# Competing/Complementary Broadband Access Technologies

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## 1 Introduction

In today?s networked world the phrase that is on everybody?s lips is broadband access. Just a few years ago when the Internet was being used to send only text, 56 kbps seemed a blazing speed. Nowadays however, with ever increasing demands on data transmission, 56 kbps seems snail-like, hence the nickname "World Wide Wait." Internet content providers are continually raising the yardstick by building in more and more graphical and multimedia content such as streaming audio and video into their free and e-commerce applications. But as it turns out, they can build them faster than consumers can download them resulting in bumper to bumper traffic on the information super highway. Furthermore, industry prognosticators say that Internet traffic will continue to double about every nine months for several years at least. As web sites obese with multimedia applications grow in popularity, and as the population of the on-line community swells, the stream of data is often reduced to but a trickle. This bottleneck has handcuffed content providers? ability to grow their markets and revenues even faster than they are today.

But content providers are not the only ones handcuffed by lack of broadband access. Businesses are too. What?s worse, Internet access is not the only need that businesses have for bandwidth. Business customers need high-speed intranets and local area networks that allow them to unite workers at numerous remote sites into a single "virtual office." On another front, residential customers are frustrated by their inability to access the material and applications they want and need because of data transmission speed limitations. Thus there exists widespread demand for broadband access, not only to provide quicker access to today?s content but also to ensure that future application development with even higher resource demands has a wide enough conduit across which to be delivered to customers.

Although there is some availability of broadband access today, it is mostly limited to companies (which can afford a T1 or T3 line because of economies of scale) or to people who are fortunate enough to live in residential areas where broadband has been brought into the neighborhood. Nonetheless, these represent a vast minority of the people interested in getting broadband access. Therefore, numerous companies are concentrating their energies on (channeling their efforts towards) providing widely available broadband access through a number of different technologies at a price customers can afford. This report examines four of these alternatives: cable modems, xDSL technology, satellite access and national fiber optic networks. In addition to descriptions of these technologies, we will discuss what shape the future of this market might take.

# 2 Technology Analysis

This section examines four competing/complementary broadband access alternatives: cable modems, xDSL technology, wireless networks and national fiber optic networks across four dimensions: players, technology fundamentals, benefits/drawbacks, and costs.

## 2.1 xDSL

**Players**

Amongst the players in this arena are: Microsoft, 3Com, Compaq, Intel, the Baby Bells.

**Technology Fundamentals**

Originally, Bell Communications Research (Bellcore) intended to use xDSL technology to provide video-on-demand and interactive TV applications over twisted-pair wires, but its current use has exceeded its inital purpose.  xDSL technology now provides multiple forms of data, voice, and video to be carried over twisted-pair copper wire on the local loop between a network service provider's (NSP's) central office (CO) and the customer site.  Because xDSL uses new signal processing techniques it is able to leverage the existing local loop infrastructure in order to increase the amount of data transmitted over analog lines.  This has led it to be touted as one of the most viable options to alleviate the problems of limited bandwidth. Since it requires minimal investment on the carrier's side, carriers could potentially introduce xDSL services to its customers faster and more cost-effectively than other options.

Customers interested in xDSL services can choose from a number of DSL transmission technologies. The table below summarizes each technology based on: mode, maximum baud rate, maximum distance the technology can travel over twisted-pair wires, and the types of applications each technology is best suited for.  The table also illustrates the fundamental trade-off of DSL technology - baud rate decreases as the maximum distance increases from the customer's site to the CO.

**xDSL Transmission Technologies**

| Technology | Mode* | Maximum baud rate | Maximum distance over 24 gauge LTP | Application |
|---|---|---|---|---|
| ADSL/RADSL | Asymmetric | Downstream 1.5 to 9Mbps; Upstream 16 to 640kbps | 18,000 feet (12,000 feet for speeds above 1.5Mbps) | Internet/intranet access, video on demand, database access, remote LAN access, interactive multimedia, lifeline phone service |
| HDSL | Duplex | T1 up to 1.544Mbps; E1 up to 2.048Mbps | 15,000 feet | Replace local repeatered T1/E1 trunk, PBX interconnection |
| SDSL | Duplex | T1 up to 1.544Mbps; E1 up to 2.048Mbps | 10,000 feet | Same as HDSL plus premises access for symetric services like video conferencing |
| VDSL | Asymmetric | Downstream 13 to 52Mbps; Upstream 1.5 to 2.3 Mbps | 1,000 to 4,500 feet | Same as ADSL plus HDTV |

*Technologies that transmit data at the same rate both upstream and downstream are duplex. Technologies that have different transmission rates upstream and downstream use an asymmetric mode.

ADSL = Asymetric Digital Subscriber Line
RADSL = Rate-Adaptive Digital Subscriber Line
SDSL = Single-pair Digital Subscriber Line
VDSL = Very high bit-rate Digital Subscriber Line

Despite the fact that a number of DSL technologies exist, most of these are still experimental with no standards or marketplace implementation set in the near future. The one DSL technology that has the strongest potential for immediate commercial introduction is ADSL. Market trials have already been conducted for ADSL domestically as well as internationally. Component manufacturers already have the capacity to produce ADSL related equipment e.g. ADSL interface cards and modems. But most importantly, ADSL has already been standardized by ANSI (American National Standards Institute).

### Benefits

- Uses new signal processing techniques to leverage existing local loop infrastructure in order to get more on and off analog lines.
- ADSL users can use a single twisted pair for both data and voice communications.
- Carrier powered over copper wire Therefore, xDSL users will still be able to receive service even in the event of a power failure.

### Drawbacks

- Competing standards on how to modulate frequency. The two main competitors are DMT and CAP.

- No interoperability due to lack of standards among component manufacturers and carriers.
- Cross-talk interferance from nearby wires.
- Need to lower power system requirements from the present 8 to 12 watts down to 2 to 3 to abide by federal regulations.
- Tradeoff betwen length of lines, data speeds, and differences in upstream and downstream traffic.

**Costs**

For the consumer, the costs of switching to ADSL service requires the purchase of an ADSL modem, a POTS splitter (allowing the ADSL connection to accomodate both voice and data communications simultaneously on the same line), and a patch to reconfigure the consumer's computer operating system to recognize an ADSL modem rather than a Hayes compatible one i.e. analog modem. Unfortunately, the two main reasons that the average consumer has not taken advantage of ADSL is the lack of affordable equipment and service plans for him/her. The cost of an ADSL modem is in the hundreds of dollars. Service plans are still relatively expensive and only a few carriers have even started offering ADSL services as part of their package. Therefore, the average consumer may not find the ADSL option viable for his/her needs. But a SOHO (small office, home office) user may find ADSL the ideal choice compared to ISDN or T1 options depending on the SOHO's proximity to the CO and whether his/her carrier offers ADSL as an alternative. This is why carriers have initially targeted ADSL services to the SOHO user rather than the average consumer. With time, the economies of scale could lower the entrance cost, making it a feasible alternative for the average consumer.

Carrier costs, on the other hand, are spread over three major areas. First, it necessitates a quality line connection between the CO and the consumer. Figures estimate that up to 80% of the twisted-pair lines are viable after some line conditioning. The other 20% of the twisted-pairs are not capable of providing ADSL, but since most of those wires reside in rural areas the impact would be negligible. Carriers would also need to replace their interface cards with an ADSL compatible one. And last but not least, carriers will need to establish the administrative infrastructure to support ADSL service plans e.g. pricing plans, coverage areas, agreements with equipment manufacturers. Unfortunately, the true costs to carriers remains to be determined primarily because of regulatory issues dealing with the Telecommunications Reform Act of 1996. There is lack of clarity on whether telecos need to unbundle xDSL service and how costs are to be allocated between Bells and outside competitors. If the Baby Bells aren't required by law to unbundle services, then it would become more expensive for competitors to enter the xDSL market. In addition, no aggreement has been reached regarding whose responsibility it is to pay for line conditioning. Is it the Baby Bells responsibility to condition their lines even if they aren't providing DSL services but their competitors wish to? Or do competitors have to pay these costs even though they are paying to improve twisted-pair wires that don't even belong to them? Such ambiguity has not made it cost-effective for outside competitors to deploy DSL services yet and place the ball in the Baby Bell's court on how and when to market DSL.

## 2.2 Fiber Optic Networks

The creation of national fiber optic networks for access to the backbone is viewed as a very costly but also as a very necessary and inevitable outcome. Cable modems, xDSL and wireless access are excellent, much lower initial capital investment alternatives to fiber optic networks. A combination of these technologies may satisfy the need for broadband access until enough companies pursue investment in private national fiber optic networks. Several companies have already taken the plunge and more are sure to follow. The initial investment in laying down fiber optic cables is much more costly but the payoffs are likely to be extraordinary. Today, the fiber optic cables which the Internet backbone is composed of carry IP packets at a rate of up to 622Mbps, 20 to 500 times faster than the other technologies discussed above. Fiber optic connections to the home are not likely to be this fast but will still far outstrip cable modems, xDSL and wireless communications. A discussion along the same dimensions utilized for the above technologies follows.

**Players**

There are currently five companies which have launched national fiber optic network projects. These are Qwest Communications International Inc., a subsidiary of Anschutz Corp., IXC, Media One Group, the cable television and wireless communications company, Williams Cos., the nation’s largest operator of natural gas pipelines, and Level 3 Communications Inc., a subsidiary of Peter Kiewit Sons Inc. which that has its primary operations in construction and mining. Qwest is constructing a $1.4 billion fiber optic network and IXC is constructing a $500 million network. Media One offers a fiber optic network in the city of Los Angeles and plans to spend $2.8 billion on a national network. Two of the more interesting stories are Williams Cos. and Level 3.

Williams Cos. is building an 11,000-mile national fiber optic network. In 1998-1999 its $750 million investment will bring the network?s total investment to over $1 billion. Interestingly, this is Williams? second foray into the business. In 1995 it sold its previous network, known as Wiltel, to LDDS, which subsequently changed its name to Worldcom Inc. Since then, Williams began to rebuild the same sort of network it sold in 1995, only this time using more advanced communications technology and more experience.

Level 3 Communications intends to spend up to $3 billion over the next three years to build a 20,000-mile web of fiber optic cable. The system, which the company wants to complete by 2001, would be the first national fiber optic network based on Internet technology (IP) rather than on standard telephone technology. IP can allow networks to be used more efficiently but can also be less reliable than traditional networks. Traditional networks generally allow voice and data messages to be transmitted in one continuous chunk. IP networks break messages into small packets that are each sent independently to their destination. With today’s technology, IP is fine for anything that’s not timing-sensitive, like data or fax. Anything that’s timing-sensitive, primarily voice and video, isn’t handled very well. However, advances in the technology over the next few years would allow Level 3 to offer voice quality equal to that of more traditional systems. If the Internet technology works as predicted, it could allow Level 3 to charge prices for voice and data communications much lower than those of its competitors, while maintaining healthy profit margins. Level 3 plans to sell access to its network only to business customers. Most of those would be small and medium-sized companies, but some could be upstart long-distance carriers that would resell time on the Level 3 network to consumers.

In addition to national fiber optic networks, there are a number of initiatives on the migration path from today?s analog modems to tomorrow?s fiber optic connected world, namely local fiber optic networks. In Palo Alto for example, a combination of public and private investment has created the highest-capacity switching point on the Internet. In spring 1997 the city completed construction of a $2 million, 15-mile-long fiber optic ring that snakes beneath its suburban streets. Palo Alto’s fiber-optic data and voice network comes within one mile of every home and business in the city. It will permit residents, businesses and organizations to link to the global computer network at speeds that will dwarf even today’s fastest cable modems. Other such infrastructure projects are underway or already completed in places like Los Angeles, Anaheim and San Diego, California as well as Winston-Salem, North Carolina. On an even smaller level there are now cyber buildings equipped with high-speed T1 lines in New York City.

In an even more radical move to achieve broadband access, a new Internet is available, although access is still strictly limited and its users tend to be astrophysicists, engineers, medical researchers and other specialists. About 100 U.S. computer scientists are using this second generation Internet in preference to the crowded old network they invented just a couple of decades ago.

The new network, called the Very-High-Performance Backbone Network Service, is sponsored by the National Science Foundation and built by MCI Communications using some of its existing fiber-optic networks. Looping around the country in a giant, 14,000-mile Figure 8, it links the nation's five academic supercomputer centers.

**Technical Fundamentals**

Fiber-optic networks carry digital data as rapid pulses of light, permitting telephone companies to send voice and data at rates of billions of bits a second. But even at these carrying capacities, major telecommunications routes are becoming overloaded by the explosion of telecommunications applications that range from the Internet to new types of cellular phones.

A new technology called wave division multiplexing, or WDM, is emerging. The technique is roughly equivalent to using a bundle of flashlights -- each with different colored light -- in place of a single flashlight to transmit data through fiber-optic networks. Each color can carry a stream of information that does not interfere with the streams of other colors.

The competition to achieve higher and more cost-effective fiber-optic capacity is intense. Companies already offering various forms of transmission enhancements include Lucent, formerly part of AT&T Corp.; Alcatel Alsthom Group; Northern Telecom Inc.; NEC Corp.; Pirelli SpA, and Siemens AG. Lucent and others have already said they plan to enter the market with WDM equipment.

The super-high-speed pipelines composed of fiber optics in which all the packets of bits and bytes traveling between you and some remote server merge with packets being exchanged by millions of other users, some human, some robotic, all vying for a bigger, faster ride through the pipe. Internet connectivity is provided through a backbone network with spurs shooting off the backbone to extend connectivity. The backbone is composed of high-speed fiber-optic cables which shuttle information through the internet at 45 million to 622 million bits per second -- more than 10,000 times the capacity of a 56 kbps computer modem. However, most people still do not have data transmission capabilities over 56 kbps. In addition to the lines themselves, the backbone system consists of huge hubs where all the intersecting high-speed lines merge to reroute billions of packets of data and send them on their way to their next stop -- either the Internet service provider from which they've been requested or, along a different line, to another hub for further routing.

**Benefits/Drawbacks**

- Backbone: The high-speed fiber-optic cables which shuttle information through the internet at 45 to 622Mbps -- more than 20,000 times faster than a 28.8 modem (MCI spent $60 million to go from 155 Mbps to 622 mbps).

T1 = 1.5 Mbps
T3 = 45 Mbps
OC3 = 155.5 Mbps (2016 simultaneous phone calls)
OC12 = 622 Mbps (8064 simultaneous phone calls)

- Suffers from the same security problems that all land line data transmission connections suffer except for cable modems. However, these security concerns for land line connections as a group are significantly lower than for wireless connections.
- Not easily scalable because the investment required to install additional fiber optic lines is significant. This problem is largely mitigated however by the potential capacity of just one fiber optic strand.
- Reliable because there is a physical connection as opposed to wireless data transmission which can more easily manifest interference and communication connection breakdowns.
- Right now, availability and accessibility are low. This will change with time as fiber optic network investments mature.
- Fiber optic land line connections are extremely usable. Unlike ISDN modems for example, a T1 or T3 connection is not rocket science.

**Cost/Revenue Model**

Laying down a national fiber optic network requires a significant up front investment - anywhere from hundreds of millions of dollars to billions. The lack of an economic rationale for raising the Internet’s speed limit is a major cause of its latency -- at times outright gridlock -- and a gaping pothole smack in the middle of the road to the network’s future. The owners and operators of the public portion of the Internet backbone are private businesses. And they are frankly perplexed about how they’re going to make a return on the enormous investment it will take to widen the highway and unclog the pipes. Much of the Internet’s backbone system consists of common information conduits, and the companies that manage them hesitate to spend money upgrading them, because the investment could benefit competitors who also make use of those conduits. There exist three billing models: flat rate, metered usage, and timed charges. There is a growing consensus that only metered billing can provide enough profits for service providers and backbone administrators to expand their bandwidth. In other words, you’re probably going to be paying a lot more in the future for fancy real-time audio and video on the Net than you’ll be paying to send and receive your e-mail.

## 2.3 Cable Networks

**Players**

The major players in cable TV are Tele-Communications Inc. (TCI), Time Warner Cable, Cox Cable, Comcast, Cablevision, and MediaOne. Another "hot" company is @Home, which is owned by an alliance that includes Comcast Corp, Cox Communications Inc., TCI and venture capital firm Kleiner Perkins Caufield & Byers. Some of them are also content providers. Time Warner owns Warner Brothers, Turner Broadcasting, and a host of magazines (Time, Life, People, ports Illustrated, and Fortune); TCI owns Liberty Media. This vertical integration give the cable companies an competitive advantage over the phone companies.

**Technical fundamentals**

The cable TV network has a tree and brand topology. The root of the tree is the facility called headend, which sends out programs to the trunk cable, and the leaves are the subscribers. This network is shared in that multiple households connect to a common piece of wire, and was designed for one-way broadcasting. These characteristics pose some challenge for data services.

The coax system lacks robustness. Since signal attenuates over long distance, amplifiers are placed roughly one kilometer apart. If an amplifier malfunctions near the headend, all subscribers downstream from the bad amplifier lose service. In addition, coaxial cable systems are very complicated to design and maintain. One way to solve these problems is to replace coaxial cable trunks with multiple fiber-optic cable, resulting to a hybrid fiber coax (HFC) networks. The cost for this upgrade is about $16732 per mile for aerial and $23494 per mile for underground, according to one study. Given a take rate of 65 percent and a residential density of 80 home per mile, this capital upgrade is $322 per subscriber for aerial upgrades and $452 for underground upgrades.

One important step toward data service is the creation of an upstream transmission capability. To use the existing cable infrastructure, the upstream traffic is separated from downstream in frequency. Most cable operators assign the frequency range 4-42 MHz for upstream, which is below the frequencies used for broadcast television. This low frequency range has good attenuation characteristics, but are subject to more noise interference, and requires additional filtering or more complicated transmission techniques.

A short term alternative is to use telephone line for the return path. This is the approach several companies are pursuing, including MediaOne(Boston), US West Inc. and @Home. However, many observers contend that this is not a viable solution even in the interrim. Some of the problems include that the consumer loses use of telephone; may get busy signals; call set up is long; the slow return path will limit the forward speed to 500 kbps or so, far less than the advocated 27 mbps; and the cost for operating the telephone return path makes the cost differential with the cable return narrow.

## Benefits/Drawbacks

### Speed and Scalability

A cable channel comprises 6 MHz of spectrum and can deliver data at anywhere from 27 Mbit/s to 40 Mbit/s. Most cable providers design their networks so that each network node passes about 500 potential customers. Under a highly optimistic scenario, 60 percent of the household subscribe cable TV services and 20 percent of those customers subscribe to data service, the average node would have 60 data subscribers. Studies show that at peak times, about 30 percent of all subscribers are online at the same time. That means 18 subscribers will be sharing the 27 Mbit/s of bandwidth offered by the cable data channel. That works out to an average bandwidth availability of 1.5 Mbit/s per subscriber--short of the multimegabit rates that cable modem vendors are now promising. However, since most data traffic is not continuous, subscribers use bandwidth only when they are actively sending of downloading files, the bandwidth bottleneck can be ameliorated by this "bursty" nature of data transfer.

People hold different opinions on the scalability problem. Steve Craddock, vice president of new media development at Comcast, the fourth-largest cable operator in the United States, says, "Whether it scales or not is still an open issue. It’s easy to work a trial of a couple of hundred subscribers. But what happens when you have 50,000 subscribers using all this stuff?" Contrary to Craddock, Frank Cotter, vice president of operations for Wave, the cable modem service of Rogers Cablesystems, argues: "Most data networks are shared, The Internet is a shared resource. So are packet-switched networks and office LANs."

#### Security

Since HFC is a shared medium, each user’s data is, in principle, exposed to other users in the cluster. To ensure security, proper authentication, encryption measures are required. This remains an open issue in standard discussion.

#### Accessibility

In 1996, there were between 62 million and 63 million cable households in the US; by 2000, that number could reach 70 million. The capital cost to build the return path is lower than the forward path, but the work is labor intensive and requires skilled workers. Some people think labor availability is a restrictive factor given the size of the network. In addition, the return path requires significant incremental, periodic maintenance. According to Paul Kagan Associates Inc., only about 11 percent of all U.S. cable households are passed by two-way cable infrastructure in 1996. By 2000, that number will climb up to 40 percent. That implies 28 million homes will have access to two-way cable data service at the turn of the century. Dataquest Inc. estimated that 1.8 million cable modems will be deployed in 2000, which works out to a market penetration of 6.4 percent, taking both estimates together.

In the San Francisco Bay area, @Home currently offers service in Fremont, and is at or near launch in Sunnyvale.

### Cost

The cost for upgrading the existing cable TV network for two-way data service is significant. Abe’s book gives a good estimated break-down for the per subscriber cost:

- HFC upgrade ($20 K/mile; 80 homes passed/mile; $400 62.5% take rate)
- Two-way upgrade $50
- Headend equipment $250
- Subscriber equipment $250
- Test equipment, tools, training, initial $50 marketing
- Total Cost $1000

For consumers, the cable modem can be leased from the local cable company for rates between $15-$40. The home user will also need to equip his computer with an ethernet card (if not already installed, typically less than $100). There is usually a one-time installation charge of $50-$150. The monthly service charge is around $40.

## 2.4 Wireless Networks

xDSL, fiber optic networks, and cable networks are all wired broadband solutions. In contrast, several wireless technologies are also capable of delivering broadband access. Wireless networks have unique characterisitics which make them viable alternatives to wired networks.

Wireless networks utilize a "saturation bombing" technique to overcome many of these startup problems. Once a wireless network is deployed, it can cover a broad geographical area of users in order to achieve economies of scale. For example, Teledesic?s proposed 288 satellite constellation will provide global coverage, and in the local-loop a single MMDS transmitter can cover an entire metropolitan area. Because of this characteristic, wireless networks may have large market opportunities in rural areas and developing countries that do not have existing communication infrastructures. Wireless networks have already proven to be commercially viable - with technologies including broadcast tv, cellular phones, paging and direct broadcast satellites.

Several wireless technologies for delivering broadband services either already exist or are undergoing active research. These are divided into two camps: satellite technologies and over-the-air technologies. Satellite wireless technologies include direct broadcast satellites (DBS) and low earth orbit satellites (LEO). Over-the-air technologies include multichannel multipoint distribution services (MMDS) and local multipoint distribution services (LMDS), both which allow wireless local loops (WLLs). Other futuristic wireless technologies have been proposed as well: helium-filled balloons, aircraft networks, airships, and dirigibles.

Since all wireless technologies transmit data through the air, there are inherent technological drawbacks with using wireless technologies for broadband data services. A major problem is transmission errors due to interference. Transmission errors result in lost data packets, which can either reduce throughput or cause unreliable data transfer. A second problem is security. Since data traveling through the air can easily be intercepted, additional measures must be employed in order to guarantee the security and integrity of the data. Yet another problem is latency, particularly in DBS networks which utilize GEO (geostationary earth orbit) satellites. Since the satellites are very high in the sky, transmitting data up to the satellite and back down to earth incurs large delay overheads.

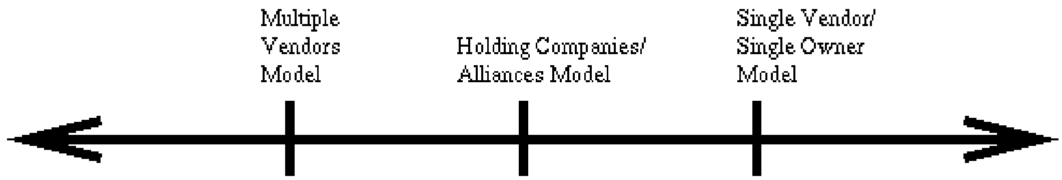
| Technology | Players | Benefits | Drawbacks | Costs |
|---|---|---|---|---|
| DBS | Primestar, DirecTV, USSB Echostar, AskyB | ·GEO satellites - one satellite can achieve national coverage<br>·High-bit rate service - HDTV is possible over DBS | ·One-way service - an alternative technology is needed for upstream connections<br>·Large service footprint - since bandwidth is shared by many, not scalable for broadband data services.<br>·Good for large-scale broadcasts, but not really suitable for broadband data services (lack of scalability). | ·~$1B to launch satellite<br>·~$500 for home satellite dish<br>·~$50/month for service |
| LEO | Globalstar, Motorola (Iridium, Celestri), Teledesic | ·Full-duplex service - can be used for upstream and downstream connections<br>·Provides worldwide coverage | ·High startup costs | ·Teledesic ~$9B to launch constellation<br>·<$1000 for home antenna<br>·~$30-$50/month for service |
| MMDS | Heartland, People's Choice, CAI Wireless, American Telecasting, RBOCS | ·Low startup costs<br>·Coverage area is only limited by line of site - one antenna can service 1 million users | ·One-way service - an alternative technology is needed for upstream connections | ·$4M to install antenna<br>·<$500 for receiver<br>·~$30-$50/month for service |
| LMDS | CellularVision | ·Low startup costs<br>·Full-duplex service - can be used for upstream and downstream connections | ·Wireless signal can easily be attenuated - small objects such as leaves and rain can interfere with signal<br>·Small coverage area - each tower can service about 6000 users | ·$500,000 - $1M to install tower<br>·<$500 for receiver<br>·~$30-$50/month for service |

## 2.5 Comparative Table of Broadband Technologies

| Technology | Expected baud rate | Market Segment | Geographical Location | Consumer Cost | Carrier Cost | Players | Barriers |
|---|---|---|---|---|---|---|---|
| xDSL | 16Kbps - 52Mbps | Residential, Small Office Home Office (SOHO) | Urban areas | DSL modem, POTS splitter, and OS patch | DSL interface card, change in administrative procedures & pricing, and cost of line conditioning (which is presently undetermined) | Microsoft, 3Com, Compaq, Intel, the Baby Bells | Lack of standardization ambiguity in Telecommunic Reform Act of |
| Private fiber optics | 622Mbps | Residential, SOHO, Business | Urban/rural areas | Network Interface Card (NIC) | Fiber optic cabling | Qwest, IXC, Media One Group, Williams Cos., Level 3 Communications | High capital investment, Dif logistics |
| Cable modems | 1.5Mbps - 27Mbps | Residential | Urban/rural areas | Cable modem | HFC upgrades, two-way upgrades, Headend equipment | TCI, Time Warner Cable, Cox Cable, Comcast, Cablevision, MediaOne, @Home | High upgrade c Stranded invest |
| Wireless networks | 16Kbps - 45Mbs | Business, developing countries | Rural areas, developing countries | Receiver | Satellites, transmission towers | PrimeStar, DirecTV, Iridium, Teledesic, Heartland, People's Choice, CellularVision | High capital investment, Difficult logisti Stranded invest |

# 3 Industry Analysis

The different segments of the telecommunications industry have historically been separate and distinct. Telephone carriers focused on providing either long distance or local connections for consumers. Cable companies provided access to a range of television channels. ISPs concentrated on giving clients Internet access. However, governmental deregulation in the form of the Telecommunications Reform Act of 1996 has changed industry dynamics by permitting telco organizations to not only compete against organizations within their own sector, but also to venture outside of their traditional industry segments. There exists a continuum of industry structure models which may be adopted. At one end is the Multiple Vendors model which reflects today's prevailing highly fragmented industry structure. Near the continuum's middle ground lies the Holding Companies / Alliances model which represents industry consolidation while preserving a healthy level of competition with multiple business interests in each region. At the continuum's other end is the Single Vendor / Single Owner model in which winner-take-all effects sweep one company to market dominance in its respective geographic region. The following is a more detailed examination of these three models.




Continuum of Industry Structure Models

## 3.1 Multiple Vendors Model

The multiple vendors model is an extension of the current status quo, i.e., multiple companies carrying different technologies compete head to head for consumers. Technology wise, xDSL, cable modems, and satellite access will be the primary contestants in the race. ISDN will continue to be the most widely available technology in the next few years, but many people are saying it offers too little, too late (and interpret the acronym ISDN as "It Still Does Nothing", or "Imaginary Service Delivered Nowhere"), so it probably won’t be attractive anymore after the other technologies mature. Fiber will most likely be the eventual solution for high speed connection, but it won’t be feasible for large scale deployment in the near future as the high initial investment of building the fiber network is almost prohibitive.

**Intense Competition**

While satellite is probably most viable in sparsely populated regions, most competition in well-populated areas will be between cable and phone companies under this multiple vendors model. This competition will be cutthroat as losing the battle in high speed access will also mean losing part of their traditional business. If the cable system becomes dominant, internet telephony through cable will take away phone companies’ business, and network externalities may even drive the phone companies out of business. On the other hand, since ADSL was originally designed as the delivery vehicle for Interactive TV, its success will have a similar effect on cable companies. Both technologies have reason to succeed. Each has some industrial giants backers. In the case of xDSL, Compaq, Intel and Microsoft formed a consortium with the nation’s largest local phone companies to make a standard. As far as cable modem technology goes, the major investors include AT&T, Digital (acquired by Compaq), General Instrument, Hewlett-Packard, Intel, Motorola, and Zenith. Interestingly, many companies are hedging their bets by actively promoting both technologies simultaneously. For example, Microsoft also bought WebTV, invested $1 Billion in US West cable business.

**Technology Lock-in**

It is still not clear how likely it is that the "perfect" competition multi-vendor model will become a reality. But this model will have many positive and negative implications for consumers. The good part is that the service price will be competed down, but consumers will likely be locked in to a particular technology once they choose one. Both cable and ADSL modems cost several hundred dollars, and installation charges apply too. So, switching costs are substantial. Because of the Telecommunication Reform Act of 1996, multiple vendors with the same technology may compete in one area, giving consumers the opportunity to switch companies using the same technology, as long as a nationwide standard is designed and followed, just as people can switch ISPs now and continue using the same analog modem. In this sense, it is unlikely for vendor lock-in to happen, unless there is only one vendor in an area. To reduce the degree of technology lock-in in the early stage, consumers can choose to lease the modem instead of buying during a trial period before investing in the equipment.

## 3.2 Holding Companies / Alliances Model

A middle of the road stop on the continuum from multiple vendors to single vendor/single owner is holding companies/alliances. As it stands now the telecommunications industry is highly fragmented. This structure does not reflect how customers would like to buy services. There is a strong tendency for the industry to consolidate in order to gain market power and economies of scale. This is the simple tendency of big fish to swallow up little fish and take over their territory. As mentioned above, there have been and will continue to be a flurry of mergers and acquisitions in the telecommunications marketplace.

If the party continues on Wall Street, telecommunications companies will have the financial backing to make deals. Then, the factors that actually have to do with the workings of the industry can take over. Foremost among them is fear -- fear that companies that do not offer nearly every service imaginable will not thrive, and fear of passing up the chance to gain a financial edge by combining with a rival and cutting costs. The first fear gets more attention. If so, what may evolve is a situation in which multiple holding companies and/or alliances are formed in each geography offering a full array of telecommunications services including local and long distance telephony and broadband data communications.

The flurry of merger and acquisition activity on Wall Street is evidence that the telecommunications industry is already moving in this direction. The question is, will it stop here or continue onto the single vendor / single owner model? The emerging regulatory environment will eventually answer this question.

There is a huge pent-up desire among both the Bell operating companies (BOCs) and the long distance carriers to link with one another in order to provide vertically integrated local and long distance telephony services along with broadband access data communications. Nonetheless, through the Telecommunications Reform Act of 1996 (Section 271), which deregulated much of the industry, the Federal Communications Commission and the antitrust division of the Justice Department made it clear they would not allow industry-wide vertical mergers until the BOCs sufficiently opened their local markets to competitors. So, although corporate executives would most like to pull off vertical acquisitions, those involving companies in complementary but not identical businesses, up until now Federal regulators had allowed only the biggest horizontal mergers and vertical deals on the margins. Thus, companies that offer similar service -- like Bell Atlantic and Nynex, or Worldcom and MCI -- have been allowed to merge, while proposed deals between local and long distance operators have received sharp denunciations from regulators.

However, in January 1998 a Federal judge in Texas ruled that the regulatory hoops that the Bells must jump through before they may offer long distance service are unconstitutional. If the ruling withstands the Government’s appeals, the decision would completely change the telecommunications landscape allowing the Bells to offer long distance service almost immediately, and allowing just the type of vertical acquisitions previously frowned upon while removing barriers to broadband access. This is just one more factor in favor of the emergence of a holding companies/alliances or single vendor / single owner model.

Eventually, anti-trust concerns may prevent this tendency from fully maturing into a market in which individual companies are the sole providers of all services in a given geographic region. Under this scenario just as in the single vendor / single owner model, the general public will continue to be well served by large companies capable of providing integrated telecommunications services with one bill at the end of the month but competition will be preserved. The free market rules in the Telecommunications Act of 1996 will be the ultimate arbiter of the future shape of broadband access as well as the telecommunications industry in general.

## 3.3 Single Vendor / Single Owner Model

Rather than solve the residential broadband problem by forcing consumers to select one technological solution, the Telecommunications Reform Act of 1996 allows telcos to alleviate the current lack of bandwidth by creating a situation in which one vendor can purchase enough infrastructure to provide the entire range of consumer telco needs. As mentioned above, this single vendor / single owner model lies on one extreme of the continuum of possibilities. Telco desires to adopt this model are motivated by a desire to dominate the telecommunications market. Telcos are chomping at the bit for fear of losing first mover advantage. They may however be underestimating the difficulty of successfully implementing this dream. They may be carrying a double-edged sword that ultimately makes this model less profitable than their current expectations. In addition, they presume the FCC's eventual willingness to permit the development of a telco giant capable of providing one-stop shopping. Despite these drawbacks, telcos have still chosen to proceed with this course of action in the hopes that they can be the exception to the anti-trust rule.

These hopes are grounded in the aspiration to achieve a first mover advantage, because the first telco which successfully achieves a single vendor / single owner position will have a significant competitive edge in the marketplace. It could become a highly attractive solution to the average consumer who prefers to receive all his/her services from one vendor on one monthly bill. Through mergers with other telcos, the telco giant could leverage each portion of the organization's existing installed base to market other products and services. Because consumer data would already exist on each of those customers, the telco giant could even personalize prices and packages prior to contacting the individual. Finally, this model would allow a large vendor to use its economies of scale to provide lower prices to consumers by enticing customers with promises of lower overall rates based on bundling. For instance, if a customer purchased long distance, local telephone, cable, and ISP services from the same source, the telco giant could offer a 5% discount off monthly bills. Such discounts could consistently undercut those offered by other competitors while still allowing the telco giant to recoup a large enough profit.

While the payoffs to achieving this model seem obvious, the true costs don't. In order to achieve this model, a great deal of money, time and effort need to be invested to create a single vendor/single owner.

- *Acquiring Infrastructure*: Rather than build the infrastructure to provide the range of consumer telco needs, most companies recognize that it's faster and cheaper to just purchase it elsewhere through takeovers or mergers. A flurry of these activities have already been occurring since the Telecommunications Reform Act of 1996. MCI and WorldCom merged. MCI and British Telecom have also merged and created a holding company called Concert in order to promote more global cooperation. WorldCom bought UUNET (the Internet provider), CompuServe Network Services, Brooks Fiber Properties, and MFS Communications (a long distance provider) all within nine months. Sprint merged with France Telecom and Deutsche Telekom. These mergers and acquisitions are only the tip of the iceberg. Dozens more are in the works.

- *Merging consolidated companies*: Simply purchasing infrastructure is not enough to ensure that a company will even be able to provide consumers those services. Administrative activities need to be in place or developed to allow a consolidated company to work seamlessly. Information systems need to be nimble enough to communicate data from one source to another even if they originally resided on systems that belonged to different companies. Different organizational cultures and business processes need to be resolved. Personnel reorganization has to be conducted. All these tasks require time to investigate the proper course to follow and necessitate further financial investment to fund those decisions.

- *The FCC's influence*: Even though the Telecommunications Reform Act of 1996 deregulated certain aspects of the telco industry, the FCC still wields a great deal of power. It permits or denies merger requests according to pre-defined criteria applicants must meet. It will determine how much the Baby Bells can charge for reselling capacity to competitors. It will "figure out how to unbundle local phone services" to prevent the Bells from unfairly forcing competitors to purchase all services rather than the ones they specifically need. It will determine standards for connecting existing networks with any new networks that are created. Additionally, it is expected to release up to eighteen new cable rules to foster further competition in this telco sector. Therefore, any telco with aspirations to become a single vendor / single owner must contend with FCC rulings. Even if a telco can afford to purchase all the infrastructure it wants and invest the time and effort to make consolidated companies an efficient whole, it can't do this without the consent and approval of the FCC. It remains to be seen whether the FCC would even permit this to occur. Only those telcos with enough political influence, money, and time to pursue petitioning the FCC will ever find out.

Until now the discussion has focused on the competitive edge to be gained by being the first telco giant. It has not addressed the inherent assumptions that might lead to erroneous conclusions. Standard discussions have equated size to efficiency and lower cost structures when in fact they might lead to the exact opposite. Under the weight of consolidating multiple companies and installed bases, a telco giant could fall under the weight of its own potential assets. With too much infrastructure and too many customers to manage, a telco giant with poor administrative skills may be unable to lower cost structures enough compared to competitors that move more quickly to take advantage of windows of opportunity. Another assumption is that consumers will want to purchase all their telco needs from one source. While the average consumer might find such a situation highly attractive, corporations are already worrying about vendor lock-in. In fact, CIO Magazine recently published an article specifically addressing ways to deal with vendor lock-in and some of the tactics telcos have used to entice corporations into purchasing services from them. "For example, MCI Communications Corp. plans to offer service guarantees for T3, promising to keep the lines available 99.9 percent of the time, according to Traver Kennedy, managing director of telecom research for Aberdeen Group. If the service goes down for more than one minute in a given month, MCI claims it will cut the bill in half." These types of promises might be enough to convince some corporations. On the other hand, they may not in which case a telco giant might not get the profit margins it expects from its ability to provide one-stop shopping.

Regardless of the obstacles faced by potential telcos vying for first mover advantage, companies feel they may have no choice but to pursue this aim. This fear is founded on the possibility that a competitor might be able to claim the prize. If that happens, competitors would be so far behind that they might never catch up. Rather they might be gobbled up by the telco giant or lose significant market share. Either option is too frightening to imagine so telcos prefer to deal with the possibility by consolidating as much as possible, hoping that they will claim the brass ring, or praying that at least none of their competitors will ever achieve such heights.

## 3.4 The International Perspective

In addition to traditional competition issues, broadband access providers must consider international issues if they plan to compete in the global market. Social, cultural, political, and economic differences must be taken into account when entering foreign markets.

Unlike the U.S. and other developed nations, most of the world has limited, if any, access to communications technology and installed infrastructure. In fact, basic phone penetration ranges from 99% in Monaco, to 0.07% in Cambodia. In these developing nations, the question may not be how to provide broadband access, but simply how to provide basic services. The International Telecommunication Union (ITU), which oversees global telecommunications regulation, recently adopted the Valetta Declaration and Action Plan. Basically, this outlined a plan to provide at least 10 phones per 1000 people worldwide. Global satellite access providers such as Teledesic stand to benefit the most since their satellite constellations could be tailored to provide global communications access.

Also, multinational corporations must be careful not to disrupt the fragile balance between social, political and economic reform within these developing countries. Introducing new technologies could create a division between the haves and the have-nots that could cause civil unrest and negatively impact economic development. In addition, many developing nations have a bitter resentment towards multinational corporations, since many of these countries were exploited by the industrial multinationals for their raw materials in the past.

U.S. based broadband access providers will even face social, cultural, political, and economic differences when looking to expand into other developed nations. In Europe, for example, the European Telecommunications Standards Institute (ETSI) decides standards for telecommunications in Europe. Furthermore, many European governments impose regulations which restrict free competition. Since Europe has a more regulated, standards-based culture, the cutthroat winner-take-all competition based on competing technologies in which many U.S. corporations engage may not be favorably looked upon or even tolerated in Europe. Additionally, even though the World Trade Organization’s (WTO) Basic Telecom Agreement (1997) relaxed many of the restrictions on international telecommunications competition, U.S. companies may find it difficult to significantly penetrate markets in developed countries since they are already mature with established telcos. Thus, it may be more economical for U.S. companies to form global alliances with these established telcos, which have a much greater understanding of their country?s market structures and dynamics.

Since the Internet is a global phenomenon, policy which affects the Internet should be decided globally. The U.S. government?s recent "green paper" which turned the Internet domain name service (DNS) over to a private U.S. company was a sign of global arrogance and outraged many foreign nations. In fact, France even considered creating its own Internet naming service. Broadband access providers with global network aspirations also need to understand and consider international issues if they are to succeed.

# 4 Conclusions

Broadband access still poses a major challenge to the industry.  Myriad options and possible combinations make it an interesting game.  The above technologies may appear on the surface to be competitive but at least in the medium term they may prove to be quite complementary.  A more important analysis involves determining what form the market structure eventually assumes.  Regulatory concerns will go a long way toward shaping the industry.  What is sure, however, is that consumers will have a choice of technologies that provide broadband access.  Broadband access prices are likely to be competed down once standards are established and big players throw their weight around.  But in this game, the real winners will be the consumer.

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