastic (-0.47) than it was a year earlier. This suggests that broadband is moving from the "luxury" category to one closer to a "necessity," particularly as consumers learn to use it and increasingly understand its potential benefits.

More recent work by Rappoport, et. al., (2003) employs 2002 survey data on households' willingness to pay for DSL and cable modem service. Therefore, these results reflect the most recent reaction of households to the choice of Internet service. Rappoport and his colleagues find that willingness to pay is inversely related to age and not very strongly related to household income. More importantly, they find that the own-price elasticity of demand for both broadband technologies declines from about -3.0 to the range of -1.0 as the price falls from $50 per month to $20 per month and that the own-price elasticity of demand is higher for DSL than for cable modem service.

5. Network and Bandwagon Effects

Broadband access to the Internet opens up vast new opportunities for subscribers to use their connections. What began as a popular medium for exchanging e-mails may now evolve into one that allows users to manipulate large video files, watch a variety of filmed content, or participate in real-time video games with others around the world. It is likely that these and totally unforeseen new uses will develop in the next few years, but it is not clear that the existing market organization provides sufficient incentives for the efficient development of this content.

5.1 Internalizing Network Externalities

As each new mass medium developed, the owners of the distribution facilities or networks were initially integrated into the supply of content. Such integration allowed them to exploit the network effects created by their investments. The value of any increment of content is a direct function of the deployment of distribution assets, and the value of the distribution assets is also directly related to the amount of content available. Therefore, vertical integration between content production and distribution creates incentives for production and investment that would not exist if the two stages of production were independent and unable to negotiate efficient, enforceable long term contracts. (Katz and Shapiro, 1985, 1994)

For instance, motion picture companies integrated production, distribution, and even exhibition into their operations in the early 20^{th} century. (Crandall (1975, 2001) Shortly after World War II, the new television networks initially produced a substantial share of their own programs. As a vibrant program production sector developed, generally among the motion picture companies in Hollywood, the networks receded to financing new programs that would be contracted out to independent producers. (Fisher, 1985; Crandall, 1972) Three decades later, when the cable television industry was freed of regulation that had been designed to protect the television broadcasters, cable companies expanded their channel capacity dramatically and integrated backward into programming to fill these channels. (Chipty, 2001)

Broadband Internet access presents opportunities and problems similar to those experienced by motion picture distributors, television networks, and cable networks. The investment in distribution capacity is obviously driven by perceptions of consumer demand, which in turn requires the development of consumer applications for use over these high-speed networks. One only has to look back as far as 1998-99 to Varian’s

INDEX experiment to find evidence that a set of informed consumers placed little value on increased access speed for using the Internet.

Who will provide new broadband content? It is unlikely that regulated telephone companies will have a comparative advantage in developing new, innovative uses of the Internet. The owners of some broadband content, the large motion picture companies, appear to be afraid of the lack of intellectual property protection if they make their products widely available on the Internet. Some integration between entities with experience in creating content and broadband networks distributing it would seem to be required for efficient exploitation of network economies.

This type of integration was what was anticipated when AOL, the leading U.S. Internet Service Provider, announced a merger with Time Warner a major cable, media, and motion picture company. Unfortunately, this combination did not succeed for reasons that are not entirely clear. Nevertheless, both the U.S. Federal Trade Commission and Federal Communications Commission delayed the merger's completion through extensive investigations and the imposition of several conditions before they would approve the merger.

5.2 Network Effects and First-Mover Advantages

The existence of network effects can be shown to lead to a "tipping" of the market towards the successful first mover under certain conditions.[14] Even if the first mover chooses an inferior technology, he may dominate the market because subsequent producers cannot overcome the advantages that the first mover obtains through early adoptions. The most cited examples of this tipping towards inefficient technologies are the QWERTY typewriter keyboard and the VHS videotape format. These examples of market failure have been challenged by Liebowitz and Margolis.[15]

Are there any possibilities of market failures due to tipping in the case of broadband? Specifically, is it possible that vertical integration into content by a large broadband distributor could allow that distributor to dominate broadband distribution and even to direct resources to an inefficient distribution technology? Faulhaber (2002) demonstrates that the likelihood of such tipping in the case of broadband Internet services is remote. The key question in Faulhaber's analysis is whether the integrated supplier chooses *interoperability* with other broadband content.

If the integrated firm does not have an overwhelming share of broadband distribution and cannot use its current position in distribution or content to deny rivals in either sector the ability to survive, it has the incentive to offer its software to competing platforms and to distribute other firms' content on its platform. It must weigh the benefits from wider distribution of its own content against the possible benefits to its distribution operations from denying rival distributors its content. Similarly, it must weigh the

[14] See Katz and Shapiro (1994).

[15] Liebowitz and Margolis (1994, 2001)

benefits that it can reap from greater subscriptions to its distribution services from allowing other content suppliers to distribute over its platform versus the possible benefits in the content market from denying rival content suppliers access to its distribution network.

In many of the earlier examples related to consumer markets with network effects, such as motion pictures, television, and cable television, the integrated owners of distribution facilities decided to interoperate with content provided by rival content suppliers. The notable example of non-interoperability was the early AT&T company which denied independent distributors (local telephone companies) interconnection with its local and long distance facilities. (Mueller, 1997)

In the case of broadband Internet services, no distributor or owner of content has or is likely to have sufficient first-mover advantages to tip the market. In the U.S., the large cable companies perhaps come closest to such a position, but none has exhibited any ability to leapfrog ahead of rival distributors through investments in content. Indeed, one of the early cable-company ISPs, @Home, declared bankruptcy and disappeared after a few years. Even if they were to achieve a dominant position, however, one would have to weigh the benefits from more rapid development of content facilitated by vertical integration against any possible loss of output to monopoly in a "tipped" market.

5.3 The Broadband "Bandwagon"

Rohlfs (2001) has provided an intriguing analysis of a form of network effects that he calls "bandwagon effects." As more and more people adopt a service or buy a good, others are attracted to it. Even if there are no network externalities, *per se*, these bandwagon effects can be important to suppliers of the service. Rohlfs examines how bandwagon effects developed for several new products or technologies, including telephones, VCRs, personal computers and the Internet. His analysis of the development of bandwagon effects through the Internet is quite simple. Interlinking hundreds or even thousands of networks reduced transactions costs and brought a flood of free information to subscribers. As the Internet became virtually ubiquitous, new uses for it developed, such as the handling of commercial transactions, searching for recent news stories, looking for weather predictions in distant locations, or finding alternative entertainment options.

Broadband simply extends the scope of the Internet's bandwagon effects because it permits new and potentially more attractive uses of the Internet to be developed.. As more subscribers sign up for high speed access, more and more Internet content or applications will develop, leading still others to subscribe. As this chapter is being written, only about 10 percent of households in OECD countries have broadband access. With penetration this low, the returns to developing new content are attenuated. In addition, the owners of content that is currently exploited commercially through other media, such as motion pictures, audio recordings, and books, may be reluctant to try to adapt their products for broadband distribution because of the absence of intellectual property protection in many countries.

5.4 Consumer Value after the Bandwagon

Crandall and Jackson (2003) have attempted to estimate the value of broadband to consumers in a hypothetical future world in which broadband services become virtually ubiquitous among households, much as basic telephone service has become. They conclude that broadband could confer as much as $300 billion per year in consumers' surplus on U.S. households. Their analysis is based on the likely price elasticity of demand for broadband when and if U.S. broadband subscriptions are as ubiquitous as ordinary telephone service, *i.e.*, when broadband subscriptions spread to 94 percent of U.S. households. As Rappoport, *et.al,* have shown, the price elasticity of demand for broadband has fallen as subscriptions have risen. Crandall and Jackson assume a linear demand curve and an own-price elasticity of -0.12 at 94 percent penetration, which is substantially greater in absolute terms than the elasticity of demand for ordinary telephone service. If, however, the demand curve is loglinear with a "choke point," the estimates are likely to be substantially smaller. (Crandall, Hahn, and Tardiff, 2002). Crandall and Jackson also support their estimate by adding up the potential consumer welfare gains from broadband service applications that are likely to exist once a large share of households subscribe to high-speed services.

6. Regulation and Competition

In its first few years, broadband deployment has been driven by incumbent telephone companies and cable television companies. Neither of these two participants' networks was initially able to deliver high-speed, two way Internet connections without required substantial additional investment in network capacity and electronics. This process has inevitably been a slow one; indeed, many countries even lack a cable television infrastructure through which cable modem service could be delivered. In others, regulatory disputes have slowed the deployment of network facilities or at least clouded the prospects for successful exploitation of such investment. Nevertheless, *platform* competition between DSL and cable modem service remains a very important component of most countries' strategies for obtaining rapid diffusion of broadband.

Because broadband services evolved from a regulated network industry -- telecommunications --that was being liberalized in most advanced countries, much of its early development has occurred in an environment of contentious regulatory disputes, particularly in the United States and Europe. These disputes generally involve two major issues:

- The need for incumbent telecommunications carriers to allow entrants to use their facilities in offering competitive broadband services

- Whether carriers, particularly cable television companies, should be required to provide “open access” to Internet Service Providers or other suppliers of broadband content

As this chapter is being written, many of these disputes remain unresolved, particularly in the United States. Changes in policy in this area in the next few years are inevitable.

6.1 Platform Competition

Telecommunications networks exhibit obvious economies of density, scale, and scope. Entrants into the provision of broadband services may find it difficult to build their own networks to compete with incumbents, particularly if the incumbent is a “natural monopoly.” For this reason, there is a strong argument that entrants should not be required to engage in wasteful duplication of network assets to compete with incumbents in the delivery of traditional “narrowband” voice-data services. Incumbents might therefore be required to share the last-mile copper loop network with entrants if the loop is a bottleneck “essential facility” because are no other economically viable technological options for reaching the subscriber.

In the case of broadband, however, the copper loop is not the only means of reaching the consumer. Indeed, as I have shown above, there are other technologies available, and one of these alternatives – cable television systems – appears to enjoy a cost advantage over copper loop telephone systems. In addition, in many jurisdictions the copper loop plant requires substantial additional investment to allow it to deliver a DSL service to large numbers of subscribers. In areas of low population density, this investment may involve the extension of fiber optics far out from the telephone company’s central office and the location of the electronics (DSLAMS) in remote terminals. If the incumbent still has to build this fiber, in the form of “digital loop carrier,” it is not an essential facility in the usual sense. Anyone could build it. Indeed, Faulhaber and Hogendorn (2000) have shown that competition among new fiber-coaxial cable networks is possible in the delivery of broadband services.

The importance of platform competition has been noted in numerous studies of broadband and its regulation. For instance, in its Eighth Report on implementation of telecommunications reform in Europe, The European Commission (2002) noted that

> “Cable modem access had notable success in the Netherlands, Belgium, and the United Kingdom, while it is also quite strong in Spain, Austria and France. Cable network operators are faced with a series of regulatory and financial obstacles concerning the upgrading of their networks, which means that, outside of the above countries, they are not in a position to offer serious competition for the moment, nor to develop their broadband facilities at a pace sufficient to keep up with the speed of development of competing DSL providers.”

For these reasons, the EU has stressed the need for local loop unbundling for competitive DSL providers to supplement platform competition.

The OECD (2001) has also stressed the importance of platform competition in its analysis of the adoption of broadband technology in the 30 OECD member countries. . The OECD report found that "[o]ne of the key ingredients in why some countries are forging ahead, is whether there is competition between different networks and networks with different technologies," and that "[t]here is a significant correlation between the growth of cable modems and DSL services."

An early study of broadband deployment in the United States by Gabel and Kwan(2000) used a logit regression to estimate the determinants of the availability of DSL and cable modems in February 2000 across 286 wire centers. They find that household income, the age of the head of household, population density, and the age of the housing stock have an effect on the availability of high-speed service (DSL and/or cable modem service). Similar but less pronounced results are also obtained for the availability of DSL service. They test for the effects of asymmetric regulation of Regional Bell Operating Companies (RBOCs) by simply inserting dummy variables for the RBOCs and find no significant effect. However, their test does not capture the effects of differential regulation of RBOC broadband services across states and is therefore not very powerful.

More recently, Burnstein and Aron (2002) have studied the effect of platform competition on broadband penetration in the United States. Using state data for 46 states in 2000, they estimate a "reduced form" logit model of broadband penetration that includes both demand and supply variables, such as household income, average length of the telephone local loop, the number of telephone lines per square mile, the wholesale price of an unbundled local loop, household Internet penetration, dummy variables for each RBOC, and a measure of the availability of cable modem service and DSL service in the state. They find that the length of loop, the density of telephone lines, education, and Internet penetration are all strongly related to broadband penetration. More importantly, they find that the presence of both cable modem service and DSL service is associated with greatly increased household subscription to broadband services. Their result suggests that in 2002, when about 8 percent of households subscribed to broadband, the presence of both cable modem service and DSL was associated with an increased penetration of 6.5 percentage points. However, because this is a single-equation analysis, there remains the question of whether the supply of service by both networks responds to greater demand or whether greater penetration is the result of increased competition.

6.2 Interconnection and Network Unbundling

Despite the fact that the copper loop may not be an essential facility for the delivery of broadband, because there are competing platforms, there is still an argument for requiring incumbent telephone companies to unbundle the last-mile copper loop.

First, because of "universal service" regulation, telephone companies are often allowed to charge very high rates on high-speed business lines to defray the losses on under-priced residential lines. These companies may therefore be reluctant to deploy DSL services for fear that such services will compete with their own high-speed business services. Second, given decades of regulation, incumbent telephone companies may not be sufficiently entrepreneurial to develop new services, such as DSL. Allowing entrants to use their copper loops at wholesale prices may therefore accelerate the deployment of the new service. Finally, cable television may not exist in many jurisdictions, often because of past government policy. Without the external competition of cable modem service and while fixed wireless or satellite services are still in their infancy, it is sometimes argued that allowing entrants access to the incumbents' copper loops may be the most effective for stimulating the deployment of DSL.

6.2.1 Broadband Unbundling in the United States

The United States led the way among developed countries in opening its telecommunications markets to competition, capping its efforts with the 1996 Telecommunications Act. This statute embraced a concept of "unbundling" network facilities that are needed by new entrants to compete and offering them to entrants at cost-based rates, but it did so without the specific use of the phrase "essential facilities."[16] For seven years, the U.S. Federal Communications Commission has been embroiled in controversy over the required extent of unbundling of incumbents' network facilities for broadband DSL services.

Initially, the FCC ruled that the electronics equipment required to deliver broadband services, the DSLAMs and ATM switches, did not have to be unbundled and provided to entrants at cost-based rates.[17] However, the Commission required that the copper loop be unbundled for both narrowband and broadband uses. Because some entrants wanted to offer DSL alone, they asked the Commission to require that incumbents *share* the loop with them, a request that the FCC eventually granted.

Because much of the U.S. has low population density, incumbents have deployed substantial amounts of digital loop carrier and need to continue to extend fiber farther out from many central offices. This, in turn, has led to controversy over the effectiveness of the FCC's unbundling and line sharing mandates in promoting competition. Entrants have not wanted to deploy their own electronic equipment in hundreds or even thousands of remote terminals, asking instead that regulators require the incumbents offer them a wholesale product that extends from the central office to the subscriber at regulated, cost-based rates. These demands were being arbitrated in various states when the FCC ruled in

[16] The United States was not the first country to mandate unbundling. Hong Kong required its incumbent telephone company to unbundle copper loops in 1985 despite the fact that Hong Kong had the highest density of telephone lines of any major political jurisdiction in the world.

[17] I do not attempt to cite to each of the FCC decisions or the court appeals that followed. The interest reader may find the entire history extensively recoded at http://www.fcc.gov.

February 2003, in response to an appellate court remand of its rules, that line sharing would no longer be required and that the electronics portion of the incumbent's broadband network need not be unbundled.[18]

Despite its very aggressive unbundling and line sharing policy before 1993, the FCC was not successful in stimulating sustainable entry from independent providers of DSL services. As Table 4 shows, competition for the incumbents' DSL broadband services is provided by cable television companies, who enjoy a lead in network development and subscriber enrollments, but not from independent suppliers of DSL services. Most entrants who have tried to offer DSL by leasing a portion of the incumbents' lines have failed and have abandoned the business. This undoubtedly explains Burnstein and Aron's (2002) result that overall broadband penetration is not related to the regulated wholesale price of an unbundled loop in the 46 U.S. states that they studied.

Table 4
High-Speed Subscriber Lines in the United States
(Lines offering 200kb/s or more in at least one direction)

Technology	12/31/99	12/31/00	12/31/01	6/30/02
ADSL Total:	**369,792**	**1,977,101**	**3,947,808**	**5,101,493**
Incumbents		*1,814,776*	*3,839,666*	*4,875,244*
Entrants		*162,225*	*108,142*	*226,249*
Other Wireline	**609,909**	**1,021,291**	**1,078,597**	**1,186,680**
Coaxial Cable	**1,411,977**	**3,582,874**	**7,059,598**	**9,172,895**
Fiber	**312,204**	**376,203**	**494,199**	**520,884**
Satellite or Fixed Wireless	**50,404**	**112,405**	**212,610**	**220,588**
Total	**2,754,286**	**7,069,874**	**12,792,812**	**16,202,540**

Source: U.S. Federal Communications Commission (2002).

Several studies have criticized the effects of the pre-2003 U.S. broadband unbundling policy. Hausman (2002a) has been particularly critical of U.S. unbundling policies. Utilizing a Hausman-Sidak (1999) consumer-welfare test for determining

[18] See "FCC Adopts New Rules for Network Unbundling Obligations of Incumbent Local Phone Carriers," February 24, 2003, available at http://www.fcc.gov/wcb/cpd/.

whether network facilities should be unbundled, he concludes that there is no compelling case for requiring incumbent telephone companies in the United States to supply network facilities to entrants at regulated rates because the incumbents do not have monopoly power in the broadband market. In addition, entrants can feasibly construct their own broadband facilities in many urban areas. He concludes that such regulation has impeded the incumbents' deployment of the network facilities required for DSL, conveying market power on the cable operators who control two-thirds of the U.S. broadband market. Faulhaber (2002a) is less critical of unbundling in general, but he agrees that network unbundling should not be required for new facilities because of the effect of such a policy on investment incentives.

Bittlingmayer and Hazlett (2002) show that proposed U.S. legislation to curb wholesale unbundling for DSL services is associated with a significant increase in the value of the common equities of facilities-based competitive carriers, but has no statistically significant effect on incumbent telephone companies' stock prices or the stock prices of competitive carriers using unbundled elements. The latter result may reflect the fact that, as Table 4 shows, entrants have simply not been able to succeed in offering DSL through unbundled elements. Hazlett (2002) also suggests that the mere threat of regulation could explain why U.S. cable television operators allocate only one 6 Mhz channel of their 750 Mhz of capacity to broadband Internet services despite problems with consumer congestion on this single channel.[19] Were they to devote a second or third 6Mhz channel to this service, regulators might opportunistically seek to impose "common carrier" regulation on such services according to Hazlett.

Others, such as Glassman and Lehr (2002) claim that any reduction of network unbundling for broadband places downward pressure on the competitive carriers' equity prices, thereby reducing investment by entrants in network facilities. However, the failure of most of these entrants even before the FCC's 2003 decision ending line sharing and the unbundling of the electronics required for broadband deliver, suggests that these companies were not viable anyway.

6.2.2 Wholesale Regulation and Unbundling in Europe

The European Commission did not require national authorities to mandate unbundling of network facilities until January 1, 2001, and even then it only required the unbundling of the local loop. Unlike the United States, the EU did not mandate unbundling to promote narrowband voice/data services competition but rather to accelerate the deployment of broadband services. Germany had begun local loop unbundling (LLU) in 1998 when the EU first began to liberalize telecommunications, but a large of share of unbundled lines were devoted to the competitive supply of ISDN, not broadband.

[19] It is likely, however, that many cable companies already must allocate more than one channel for their own cable modem service as usage increases and congestion becomes a problem.

Local loop unbundling was not a notable success in the EU in its first two years. As Table 5 shows, very few DSL lines were supplied by entrants over unbundled loops. Most of the DSL competitors in Europe are simply reselling the incumbents' services which they acquire through services such as "bitstream access" at regulated wholesale rates. This resale accounted for 15 percent of DSL lines at the end of 2002. Unbundled local loops and line sharing accounted for less than 5 percent of DSL lines, and perhaps substantially less,[20] and only about 3 percent of all broadband lines. As in the United States, competition in European broadband was largely between the incumbent telephone companies (or their ISPs) and cable companies. In countries with very weak cable television systems, such as France, Germany, and Italy, such competition was not very strong and broadband subscriptions languished in the range of 4 to 6 percent of telephone access lines. By contrast, U.S. broadband subscriptions at the end of 2002 were about 10 percent of telephone access lines.

Kosmides (2002) suggests that the EU decision to require network unbundling was driven by the European Commission's view that the slow start to broadband in the United States was due to "incentive problems" among incumbent telephone companies. But her analysis concludes that platform competition has worked to stimulate broadband in Europe while local loop unbundling has been a failure thus far. She favors a technology-neutral system of broadband regulation for Europe perhaps supplemented with regional or state subsidies for infrastructure or broadband applications.

Table 5
Broadband Competition in Europe as of December 2002

Country	Incumbent DSL Lines	Entrant DSL Lines Resale	Entrant DSL Lines Using LLU or Own Facilities	Cable Modem Subscribers	Other Technologies Subscribers	Total Broadband Subscribers (As Share of Access Lines)
Austria	143,000	31,000	5,500	360,000	0	539,500 (0.17)
Belgium	423,500	78,400	3,641	280,000	0	785,541 (0.17)
Denmark	184,600	0	47,652	122,000	5,000	359,252 (0.13)
Finland	175,000	5,000	39,000	54,000	500	273,500 (0.09)
France	987,000	413,000	6,769	248,519	0	1,655,288 (0.05)
Germany	2,800,000	0	210,000	120,000	0	3,130,000 (0.06)
Greece	0	0	0	0	0	0 (0.00)
Ireland	2,645	9	633	4,000	3,000	10,287 (0.01)
Italy	475,000	175,000	50,400	0	0	700,300 (0.04)
Luxembourg	4,300	0	130	70	0	4,500 (0.01)
Netherlands	316,450	0	43,152	700,000	0	1,059,602 (0.13)
Portugal	43,657	9,046	54	207,000	0	259,757 (0.06)
Spain	734,087	223,117	3,099	230,000	0	1,190,303 (0.07)

[20] The data in Table 5, column 4 reflect competitors' DSL lines that are not resold lines. These could be lines offered over incumbents' loops or over the entrants' own facilities.

Sweden	314,000	104,000	5,063	150,000	200,000	773,063 (0.13)
United Kingdom	300,000	290,000	2,000	736,000	6,500	1,334,500 (0.05)
Total EU	6,903,239	1,328,572	417,093	3,211,589	205,100	12,065,593 (0.06)

Source: ECTA (2003)

One puzzle that emerges from the data in Table 5 is the United Kingdom's exceedingly low rate of broadband penetration despite the country's extensive cable television network and emphasis on platform competition. The UK regulator, Oftel, has favored a facilities-based competition policy for nearly two decades, and it created an environment that was conducive to the growth of cable as an alternative to the incumbent telephone company, British Telecom.[21] This policy was a success in inducing competition for local telephone service. The two major cable companies have more local telephone subscribers than cable television subscribers today, and BT has lost one-third of the local calling market to cable companies and other rivals. (European Commission, 2002) Why, then, did cable not move aggressively to exploit broadband Internet connections? One possible explanation is that the policy of licensing large numbers of cable companies throughout the UK denied them the economies of scale and scope enjoyed by U.S. cable companies, but the U.S. cable industry began in much the same way with thousands of locally-franchised companies. Therefore, the failure of platform competition to develop in the UK broadband market through 2002 remains a mystery.

6.2.3 Success without Unbundling -- Korea

Korea provides a fascinating case study in the deployment of broadband because it has moved so far ahead of all other countries in broadband penetration without any formal wholesale regulation of the incumbent telecommunications carrier, Korea Telecom. As Figure 1 shows, Korea has about twice as many broadband subscribers per 100 persons than Canada, which is in second place, more than three times as many than the U.S., and nearly five times as many as the European Union. Surely, this stunning level of adoption of a new technology cannot be explained on the basis of household disposable income or even the relative price of broadband. Korea has a lower average household income than Japan, North America, or the European Union, and its broadband prices are no lower than those of Japan.

Korea has very densely populated residential areas with large, relatively new high-rise buildings to which the government has directed the construction of an advanced fiber optic network by the electric utility company, Korea Electric Power Corporation, which is not in the business of supplying retail broadband services. (See Hausman, 2002a.) With this network in place, competitive suppliers of broadband services can gain ready access to transmission facilities. Thrunet, Hanaro Telecom, and a variety of other carriers compete aggressively with Korea Telecom, the incumbent telephone company. Because so many of the residential facilities are new high-rise apartments, these buildings

[21] For a summary of Oftel Policy, see Oftel (2003).

have been apparently constructed in a manner that permits easy access to rival carriers. Therefore, competition in Korea does not depend on mandated unbundling or the provision of wholesale broadband services by the incumbent carrier. Despite the absence of such regulation, DSL commands nearly two-thirds of this very large and growing broadband market. In all other countries with sizable broadband penetration, except Belgium, cable modem service enjoys a substantial lead.

Among the reasons for the popularity of broadband in Korea are the high speeds available and the considerable interest in "network gaming." OECD's (2001) comparison of DSL across 30 OECD countries showed that Korea's DSL had the highest speed, up to 8.0 Mb/s compared with less than 1.0 Mb/s in all EU and North American countries. Survey data for the same period show that 54 percent of Korean households used the Internet for networked games in a survey month compared to only 6 in the United States. (Lee, 2002) Korea is far ahead of the U.S. in broadband penetration despite the fact that the U.S. leads Korea in Internet domains per capita, e-commerce, and secure servers. As Lee (2002) explains, Koreans use the Internet much more for content than for e-commerce.

Despite its success in achieving a huge early lead in broadband penetration, Korea is now (2003) moving to implement local loop unbundling. It appears that its motivation in pursuing this regulatory strategy is to increase competition in narrowband services, not in broadband.

6.2.4 Unbundling in Japan

If Korea provides the best example of the benefits of regulatory forbearance, perhaps Japan provides the best counterexample – at least for a brief time. Local loop unbundling was introduced in Japan in September 2000 and the wholesale rate for a loop was set in December 2000. (Fuke, 2002) At that time, there were fewer than 10,000 DSL subscribers and 625,000 cable modems in Japan. After local loop unbundling was authorized, Softbank established Yahoo Japan, "Yahoo BB," to begin offering ADSL service in September 2001. Yahoo has established a very low monthly rate for its service, roughly U.S. $20 per month, for a service with speeds up to 8.0 Mb/s and launched a vigorous promotional program that included a free modem. The result was an enormous surge in DSL subscriptions, which totaled nearly 4 million by August 2002, a ten-fold increase in just one year. At the same time, cable modem subscriptions increased to 1.8 million (Tsuji, 2002)

The recent surge of broadband in Japan is clearly due to one company's aggressive pricing and promotion policies in offering a service that relies entirely on NTT's local loops. Unfortunately, Yahoo BB is incurring huge losses that may not be sustainable in the long run. It hopes to grow rapidly and then deploy a variety of new services, such as video on demand that it can exploit over its large subscriber base. In essence, it is attempting to create its own "bandwagon" and to exploit the benefits from it through much higher revenues per subscriber than it currently obtains. This may prove to be a great success that can be attributed to loop unbundling. On the other hand, it may be just one more failure to add to the impressive list of failed new telecom enterprises in the U.S. and the EU, particularly those relying on incumbents' facilities.

6.2.5 Hong Kong

Hong Kong was the first political jurisdiction to mandate local loop unbundling. It began to require unbundling for narrowband services in 1995 despite its very dense population. Hong Kong has an average of 15,000 lines per square mile, surely an attractive environment for facilities-based competition. Hong Kong also has a well-developed cable television company, but despite the availability of platform competition, it decided in 2000 that it would require PCCW, the incumbent telephone company, to unbundle and/or share its local loops with broadband competitors. (Telecom Authority of Hong Kong, 2000) In 2003, this decision was implemented. A major competitor and lessee of PCCW's loops is the cable television company, which has apparently decided not to invest in telephony and advanced services over its own facilities. Hong Kong's experience would appear to support the theory that network unbundling creates disincentives for network investment.

6.3 Cable Open Access

The regulation of incumbent broadband service companies also may include a requirement that Internet Service Providers (ISPs) or suppliers of content be granted access to the broadband network at regulated rates or even for a zero price. Such proposals often emanate from those who attribute the success of the Internet to the "end to end" architecture that places much of the intelligence in the network at the top of a layered system. Under this Internet model, the lower levels of the network infrastructure – the broadband "pipes" provided by telephone companies or cable companies – would be designed to be flexible and simple, but open to all potential suppliers of content. (Lemley and Lessig, 2000) To end-to-end advocates, the benefits of "open access" far exceed the internalization of network effects through vertical integration.

In the United States, telephone companies have provided open access to competing ISPs and content providers because they are subject to common-carrier regulation of their services, including broadband services. Cable companies, on the other hand, are not regulated common carriers under U.S. law, but are subject to state and local franchising regulation as well as FCC video regulation. As a result, cable companies began to offer cable modem service through their own ISPs, At Home and Road Runner. At first, this vertical integration was uncontroversial; however, once cable modem service began to grow rapidly, the ISPs who thrived under the common carriage dial-up regime felt threatened. Eventually, they persuaded state and local regulators to begin to require that cable systems provide open access to rival ISPs. After a series of court battles, the open access issue was sent to the Federal Communications Commission to resolve. As of this writing, it has not done so.[22]

Ultimately, the open access "end-to-end" issue may be distilled into one which the benefits of vertical integration must be traded off against the dangers of monopoly leveraging. Because U.S. cable companies account for two-thirds of broadband subscriptions, some economists fear that the cable companies might be able to leverage their monopoly power into downstream content markets. This was the essence of the AOL-Time Warner merger policy deliberations described by Faulhaber (2002b and 2003) above.

If the cable companies obtain sufficient market power in downstream content, they may be able to discriminate against rival distribution systems, *i.e.*, deny these systems access to their content, and thereby foreclose entry into or even monopolize the broadband service itself. Rubinfeld and Singer (2000) describe this as "content discrimination." Alternatively, owners of distribution services with downstream content investments may be able to discriminate against rival content, *i.e.*, deny rival suppliers of content access to their distribution system, thereby discouraging entry into content. Rubinfeld and Singer call this "conduit discrimination." The cable open access issue in the United States involves the latter form of discrimination.

Rubinfeld and Singer show that incentive to engage in content discrimination is likely to decline as a cable company's footprint, *i.e.*, the share of the nation that its cable systems cover, grows because the gain from content discrimination is primarily from increased sales outside its distribution areas. On the other hand, the likelihood of conduit discrimination increases with the size of the cable system's footprint. Given the national concentration levels in cable television distribution when they were writing, Rubinfeld and Singer find that such discrimination would be unlikely. Therefore, the case for open access would appear to be weak.

The other side of the open-access debate is the effect of vertical integration in internalizing network effects. (Hazlett, 2002; Crandall, Hahn and Tardiff, 2002) Without the ability to internalize the network externalities inherent in this network industry, much as motion picture companies, television networks, and cable companies did in earlier examples of the deployment of new consumer services, broadband may grow much less rapidly. Owen and Rosston (1998) argue that open-access on U.S. cable firms would reduce investment incentives required for the deployment of the cable infrastructure necessary for the delivery of broadband services, particularly in the early stages of broadband development. Noll (2002) summarizes the trade-offs involved but does not reach a definitive policy conclusion on the issue. He shows that the benefits from mandating equal access are directly related to cable's market power and the likelihood of a "lock-in" effect on consumers who buy the bundled cable modem/ISP service, but that these benefits are offset by the probability that cable companies will delay broadband deployment if regulated.

[22] Deatails may be found at the FCC web site, http://www.fcc.gov.

Bittlingmayer and Hazlett (2002) have analyzed the effect of open access proposals on U.S. carriers' common equities. They find that events that reflect setbacks to proposals for open access are associated with increases in the value of Internet stocks. They surmise that the financial markets see open access as so delaying broadband infrastructure deployment that it reduces the prospects for independent ISPs even if they do not enjoy the benefits of equal access to cable platforms.

7. Subsidies, Universal Service, and the "Digital Divide"

The development of any new technology that is likely to be valuable to consumers, and that is expensive when first purchased by early adopters, inevitably creates concerns for consumers who cannot or will not purchase it. This has been especially true for the personal computer, the Internet, and broadband. Concerns over the development of a societal "digital divide" have been expressed quite widely and given particular stress by the U.S. Department of Commerce (1999, 2000, and 2002). The initial concern was that the cost of personal computers and Internet service, coupled with low educational attainment, could create a divide between wealthier citizens and poorer citizens, including minorities in the United States. Similar concerns were expressed much earlier about Australia by Madden, Savage, and Simpson, 1996) More recently, the stress in the United States has been on an urban-rural divide in broadband subscriptions, created in part by low deployment rates in rural areas.

Given the likely network externalities from broadband subscriptions and use, it is possible to make an economic case for subsidizing populations or areas with low broadband penetration. But subsidy programs inevitably suffer from two problems: they confer substantial benefits on households already subscribing and they enjoy political support long after the need for them has diminished or expired. For this reason, Goolsbee (2002) suggests that a subsidy program target the *fixed* costs of network deployment in areas in which broadband networks have not already been built. Unfortunately, he can find only a few areas where such a subsidy would be beneficial on net. His ideal subsidy program for the United States would total only $14 million and generate benefits of $210 million in net present value. This is not a program that has captured the imagination of U.S. politicians because of its limited dimensions.

8. Conclusions

It is far too early to draw any definitive conclusions about the economics of broadband Internet service. With only seven or eight years of experience with this new medium to draw upon and the inevitable information and publishing lags, we do not yet have a robust literature on any of the important issues or phenomena relating to broadband.

Because broadband has been developed and deployed by firms in a heavily regulated sector of the economy that is now being liberalized, much of the literature that has developed has grown out of the parochial battles for regulatory favor in North America, Europe, and Asia. Some of this literature is cited in this chapter because, frankly, there is nothing better available at present.

The rapid changes in communications technologies also create problems for those studying this new medium. For example, econometric analyses of the demand for 400 or 600 kilobits per second services over DSL services in the United States may not tell us much about the demand for 20 or 100 megabits per second services provided over fiber optics in the future. Nor will the demand for broadband given the content available currently be a good predictor of demand when video streaming of motion pictures or other content becomes routinely available.

Similarly, the analysis of the effects of the current market structure on the rate of deployment of new facilities may become irrelevant once broadband becomes ubiquitous. Similarly, if wireless, satellite, and wire-based systems compete aggressively for subscribers, the current concerns over potential vertical market foreclosure evaporate.

At this early stage of the development of broadband, there is surprisingly little attention given to the obstacles to developing the content that is necessary to keep the "bandwagon" effects flowing. Are digital copyright laws too broad or are they unenforceable across the global domain of the Internet? Does the failure of the AOL-Time Warner merger signify that vertical integration will not solve the coordination problem and internalize the network externalities inherent in broadband deployment? These and many other questions are not answered by the literature now available.

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