Section 5: Digital Subscriber Line Services

DSL's foundation—existing copper lines—already reaches nearly every home and business.

Digital subscriber line (DSL) technology has rapidly emerged as a powerful enabling technology for economic high-speed Internet access and remote LAN connections. DSL technology upgrades the performance of existing copper lines by utilizing specialized electronics at both ends of the connection. With DSL, the analog access speed barrier of 56 kbps is quickly surpassed, allowing potential throughputs of 1.5 Mbps or higher over a single line. DSL installations are quickly surpassing integrated services digital network (ISDN) deployments, which operate at just 128 kbps. Because of distance limitations associated with the technology, as well as the need to install equipment at each end of a copper loop, DSL service is limited to users who are located less than approximately three miles from a DSL-equipped central office.

Like other broadband technologies, DSL has diverse applications. Today, DSL carriers principally market two services—high-speed Internet access and remote LAN access—although many are introducing Web hosting, remote back-up, and other enhanced services. Prices for DSL service vary by bandwidth for the up and downstream channels. For example, a symmetrical 1.5 Mbps line runs on the order of $200 per month (without Internet access), while a line that offers 384 kbps downstream and 144 kbps upstream goes for approximately $70 per month. Residential DSL services that offer similarly high speeds but fewer throughput guarantees are now priced in the $40 per month range in many major markets. Compared to T1 lines that cost anywhere from $500 to $1,000 per month or more, DSL pricing represents a significant price reduction.

While incumbent carriers have deployed the most DSL lines to date, competitive providers have surpassed the incumbents in geographic reach (as measured by markets served) as well as network ubiquity (as measured by addressable lines). DSL competitors ("DLECs") must collocate their equipment in the incumbent carrier's facilities and lease the actual copper lines that connect to the home or business. Although deployment of DSL by competitive providers has been made more economic by favorable regulatory decisions concerning collocation and access to unbundled network elements, the day-to-day provisioning of new lines remains a highly manual process that entails ongoing coordination with the incumbent. In fact, eliminating the provisioning bottleneck is the principal gating factor in the mass deployment of DSL deployment.

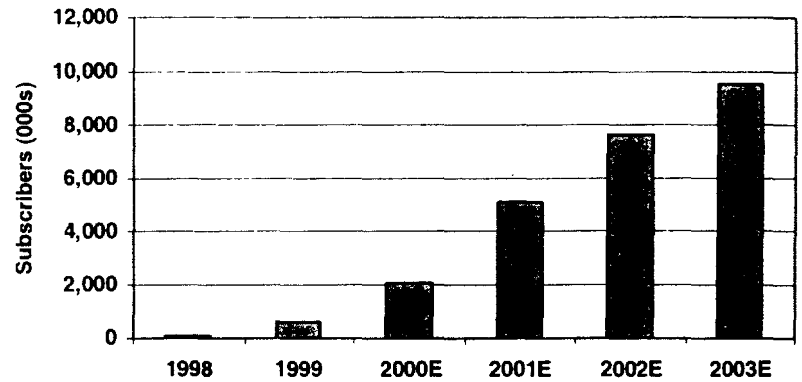
DSL capital is partially success based—a significant portion of required equipment can be purchased immediately following a customer win.

Because DSL technology uses the existing copper plant, it is significantly less expensive to deploy on a broad scale than other approaches, such as new fiber or cable construction. As a result, a significant portion of the investment in a DSL network is success-based, requiring a comparatively lower initial fixed investment. Subsequent variable investments in DSL technology are directly related to the number of paying customers.

Since phone lines are nearly ubiquitous in the United States, DSL providers are not limited to one market segment (e.g., business or residential) as are some other access technology providers. DSL has a competitive advantage in the small business sector since cable plant typically does not serve this market, and fiber optics are too expensive to deploy on a wide geographic basis. In many cases, we believe that DSL providers may face broadband wireless carriers as a primary competitor. In view of its potential to attract large numbers of users in disparate segments, DSL is expected to grow rapidly over the next five years.

Section 5: Digital Subscriber Line Services

Exhibit 5-1 ◆ Projected DSL Line Growth

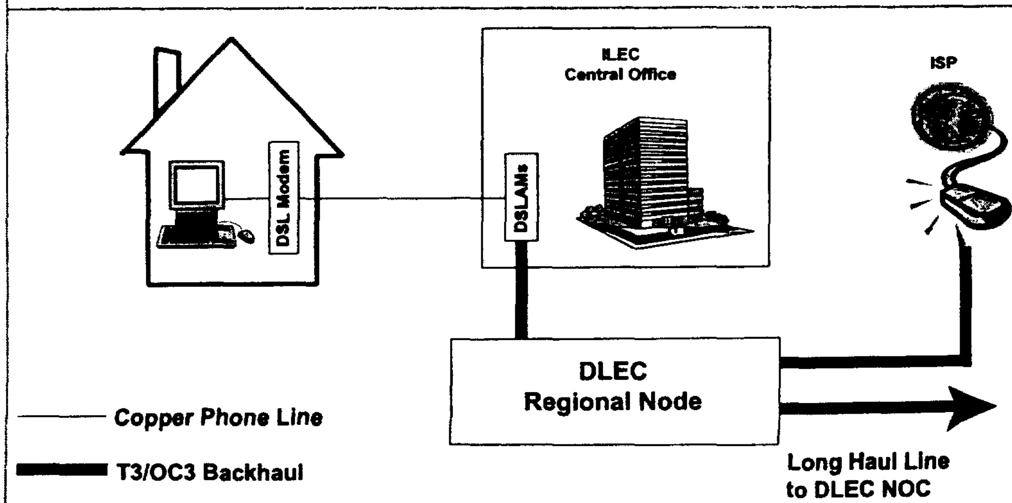


Source: Telechoice.com

◆ DSL Network Architecture and Economics

The configuration of a DSL network varies by application, target market, and provider (incumbent or competitor). A competitive DSL network consists of DSL equipment located in an ILEC central office that transmits high-speed data over copper lines between the central office and the end user. The DSL equipment is connected, in turn, from the central office to a regional network node, where data is collected in each metropolitan area. These connections typically run over leased T1 or DS-3 backhaul lines, depending on the amount of traffic. The regional node is connected, in turn, to a wide-area network (such as ATM or frame relay) or the Internet.

Exhibit 5-2 ◆ Competitive DSL Provider Network



Source: Dain Rauscher Wessels

Network Components

Customer Premise Equipment: DSL modems, located at the customer premise, receive and transmit data over copper telephone lines that are provided by the local telephone company. DSL modems cost between $200 and $300 and are dropping steadily in price—in 1998, the equipment ran at more than $500. In some cases, carriers choose to lease the equipment to end users. We anticipate that equipment prices will continue to fall as a result of advances in technology and increases in production volumes.

Local Transport: DSL-capable copper lines run from the end-user location to the ILEC central office. When a competitive provider supplies the service, the copper loop must be leased from the local telephone company (ILEC). These costs typically range from $7-$24 per loop per month. In light of recent regulatory and technical advances in the area of line sharing, competitors may now lease the data portion of an existing voice loop and pay significantly less (from zero to approximately $6 per month) in recurring costs than for a full copper loop.

Central Office Equipment: At the ILEC central office, a DSL access multiplexer (DSLAM) is required to terminate the DSL connections and interconnect with wide area networks. DSLAMs and associated loop management equipment currently cost in the $20,000-$30,000 range and can be upgraded to accommodate additional capacity simply by installing new line cards (about $4,000 each for a 24-32 port card). It is because capacity can be added at modest incremental cost that DSL is commonly noted for its "success-based" cost model relative to more capital-intensive bandwidth solutions such as fiber deployment. Up-front costs for the initial collocation are approximately $135,000, split approximately evenly between DSL equipment and fees to the incumbent carrier for cage construction, line conditioning, and other items. If carriers choose to forego a cage ("cageless") collocation, initial costs can be roughly halved.

Network Access Point and Operations Center: In each market, the DSL provider typically maintains a regional network node, which is connected to the carrier's network operations center (NOC). The regional node contains the DLEC's central operating facilities, including network monitoring equipment and operational support systems (OSS) for customer care, billing, and monitoring. At this location, the DLEC may install additional hardware to supply additional layers of service, such as Internet routers, content servers, and voice switching facilities.

Backhaul Transport: DLECs require at least two levels of back-haul transport—one to connect their NAP to the central offices on their network, and the second to connect their NAP to ISPs and potentially to long distance carriers. Depending on traffic volumes, back-haul transport requirements could range from fractional DS-3 to even OC-3 levels. Transport can be leased from the incumbent carrier or from a competitive provider.

Unit Economics

Exhibit 5-3 illustrates the central-office economics of two representative DSL deployments.

Exhibit 5-3 ◆ Unit Economics for DSL Deployment

	Wholesale	Direct
Assumptions:		
Business lines per central office	3,600	3,600
Penetration	4%	2%
Fixed Costs:		
Collocation fee to ILEC	$ 60,000	$ 30,000
DSLAM/router/other	$ 30,000	$ 30,000
Semi-Fixed Costs:		
Heating/lighting/power (monthly)	$ 495	$ 495
DS-3 backhaul (monthly)	$ 1,400	$ 1,100
CPE	$ 300	$ 300
Customer acquisition	$ 400	$ 800
Line charge (conditioning etc.)	$ 80	$ 80
Variable Costs:		
Recurring loop cost	$ 15	$ 15
Revenues:		
Blended rev/line/month	$ 80	$ 150
CPE (one-time)	$ 200	$ 200
Installation fee (one-time)	$ 100	$ 100
Margins:		
Margin/line/month	$ 49	$ 110
Gross margin	61%	73%
Payback Period:	21	15

Note: Collocation fee varies depending on cage construction; line charge amortized over 24 months; recurring loop fee assumes no benefit from line sharing.

Source: Dain Rauscher Wessels

The first column depicts a wholesale distribution model in which the DSL carrier sells high-speed connectivity to other operators (e.g., an ISP or CLEC). The second column depicts a direct-sales model in which the DSL carrier sells connectivity, Internet access, and other enhanced services directly to the end user.

We note that the individual line items in these figures can vary widely based on the specifics of the individual deployment, business model, and the central office being constructed.

◆ The State of DSL Deployment

DSL is still in its relative infancy as a broad-based solution to the local bottleneck. At first quarter 2000, some 4,000 central offices were equipped with DSL facilities, with the potential of serving approximately 35% of all telephone connections (there are some 22,000 central offices nationwide). At the close of the first quarter of 2000, there were approximately 755,000 DSL lines installed in the United States, with a backlog of at least that amount. By year end, we expect DSL coverage will reach 50%-plus of the entire market and serve 2.1 million lines.

Exhibit 5-4 ◆ DSL Deployment Summary

Service Provider	1000 Lines In Service	% Residential	% Business
ILECs	563,000	84%	16%
CLECs	179,000	22%	78%
IXCs	12,770	29%	61%
Total	754,770	69%	31%

Source: Telechoice, Inc.

DSL technology consists of numerous technological standards. As a result, the components of one vendor are often incompatible with those of other vendors, and many carriers choose to focus their deployments on a limited set of DSL variants. As discussed later, a DSL standard known as G.Lite is gaining traction in the market, which should facilitate faster deployment of asymmetric DSL services. G.Lite caters to residential customers because of the asymmetric nature of the service (faster downstream than upstream speeds) and the potential for a simpler installation process that can be handled by the layperson.

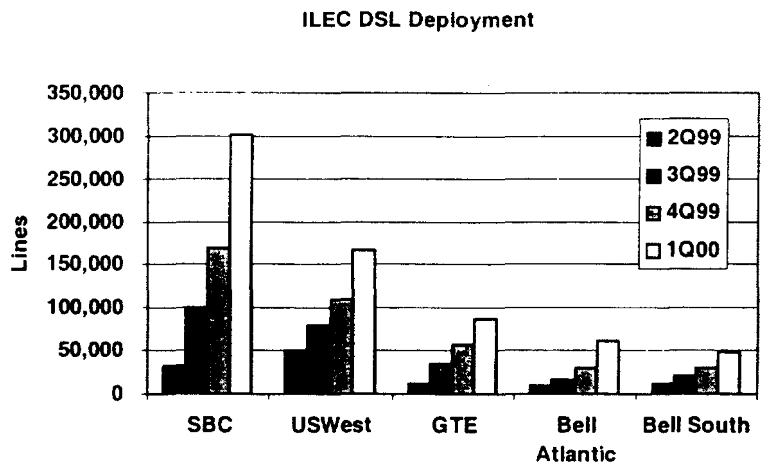
As indicated above, the day-to-day provisioning of new DSL service is a highly manual process that requires ongoing coordination with the incumbent carrier. The provisioning process typically entails separate procedures for order entry, order confirmation, loop qualification, and loop activation. Each of these steps carries the risk of miscommunication with or mismanagement by the incumbent, which is a primary factor behind today's lengthy service installation intervals of approximately 30-45 days. Eliminating the provisioning bottleneck through automation and "electronic bonding" with the incumbent is the principal factor that could lead to mass-scale deployment of DSL service.

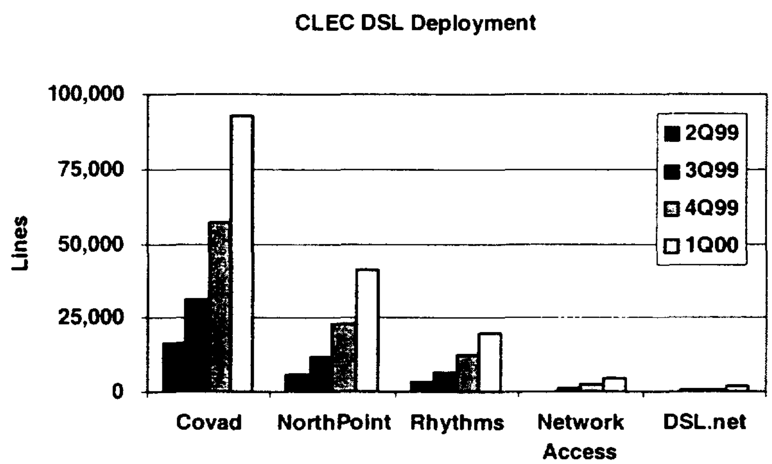
As we discuss later, DSL deployment received two significant regulatory catalysts during 1999—an FCC order mandating easier and lower-cost collocation of competitive equipment in the incumbent central office, and a separate FCC order that explicitly defined "line sharing" as an unbundled network element and set in motion state-level implementation of line sharing by June 2000.

Coverage

While DLECs have garnered the most public attention among DSL providers, to date the incumbents have deployed approximately three times as many DSL lines as competitors. However, DLECs surpass ILECs in geographic reach as well as network ubiquity (as measured by DSL-equipped central offices and addressable lines). On an individual carrier basis, several DSL competitors have networks on a national scale, with the RBOCs handicapped by their focus on in-region service. By year end 2000, we expect that total DSL service will be available to more than 50% of all telephone lines.

Exhibit 5-5 ◆ DSL Line Deployments by Carrier





Source: Company reports

◆ Incumbent Providers

With respect to new DSL deployment over the last mile, the ILECs generally have focused on asymmetric DSL to residences and, in some cases, small businesses. This contrasts with DSL deployment for internal backhaul transport, which the ILECs have employed for years. The ILEC residential strategy appears to be rooted in avoiding the cannibalization of profitable T1 business with larger commercial customers and focusing on the competitive threat posed by cable modems. Moreover, DSL has the added benefit of relieving traffic on the ILEC voice network since DSL traffic goes directly to the Internet and other data networks, bypassing voice switches. Incumbent ADSL offerings generally are provided in conjunction with Internet access. Pricing is typically in line with cable Internet service.

Exhibit 5-6 ◆ ILEC ADSL Pricing for Residences (most favorable pricing)

Company	Downstream Speed	Monthly Rate	Installation
SBC/Pac Bell	384 kbps	$39.95	Free
Bell Atlantic	640 kbps	$49.95	$99.00
Bell South	1.54 mbps	$49.95	150.00
US West	256 kbps	$19.95	69.00
GTE	768 kbps	$32.50	Free

Note: 1. Downstream speeds are typically quoted on a "best efforts" basis and are not guaranteed. 2. The US WEST offering is not an "always on" service.

Source: Dain Rauscher Wessels

◆ Competitive Providers—DLECs

As noted earlier, DLECs have quickly surpassed the incumbents in coverage, but lag considerably in actual line installations. That said, the DLEC business is less than two years old, and an initial group of industry leaders is being followed by a growing wave of start-ups. The five publicly traded DSL competitors—Covad, Rhythms, Northpoint, DSL.net, and Network Access Solutions—have attracted considerable investment interest from strategic partners, financial backers, and the public markets (all completed their IPOs during 1999). Additional DSL providers with a regional focus (at least initially) have begun offering service, often in secondary markets, and in many cases have likewise embarked on the IPO path. Finally, several competitive voice/data "smart build" providers have begun to leverage their existing networks and central office collocations with the addition of DSL technology.

Distribution Strategies

DLECs have largely focused on the small business market, whose demand for DSL capabilities is immediate and whose alternatives are few. The business market represents a more focused opportunity for DLECs, whose sales and provisioning staffs are fairly limited at this early stage. Monthly revenues from business customers of DLEC services currently average in the $85 range for wholesale carriers and up to $280 for retail carriers (whose offerings often include Internet access, remote LAN access, hosting, or other value added services). Residential customers, who produce monthly revenues of roughly $45 to wholesale providers, have been served largely through ISP resellers of DSL service.

Many DSL services are sold through third-party channels such as ISPs.

Some DLECs, including Covad, Northpoint, and New Edge Networks, distribute their services through third-party Internet service providers, long distance companies, network services firms, and other CLECs. These arrangements allow the DSL carriers to focus on securing interconnections and collocations, deploying equipment, and activating their networks while other carriers market the service. However, this strategy limits the potential revenue stream per line since the services are sold at wholesale rates to other providers. Further, by relying on third parties to market and sell the services, wholesale-oriented DLECs must find innovative ways in which to earn brand assets.

DLECs such as Rhythms and NAS are leveraging an existing skill base in developing corporate networks to directly sell DSL-based networking services. Customers receptive to such value-added capabilities are by nature higher-revenue customers, since their network needs warrant such services. This direct strategy allows the DLEC to earn a larger share of the customer's bill and facilitates the development of brand equity. However, this approach is by necessity more labor-intensive and costly, and may be more difficult to scale.

Value-Added Services

To differentiate their offerings, many DLECs are developing value-added services such as hosting, content delivery, and voice telephony.

Hosting: By and large, those DSL providers that offer hosting services are choosing to partner with specialized hosting firms, at least initially, rather than build the required competencies in house. At present, most of these services are basic, shared-server hosting, although over time, there is nothing that would prevent DSL providers from offering more sophisticated services such as dedicated hosting or applications hosting.

Voice over DSL: DLEC deployment of packetized voice over DSL (VoDSL) services is still largely in the trial phase. By offering multiple phone and data lines collapsed into one DSL pipe, DLECs are expected to be able to significantly undercut incumbent rates. VoDSL provides DLECs with access to the approximately $40-plus billion voice market among small and medium-sized businesses and accounts for more than 80% of their telecom spending. In many cases, DLECs are partnering with CLECs or long distance providers in their development of voice offerings. Examples include Covad's partnership with ICG, Northpoint's partnership with Focal Communications, and Rhythms' partnership with WorldCom. Mpower Communications, a voice/data "smart build" CLEC, has one of the more significant deployments of VoDSL to date.

Content Distribution: Many DSL providers have begun trials aimed at bringing cached Web content, streaming media, and other value-added content to their customer bases. Because these carriers have decentralized infrastructures in which to host content, caching servers, and content distribution servers at the edges of the Internet, they are an attractive option for content delivery providers to speed distribution to end users. Many DSL carriers have entered into content distribution partnerships with firms such as Akamai, Digital Island, Inc. (Nasdaq: ISLD; Strong Buy-Aggressive; $23.56), and iBeam.

Exhibit 5-7 ◆ Publicly-traded DLECs: Deployments and Strategies

Carrier	Current Coverage/Deployment	Targeted Footprint	Strategic Partners	Services	Distribution Strategy
Covad	1,350 COs, 93,000 lines deployed at 3/31/00.	Nationwide tier 1 and tier 2 markets.	NEXTLINK, Concentric, AT&T, Qwest, PSINet	Dedicated Internet access as well as wholesale ISP services to other carriers through LaserLink subsidiary. Voice services under development.	Wholesale distribution through ISPs, some direct distribution to enterprises.
Northpoint	1,260 COs, 41,300 lines deployed at 3/31/00.	Nationwide tier 1 and tier 2 markets.	MCI WorldCom, [illegible] Frontier, [illegible] Tandy [illegible]	[illegible] offering under development.	[illegible]
Rhythms	1,380 COs, 20,000 lines deployed at 3/31/00.	Nationwide tier 1 and tier 2 markets.	MCI WorldCom, Qwest, Microsoft	Dedicated Internet, remote LAN, back-up, hosting, and other services. Voice offering under development.	Direct distribution to enterprises. Focus on enhanced services. Wholesale distribution through carrier partners.
NAS	477 COs, 4,900 lines deployed at 3/31/00.	Deep coverage in Northeast and mid-Atlantic tier 1 and tier 2 markets, expanding to US WEST and BellSouth territories.	SBC/Telmex, [illegible]	Enhanced data network [illegible]	[illegible]
DSL.net	265 COs, 2,300 lines deployed at 3/31/00.	Nationwide tier 2 and tier 3 markets.	Microsoft, Staples, Webhosting.com	Dedicated Internet and hosting services. Voice offering under development.	Direct distribution to small/medium businesses using direct mail, telesales, and local partners.

Note: This table does not include several CLECs offering voice/data services, including Allegiance, Mpower, and ChoiceOne, which have signficant DSL deployments.

Source: Company reports and Dain Rauscher Wessels

DSL is not restricted to data—it can deliver multiple voice lines as well.

Other Deployments of DSL

In addition to the data-centric deployments by the DLECs, DSL is being deployed by some of the longer-established competitive carriers. Mpower Communications, Allegiance, and Choice One are three competitors that are installing DSL equipment to facilitate cost reductions and lay the groundwork for more data-centric offerings in the future. By deploying an integrated access device at the customer location, these carriers can provide both a high-speed data line and as many as 12 voice lines using one copper loop. Since these carriers already have their voice switches installed, as well as ILEC central office collocation space, they are well prepared to offer integrated voice and data service using DSL.

Exhibit 5-8 illustrates the market entry strategies of several privately held DSL-based competitors. We stress that DSL should be considered an enabling technology, not a service, and therefore the value propositions of these businesses should not be judged simply based on factors such as retail vs. wholesale distribution, size of target market, or geographic footprint.

Exhibit 5-8 ◆ Private DLEC Market Entry Approaches

	Retail Distribution	Wholesale Distribution	Current/Planned Deployment
Arrival Communications	x		tier 2/3 markets, Western states
@Link	x	x	tier 2/3 markets, Midwest
ConnectSouth	x	x	tier 2/3 markets, BellSouth, SW Bell regions
BlueStar	x		tier 2/3 markets, BellSouth region
Broadslate	x		tier 2/3 markets, mid-Atlantic, Southeast, Midwest
HarvardNet	x		tier 1/2 markets, Bell Atlantic Region
IP Communications	x	x	tier 1/2/3 markets, SBC regions
Jato	x	x	tier 2 markets, Midwest/West/Southwest
Maverix.net	x		tier 2/3 markets, Midwest
New Edge		x	tier 3/4 markets nationwide
Picus	x		tier 1/2 markets, Bell Atlantic region
Vectris	x	x	tier 2/3 markets, Southwest/Midwest

Source: Dain Rauscher Wessels

The DLEC's primary supplier is also a primary competitor.

Competition and Risks

The primary risk for all competitive DSL providers is that their primary supplier, the ILEC, is also their primary competitor. In order for a DLEC to provide service, it must:

- Negotiate an interconnection agreement with the ILEC;
- Obtain collocation space for its equipment within desired ILEC central offices;
- Order the unbundled loop from the ILEC;
- Wait for the ILEC to install the DSL-compatible line; and then
- Dispatch its own or contracted staff to the customer site for the final installation.

To date, the speed by which all this is accomplished has not facilitated mass-scale rollouts. Ultimately, the DLEC service and provisioning are only as good as the underlying quality of the ILEC network and service.

DSL pricing could fall significantly.

DSL providers also face considerable pricing uncertainty. With their initial deployments, competitive DSL providers have shaved some 50% off the effective price of a 1.5 Mbps access line, and we would not be surprised if prices were to tumble significantly in the near future in view of the low marginal cost ($20 or less) of provisioning DSL service. Thus, the evolution of DSL providers could well mirror that of CAPs, and to stay competitive, carriers will have to add value to their bandwidth. In addition, the existing base of full-service CLECs, which already have numerous ILEC collocations, are beginning to enter the fray by deploying their own DSL equipment—further increasing the pressure on DLECs to expand their service portfolio.

◆ Competitive DSL Regulation

Competitive DSL providers are regulated like any other CLEC, but as data-oriented providers, they are free of much of the regulatory oversight to which voice-centric providers are subject. Nevertheless, regulatory issues are of paramount importance to DLECs, since regulations facilitate their use of ILEC networks.

FCC rulings in 1999 significantly clarified definitions and terms for UNEs.

Competitive providers of DSL services have two principal regulatory concerns, both covered under the auspices of interconnection—access to unbundled network elements and access to collocation space. Each of these issues corresponds to language in the 1996 Telecommunications Act that requires each telecommunications carrier to interconnect with other carriers, and prohibits the installation of network features that would inhibit interconnection. Further, the Act mandates that certain network components of the ILEC network be provided to competitors at cost.

Unbundled Network Elements: Access to unbundled network elements allows DSL providers to purchase local loops at rates roughly equal to the cost of operating those loops. Following the FCC's UNE decision in September 1999, much of the uncertainty surrounding the terms and conditions for ILEC delivery of DSL-capable copper loops has been removed.

Collocation: Traditionally, CLECs have been required to construct a caged area within the CO for their equipment. DSL-based CLECs, especially those serving less dense markets and whose equipment requires relatively little space, have benefited from the FCC's requirement that ILECs offer "cageless" collocation, which reduces collocation expenses.

Line Sharing: In November 1999, the FCC mandated "line sharing" as a separate UNE. Under this ruling, competitors may provide high-speed data services over existing ILEC-operated voice lines by using only the high-frequency portion of those lines. Of note, this approach is compatible only with ADSL, which suggests its fullest impact will be seen in the residential market.

Currently, competitors that purchase unbundled copper loops from the incumbent carrier must pay to install a separate line to the customer, which entails significant time and cost. By using only the data portion of existing voice loops, line sharing enables DSL, thereby reducing service installation expenses, reducing the monthly lease expense of the circuit (from an average of $20 to $10 or lower), and significantly speeding provisioning times (currently roughly 30-40 days). At current consumer price points, we estimate that line sharing could lead to gross margin improvements on the order of 1,000 basis points and accelerate EBITDA breakeven per line by several months.

ILECs must make line sharing widely available in their regions by June 2000. Recent interim rate agreements between competitors and several ILECs suggest that DSL competitors will be able to gain access to the data portion of existing loop for monthly rates that are less than half the rate for a full copper loop.

Remote Port Access: As we describe later in this chapter, a major technological limitation of DSL is that it only functions over copper lines and cannot function through a digital loop carrier unless a remote port is installed. Since digital loop carriers serve a significant percentage of the population, remote ports must be installed in these units in order to enable high-speed DSL services. This, in essence, lies behind SBC's announced $6 billion Project Pronto, which pushes fiber deeper into residential neighborhoods via DLCs, then uses remote ports with DSL line cards connected to the final copper loop. Although this has the advantage of expanding the addressable market for DSL by removing many of the distance and network limitations of the technology, controversy has arisen around the issue of compatibility with competitors' networks. For competitors to address users served off these remote terminals, their networks must either be compatible with the specific type of line card the incumbent has deployed in the remote terminal, or there must be enough room in the remote terminal for them to place their own equipment. Since SBC's current plan does not address compatibility with competitors' networks or guaranteed space in the remote terminal for them to locate their equipment, many DLECs have protested to the FCC. Despite the generally pro-competitive environment in the Commission, there is no assurance that the CLECs will accomplish their goals on this issue because SBC will be expanding broadband access to a wider base of users, which furthers a major FCC policy goal. Although competitors would presumably be able to gain access to SBC's remote-terminal line cards, they would be forced to comply with SBC's equipment vendor selection.

◆ DSL Technology Variants

DSL is an umbrella term that includes various kinds of digital subscriber line technologies, including ADSL, RADSL, HDSL, SDSL, and VDSL. DSL employs advanced modulation techniques to take advantage of frequency spectrum within existing copper wires that is not utilized by telephone traffic. Standard voice calls utilize the spectrum between 0-4 kHz, while DSL utilizes frequencies between 26 kHz and 1 MHz and thus can encode more data and achieve higher data rates. DSL is an "always on" service, which means the connection is always available for transmission and the time-consuming dial-up sequences of analog modems are not required.

Key points to keep in mind are the trade-offs between signal distance and speed, and the differences in symmetry of upstream and downstream traffic. DSL is distance-dependent because the higher frequency signals associated with DSL attenuate, or lose strength, faster than lower frequency signals.

Asymmetric Digital Subscriber Line (ADSL) allows more bandwidth downstream (from CO to the customer) than upstream (from the customer to the CO). As many Internet users download much more information than they send, ADSL can be an attractive option for a large segment of the market. ADSL supports downstream speeds between 1.5 and 8 Mbps and upstream speeds between 640 kbps and 1.5 Mbps. ADSL can provide 1.54 Mbps transmission rates at distances of up to 18,000 feet over one wire pair. ILECs such as US West, GTE, SBC, BellSouth, and Bell Atlantic have focused almost exclusively on ADSL as their means of penetrating the consumer market, while competitive carriers are turning their attention to ADSL as a way to take advantage of line sharing.

Once the G.Lite standard gains traction in the market, deployment of ADSL can be expected to accelerate, as "truck rolls" for installation will be eliminated or significantly reduced. Further, computer makers will have a set specification to which to construct G.lite-compatible internal modems, potentially leading to a more seamless "plug and play" provisioning experience for the end user (no need for external hardware and software configuration).

Rate Adaptive Digital Subscriber Line (RADSL) operates within the same transmission rates as ADSL, but adjusts dynamically to varying lengths and qualities of copper loops during a connection. Thus, RADSL allows each end user to access the full capability of the underlying copper line. To date, Rhythms NetConnections has deployed RADSL most extensively in its network. Target customers for RADSL connections are typically small and medium-sized businesses and branch offices of large businesses needing T1 or higher speeds.

ISDN Digital Subscriber Line (IDSL) provides full symmetrical throughput at speeds up to 144 kbps in each direction. While IDSL uses the same modulation code as ISDN to deliver service without special line conditioning, it differs from ISDN in a number of ways. First, unlike ISDN, IDSL is a non-switched service, so it does not cause switch congestion at the service provider's central office. Second, unlike ISDN, ISDL, like all DSL technologies, is an "always on" service that requires no call set-up. IDSL is the only DSL technology today that can circumvent issues related to digital loop carriers (DLCs) situated between the central office and the customer location. IDSL thus allows carriers to reach virtually all end users within a central office serving area.

High Bit-Rate Digital Subscriber Line (HDSL) technology is symmetric, providing the same amount of bandwidth upstream as downstream. HDSL is the most developed of the DSL technologies, and it has been widely deployed for T1 installations. Due to its speed (1.5 Mbps over two copper pairs and 2 Mbps over three pairs), carriers commonly deploy HDSL for point-to-point T1 connections. Although HDSL's 12,000-15,000-foot operating restriction is shorter than ADSL's, phone companies can install signal repeaters to extend its useful range.

HDSL 2 is the next generation of HDLS—it offers the same performance as HDSL, but over a single copper pair.

Symmetric Digital Subscriber Line (SDSL), like HDSL, supports symmetrical T1 transmissions, but SDSL differs from HDSL in that it uses a single copper-pair wire and has a maximum operating range of 8,000-10,000 feet. Within its distance limitation, SDSL is capable of accommodating applications that require identical downstream and upstream speeds, such as video conferencing or collaborative computing. SDSL is a precursor to HDSL 2.

Very High Bit-Rate Digital Subscriber Line (VDSL) technology is the fastest DSL technology, supporting a downstream rate of 13 to 52 Mbps and an upstream rate of 1.5 to 2.3 Mbps over a single copper-pair wire. VDSL can be viewed as a cost-effective alternative to fiber to the curb. However, the maximum operating distance for this asymmetric technology is only 1,000 to 4,500 feet. VDSL deployments can be supported by running fiber optic cable from the central office to digital loop carriers and copper from that point to the user location up to 4,500 feet away. In addition to supporting the same applications as ADSL, VDSL's additional bandwidth can potentially enable carriers to deliver high-quality video services. VDSL is currently being trialed by US WEST in Phoenix and a few other markets.

Exhibit 5-9 ◆ Summary of DSL Variants

DSL Type	Maximum Downstream Speed	Maximum Upstream Speed	Maximum Distance from User to CO	Comments
ADSL	1.5 - 8 Mbps	640 kbps	18,000 ft.	Assymmetric offering most suited to residential users.
IDSL	144 kbps	[illegible]	[illegible]	Slowest speed DSL variant – currently the only solution for the DLC problem.
HDSL	1.5 Mbps	1.5 Mbps	12,000 ft.; 24,000 ft. with repeater	T1 equivalent – requires two copper pairs.
HDSL2	1.5 Mbps	[illegible]	12,000 ft.; 24,000 ft. with repeater	HDSL enhanced – requires only one copper pair.
SDSL	2.3 Mbps	2.3 Mbps	10,000 ft.	Symmetrical service, unchannelized.
RADSL	7.1 Mbps	[illegible] Mbps	12,000 ft.	Rate-adaptive ADSL.
VDSL	52 Mbps	1.5 - 2.3 Mbps	4,500 ft.	Fastest DSL variant.

Source: Company reports and Dain Rauscher Wessels

◆ DSL Performance Obstacles

There are several reasons why certain locations may not qualify for DSL. The principal ones pertain to loop length; the fact that some portion of the phone line is carried to the premises on fiber optic cable; and loop obstructions.

Loop Length: Signals fade with increasing distance, especially so for the high-frequency signals utilized by DSL. As indicated in the above discussion, the various DSL technologies (except for IDSL) have distance limitations ranging from 4,000 to 18,000 feet from the central office. As technologies improve, these limitations may ease, but as a practical matter, high-speed DSL service is currently limited to locations within a three-mile maximum loop length from the central office. As upwards of 70%-85% of end-user locations meet this requirement, the loop-length limitation is not a show-stopper. However, increased distance from the central office, even within the 18,000-foot limit, leads to slower connection speeds.

Digital Loop Carriers: Digital loop carriers, sometimes called SLICs, are refrigerator-sized units that phone companies deploy between the customer site and a central office in order to increase the effective coverage area of a central office. Typically, the DLC is connected to the central office through a fiber link, and extends to the customer site over conventional copper wiring. With the exception of IDSL, DSL technologies only function over continuous copper—thus, it is not possible to deploy them in DLC-served locations by simply installing a DSLAM in the central office. Typically, newer suburban subdivisions contain a greater proportion of DLCs than denser, downtown locations, presenting a challenge for carriers that target residential customers. Roughly 30% of local loops in the United States are affected by the DLC issue, although this varies by region.

Newer DSL technologies address the issue of digital loop carriers.

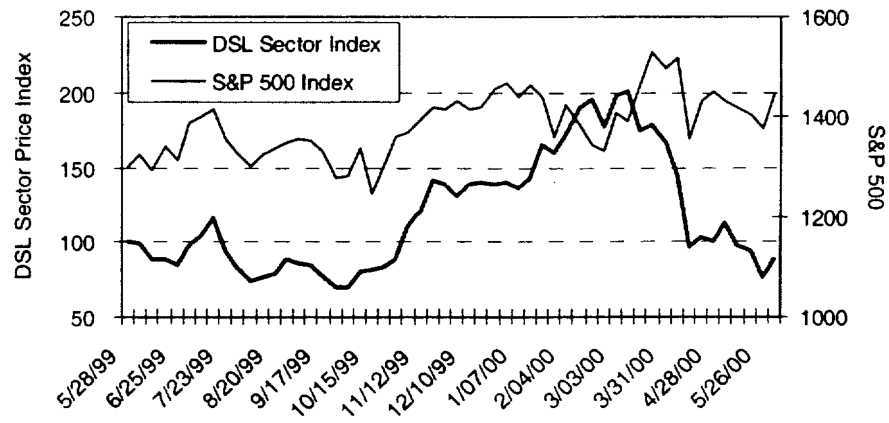
A Solution to DLCs—Remote Ports: Other than to deploy IDSL, which is limited to 144 kpbs in either direction, the main workaround to the DLC problem is to install a mini-DSLAM or remote port in the DLC. Remote DSLAM deployment is challenging because of space limitations, difficulties in supplying power, and the lack of environmental controls such as temperature or humidity. However, carriers and vendors are addressing these challenges, and the deployment of remote DSLAMs or unbundled ports is increasing. A major portion of SBC's $6 billion Project Pronto is devoted to deploying remote ports in that carrier's region to extend the reach of DSL service.

Spectral Interference (Cross-Talk): Individual copper lines are bundled together in what is known as a binder group (typically 20 or more lines per cable). Wires in a binder group are susceptible to spectral interference, or crosstalk, among lines. Cross-talk has always existed with respect to T1 services and has been managed successfully. However, the spectral interference issue is magnified by the prospect of wide-scale deployment of DSL services that deliver several orders of magnitude greater power into the loop than conventional voice services or 56 kbps analog traffic. The more power that is put in (which is directly related to loop length and speed), the more chance there is of cross-talk and interference with other services. Standards bodies are working on rules relating to binder group management and other tools to govern how DSL and other high-speed services can be offered. The FCC has struck a DLEC-favorable posture on this issue by indicating that the burden of proof relative to spectral interference should fall on the incumbent, not the competitor.

Bridged Taps: These are repeaters or portions of a loop that are not in the direct line between the end user equipment and the central office. These must be removed in most cases to enable DSL transmission.

Load Coils: Load coils allow better voice transmission over extended distances—usually beyond 18,000 feet from the central office. In longer loops, load coils are placed at approximately 6,000-foot intervals. These coils must be removed to enable DSL services. While some local carriers have few load coils in their network, others have coils in as much as 20% of local loops.

Exhibit 5-10 ◆ DSL Sector Price Index vs. S&P 500



Source: FactSet

Exhibit 5-11 ◆ Publicly Traded DSL-Based Competitors

(Amounts in millions, except per share figures)

			Stock Price Information						Balance Sheet				Revenue						Operating Metrics	
			Price	52 Week Range		Shares	FD Shares	Market	Long Term	Preferred		Enterprise				Enterprise Value / Rev.			Lines	Central
Company	Symbol	FYE	06/01/00	High	Low	Out.	Out.	Cap.	Debt	Stock	Cash	Value	CY 99	CY 00E	CY 01E	CY 00E	CY 01E		Installed	Offices
Covad Communications Group, Inc.	COVD	Dec	$24.31	$66.63	$19.06	144.86	165.28	$4,018	$375	$0	$767	$3,626	$66	$274	$560	13.2 x	6.5 x		93,000	1,350
DSL.net, Inc.	DSLN	Dec	6.41	32.56	6.13	58.38	65.23	418	2	0	79	340	1	30	112	11.3 x	3.0 x		2,300	265
mPower Communications Corp.	MPWR	Dec	48.63	78.00	15.00	23.24	35.58	1,730	157	85	125	1,847	55	106	NA	17.5 x	NM		168,786	446
Network Access Solutions Corp.	NASC	Dec	12.25	40.00	8.19	46.75	46.96	575	18	0	43	550	17	37	142	14.9 x	3.9 x		4,888	477
NorthPoint Communications Group, Inc.	NPNT	Dec	14.94	44.00	11.00	126.47	131.99	1,972	87	0	210	1,848	21	110	260	16.8 x	7.1 x		41,300	1,260
Rhythms NetConnections, Inc.	RTHM	Dec	18.00	71.00	14.38	77.15	78.58	1,414	506	0	377	1,543	1,225	2,000	2,050	0.8 x	0.8 x		20,000	1,380

* Lines installed for mPower includes non-DSL circuits

Source: FactSet

Section 5: Digital Subscriber Line Services

Broadband Services Companies	Hyperlink	Description	Address	Financial & Strategic Partners	Ticker
Covad Communications	www.covad.com	Covad Communications provides high-speed, broadband access services to businesses and residences utilizing DSL technology. The company primarily distributes its services through several hundred carrier partners. Through its recent acquisition of LaserLink.net, the company provides wholesale ISP services. The company's network includes all major U.S. markets, with 200 markets slated to be operational by year-end 2000.	2330 Central Expressway Santa Clara, California 95050	Warburg Pincus Ventures, Crosspoint Venture Partners, Intel.	COVD
DSL.net	www.dsl.net	DSL.net, Inc. is a CLEC and ISP that uses DSL technology to provide high-speed Internet solutions to small and medium-sized businesses, primarily in tier 2 and tier 3 cities throughout the United States. The company primarily uses direct distribution channels to market its Internet access, Web hosting, and other services. As of March 31, 2000, DSL.net provided service in 186 cities.	545 Long Wharf Drive New Haven, CT 06511	VantagePoint Venture Partners, Prism Venture Partners, Oak Investment Partners, Microsoft	DSLN
Network Access Solutions	www.nas-corp.com	Network Access Solutions provides DSL-enabled networking solutions to businesses. NAS offers customers broadband local, metropolitan and wide-area connectivity services using DSL access technology and its inter-city backbone. As a complement to its DSL services, the company offers customers a complete suite of value-added enterprise networking solutions, including network integration, network management, network security, and professional services.	100 Carpenter Drive Sterling, VA 20164	Spectrum Equity Investors, FBR Technology Partners, SBC Communications, Telmex	NASC
Northpoint Communications	www.northpointcom.com	NorthPoint Communications provides DSL services in all major U.S. markets. The company distributes its services through partnerships with other carriers. Through its relationships with Versatel in Europe and Call-Net in Canada, the company is building international DSL networks. The company has also embarked on a number of partnerships with streaming media and content delivery companies in order to leverage its local broadband assets.	303 2nd Street San Francisco, CA 94107	Microsoft, Tandy, Carlyle Group, Accel Partners, Benchmark Capital, Greylock, Vulcan Ventures	NPNT
Rhythms NetConnections	www.rhythms.com	Rhythms NetConnections provides DSL-based, broadband communication services to businesses and consumers in North America. The company offers an array of voice, Internet access, data networking, remote LAN access, back-up, and security services. Rhythms currently serves 49 markets covering 86 metropolitan statistical areas, and utilizes both direct, retail distribution to enterprise customers and wholesale distribution via carrier partners.	6933 South Revere Parkway Englewood, Colorado 80112	Enterprise Partners, Kleiner Perkins Caufield & Byers, Brentwood Venture Capital, MCI Worldcom Venture Fund, The Sprout Group, Enron Communications Group, Microsoft, Hicks Muse Tate & Furst, Qwest.	RTHM
Telocity	www.telocity.com	Telocity provides broadband Internet access and content services aimed primarily at the residential market. The company partners with last-mile broadband providers and utilizes a proprietary access device at the customer site that simplifies service installation and facilitates the delivery of enhanced services.	10355 North De Anza Blvd Cupertino, CA 95014	Mohr Davidow Ventures, RRE Investors, August Capital, Bessemer Venture Partners, Comdisco, Standford University	TLCT
@Link Networks	www.atlinknetworks.com	@Link Networks provides DSL-based Internet access, VPN, and other enhanced services in tier 2 and tier 3 markets, primarily in the Midwest. The company distributes its services using a mix of retail and indirect channels.	361 Centennial Parkway Louisville, CO 80027	Madison Dearborn Partners, Columbia Capital, TeleSoft Partners	private

Section 5: Digital Subscriber Line Services

Broadband Services Companies	Hyperlink	Description	Address	[illegible]	Ticker
Arrival Communications	www.arrival.com	Arrival Communications is a DSL-based CLEC and ISP targeting small and medium-sized businesses in tier 2 and tier 3 markets. The company employs a direct, retail distribution approach and has rolled out service in several California markets. Arrival intends to expand its network to other Western states.	601 Montgomery St. San Francisco, CA 94111	Alta Communications, Housatonic Partners, BancBoston Capital and certain partners of Hellman & Friedman LLC	private
BlueStar Communications	www.bluestar.net	BlueStar Communications, founded in 1998, is a DSL-based CLEC and ISP targetting tier 2 and tier 3 markets in the Southeastern U.S. The company provides DSL-based high-speed Internet access, wide-area networking, Web hosting, remote backup, security, and other services to small and medium-sized businesses. The company distributes its products and services to end-users through direct sales channels as well as through value-added resellers. BlueStar has launched operations in 40+ markets across its 10-state region.	414 Union Street Nashville, TN 37219	Crosspoint Venture Partners, Intel, Lucent	private
Broadslate Networks, Inc.	www.broadslate.com	Founded in 1999, Broadslate Networks provides DSL-based IP, data, and hosting services small and medium-sized businesses. The company is planning to deploy its network in tier 2 markets in the Southeast, Mid-Atlantic, and Midwest. Broadslate distributes its services through a direct sales force and local partners.	675 Peter Jefferson Parkway Charlottesville, VA 22911	Columbia Capital, JP Morgan Capital, Bessemer Venture Partners, Charles River Ventures	private
ConnectSouth	www.connectsouth.com	ConnectSouth provides a range of DSL-based Internet connectivity and communications services to small- and medium-sized businesses as well as other carriers. The company's initial markets include Austin, Biloxi, Birmingham, Mobile, New Orleans, Oklahoma City, Tulsa and Waco, and the company plans to expand into 22 additional markets in the fall of 2000 and to 80 southern markets by the end of 2002.	9600 Great Hills Trail Austin, TX 78759	Morgan Stanley Venture Partners, Morgan Stanley Capital Partners, Fleet Equity Partners, and Waller-Sutton Media Partners	private
Flashcom	www.flashcom.com	Flashcom provides DSL-based Internet access in over 80 metropolitan areas, serving residences, small businesses, and telecommuters, relying on partnerships with facilities-based wholesale carriers. The company also offers virtual private network, remote access, and Web hosting capabilities.	5312 Bolsa Avenue Huntington Beach, CA 92649	Communications Ventures, Mayfield Fund, Intel Corp., Behrman Capital, Capital Research and Management, Blueprint Ventures, BancBoston Ventures, The Carlyle Group, Kohlberg Kravis Roberts & Co., Tudor	private
HarvardNet	www.harvardnet.com	HarvardNet is a CLEC and ISP that provides a range of high-speed Internet and e-commerce related services business customers. The company also offers DSL-based teleworker services. The company's current markets are in New England and the mid-Atlantic.	500 Rutherford Avenue Boston, MA 02129	M/C Venture Partners, Fidelity Ventures	private
InterAccess	www.interaccess.com	InterAccess is a data CLEC and ISP based in the Chicago area. The company provides Internet access through an array of offerings, ranging from DSL, dedicated 56K to T1 and T3, ISDN, dialup and remote web hosting. InterAccess intends to expand its DSL service throughout the Midwest starting with locations in Wisconsin and Indiana.	1687 North Clinton Chicago, IL 60661		private

Section 5: Digital Subscriber Line Services

Broadband Service Company	Hyperlink	Description	Address	Financial & Strategic Partners	Ticker
Jato Communications	www.jato.net	Jato provides high-speed Internet access, network connectivity and associated broadband applications and services to small and medium-sized businesses. Jato uses digital subscriber line (DSL) and other high-speed communications transport technologies to offer a wide array of Internet-based services including Internet access, Web hosting, e-mail, and e-business applications. The company distributes its products and services directly to end-users and indirectly through Internet Service Providers (ISPs), Value Added Resellers (VARs), and other local market partners.	1099 18th Street Denver, CO 80202	Mayfield Fund, Crest Communications Partners, CEA Capital Partners, USA, ABN AMRO Capital, Inc., Access Technology Partners, TCI Satellite Entertainment, Inc., Lucent Technologies, Qwest.	private
LightNetworks	www.lightnetworks.com	LightNetworks is a broadband CLEC utilizing DSL technology to provide voice and data services to small and medium-sized businesses. The company is currently offering service in Atlanta and plans to launch operations in Nashville, Charlotte, Memphis, Miami, and Louisville in the near future.	2700 Northeast Expressway Atlanta, GA 30345	EnTrust Capital, Banc of America Securities, Goldman Sachs, Lucent Technologies.	private
Maverix.net	www.maverix.net	Founded in 1999, Maverix.net provides DSL-based Internet access, data connectivity, hosting, and other services to small and medium-sized businesses. The company distributes its services through a direct sales force, with an initial deployment in tier 2 markets in the central U.S.	20 South Clark Street Chicago, IL 60603	Schroder Ventures, Lucent Technologies	private
New Edge Networks	www.newedgenetworks.com	Founded in 1999, New Edge Networks provides DSL services on a wholesale basis to ISPs, communications companies, and other strategic partners. End users include both residential and business customers in tier 3 and tier 4 markets. The company is building out a national footprint spanning all 50 states, and uses reciprocal agreements with other carriers to provide coverage in tier 1 and tier 2 markets.	3000 Columbia House Blvd Vancouver, WA 98661	Accel Partners, Comdisco Ventures, Crosspoint Venture Partners, Greylock, Goldman Sachs, Intel Corporation, Morgan Stanley Dean Witter, Meritech Capital	private
Phoenix Networks	www.phoenixdsl.com	Phoenix Networks is a national broadband services provider that specializes in network access, hosting, and integration services. The company delivers a full range of products using DSL, ISDN and other high-speed technologies under the Phoenix DSL brand in 44 cities across the U.S.	1842 Lackland Hill Parkway St. Louis, MO 63146		private
Picus Communications	www.picus.com	Picus Communications provides a variety of voice, Internet, and high-speed data services to businesses and residences. The company is has deployed a DSL network in several mid-Atlantic markets and plans to expand to additional markets. Picus' partners include Nortel Networks, Nokia, and Coppercom.	2877 Guardian Lane Virginia Beach, VA 23452	numerous private sponsors	private
Vectris Communications	www.vectris.com	Vectris is a CLEC and ISP that uses DSL technology to provide broadband services in tier 2 and tier 3 markets in the Southwest and Midwest. The company's service offerings include data networking, Internet access, remote LAN access, and Web hosting. Vectris employs a direct-sales model for its higher-value business offering. It also offers its services through ISPs, carrier partners, and resellers.	5000 Plaza on the Lake Austin, TX 78746	Trinity Ventures, Stolberg Equity Partners, Weiss, Peck & Greer, Austin Ventures	private

Section 6: Broadband Wireless Services

Section 6: Broadband Wireless Services

Broadband wireless approaches allow competitors to bypass the incumbent's local infrastructure.

Broadband wireless technology can be deployed to offer any broadband service at throughputs ranging from DS-0 (64 kbps) to OC-3 (156 Mbps) or greater, depending on the amount of spectrum available. Terrestrial wireless networks are cellular in nature, employing small two-way antennas (transceivers) at a hub site and at a customer's premise. With a relatively small number of these cell sites, an operator can rapidly achieve broad coverage of any given market. Broadband wireless technology generally requires a line-of-sight between two transceivers. Broadband wireless networks can provide voice, two-way data, or video services. At present, there are four licensed spectrum bands commonly used for two-way broadband communications over the last mile:

- **2.5 GHz:** Services at this frequency are commonly known as multi-channel multi-point distribution service, or MMDS. MMDS was originally licensed to provide video services over approximately 120-200 MHz of spectrum but has now been authorized by the FCC for any two-way communications service. In the first half of 1999, Sprint and WorldCom each spent more than $1 billion in acquiring the MMDS licenses of several companies.
- **24 GHz:** Teligent holds the only commercial licenses for services at this frequency. The company obtained these licenses free of charge and possesses 80-400 MHz per market.
- **28 GHz:** This frequency band is known as local multi-point distribution service, or LMDS. The FCC auctioned off two LMDS licenses for each of 493 license areas in the United States during 1998 and 1999. The A band license holds 1,150 MHz and the B band license holds 150 MHz. NEXTLINK Communications is the largest holder of LMDS spectrum.
- **39 GHz:** Initially these licenses were awarded free of charge, although additional spectrum was recently auctioned by the FCC (see following discussion entitled "Spectrum-Specific Considerations"). WinStar is the largest holder of licenses at this spectrum, possessing on average 1,000 MHz per market. Other players include Advanced Radio Telecom and AT&T.

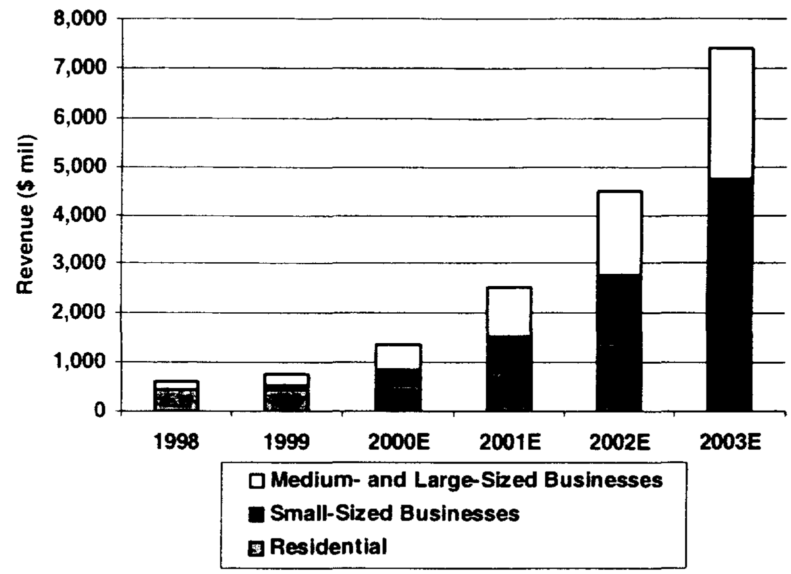
In addition, several operators provide two-way broadband services using **unlicensed** spectrum, which is free of charge and available for use by any carrier. The two most commonly offered unlicensed services are in the 2.4 GHz band and the 5 GHz band.

Because they do not require extensive rights of way or access to ILEC central offices, broadband wireless operators can enter new markets relatively quickly. Further, this technology offers carriers full control of their networks and service since they do not rely on the facilities of incumbent local carriers.

However, this technology presents a number of challenges. First, broadband wireless is only now being deployed on a large commercial scale, and the equipment is just reaching full production status. Second, because broadband wireless generally requires a line of sight between transceivers, the presence of obstacles such as foliage, buildings, and even heavy rain affects the availability of the signal. This restriction reduces the effective reach of broadband wireless to between 60%-70% of potential customer sites, although newer repeater-based approaches now being introduced may significantly improve coverage.

Depending on the frequency band used, broadband wireless deployments can be economical in dense areas, where a relatively small number of cell sites can reach a larger number of customers, or in more remote areas that are not conducive to fiber, DSL, or cable-based access. Driven by increasing demand and well-capitalized service providers, broadband wireless is expected to grow to a $7.4 billion annual market over the next three years.

Exhibit 6-1 ◆ Broadband Wireless U.S. Market Forecast



Source: IDC

◆ Broadband Wireless Players and Deployment

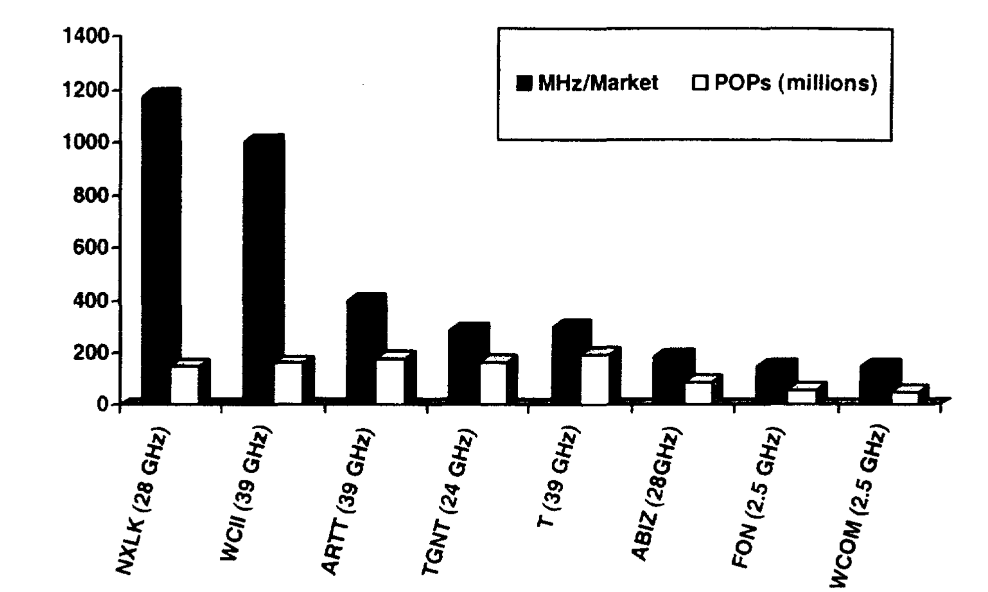
Major carriers have invested nearly $3 billion to acquire broadband wireless spectrum.

WinStar and Teligent have been the most active providers of broadband service to date, with several major players, including WorldCom, Sprint, Advanced Radio Telecom (ART), and NEXTLINK, slated to roll out services nationwide during the coming quarters. Several events have brought significant attention to the broadband wireless arena—with nearly $3 billion of new investment by major communications firms.

- In early 1999, NEXTLINK Communications became the largest holder of LMDS with its $695 acquisition of WNP Communications and its acquisition of the remaining 50% in NEXTBAND Communications. NEXTLINK is now deploying its LMDS network in major markets across the country.
- In several transactions starting in March 1999, Sprint and WorldCom each committed more than $1 billion to acquire several MMDS license holders. Trials of high-speed, two-way data services are under way, with broad-scale commercialization expected later this year and during 2001.
- In June 1999 Qwest communications and a group of private capital firms made a $251 million strategic investment in Advanced Radio Telecom. In April 2000, ART enhanced its spectrum position by purchasing 39-GHz licenses spectrum from two private firms.
- In May 2000, the FCC concluded its $400 million auction of 39-GHz licenses, with significant participation by WinStar, Advanced Radio Telecom, Adelphia Business Solutions, AT&T, and NEXTLINK.
- In May 2000, AT&T Wireless made its PCS-based fixed wireless service widely available in the Ft. Worth market. Users can subscribe to a bundle of voice and high-speed data offerings.

While the major broadband wireless players employ different frequencies and technologies, the services each plans to offer will be aimed at high-speed, last-mile access, coupled with various additional offerings. As the capabilities and capital expenditures associated with wireless technology are affected by available spectrum, it is useful to compare the respective holdings of the major broadband wireless firms.

Exhibit 6-2 ◆ Broadband Wireless Capacity Comparison



Source: FCC, Company reports, and Dain Rauscher Wessels estimates

Because signals propagate differently in the various bands, these capacity comparisons are only approximate. For instance, MMDS signals, which occupy spectrum that is only a modest amount higher than the 1.9 GHz frequency used by PCS operators, travel a much greater distance and are less affected by rain fade than higher-frequency services
Like other competitive providers, a major focus of broadband wireless operators is small and medium-sized businesses, which historically have not received customized offerings from incumbent carriers. This market provides enough density to justify network deployment costs while avoiding dense urban areas that are already served by high-capacity fiber networks.

Despite the capabilities of the technology, the most common services offering to broadband wireless customers in its initial deployment stages were conventional voice telephony. However, in view of the expanding data connectivity and Internet-related needs of small and medium-sized businesses, data-related revenues are the fastest growing portion of broadband wireless revenues. This trend toward data applications should be accelerated as the MMDS-based broadband offerings of Sprint and WorldCom go beyond the trial phase to full commercialization.

◆ Broadband Wireless Technology Overview

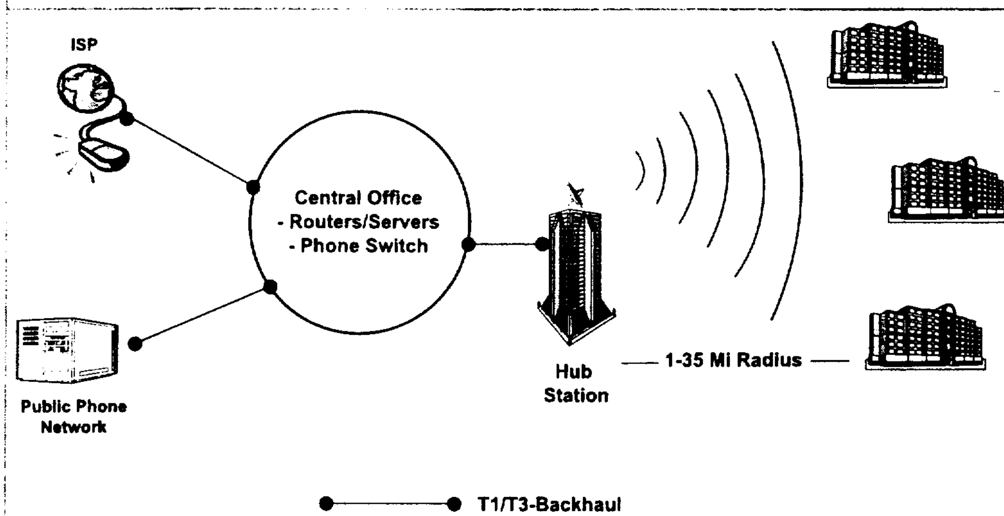
In general, broadband wireless networks are cellular in nature, employing two-way antennas (transceivers) at a hub site and at a customer's premise. Hub sites are typically connected by fiber, wireless, or other high-capacity backhaul links to a central node that contains routers (for data connectivity), switches (for interconnection with the public switched telephone network if the operator provides voice service), and servers (for content storage and delivery).

Hubs are placed between one and three miles apart for high-frequency systems such as LMDS, 24 GHz, and 39 GHz; and as much as 30 miles apart for lower frequency systems such as MMDS and the unlicensed bands. Since high-frequency signals travel a shorter distance than low-frequency signals, the hub radius is largely determined by the spectrum band at which the system operates. Frequency is thus a significant determinant of system build-out costs. Also, as spectrum is re-used from cell to cell, carriers with relatively less spectrum per market may use a smaller hub radius to increase the total capacity of its network.

Broadband wireless capital expenditures are largely success-based.

In a typical broadband wireless network, after a limited number of cells are constructed, service areas can be extended almost immediately once an order is placed, allowing operators to delay full capital costs. In a wired network, by contrast, the core infrastructure must be built out to reach all targeted customers before a network can be commercialized.

Exhibit 6-3 ◆ Representative Broadband Wireless Network Architecture



Source: Dain Rauscher Wessels

Because broadband wireless requires a line-of-sight between transceivers, a given cell may only reach 55%-60% of the buildings within its radius (depending on specific markets and topological obstructions). To address this limitation, hubs or repeaters with overlapping coverage areas can be deployed to expand effective coverage to approximately 70%-85% of buildings. Using repeaters to alleviate line of site restrictions is becoming a cost effective alternative to deploying new base stations (a repeater costs on the order of $10,000, while a new base station can cost on the order of $250,000). Apart from physical obstacles such as buildings and trees, rainfall has the most significant impact on broadband wireless performance.

As with other technologies, broadband wireless systems use special adapters installed at the customer site to integrate the last-mile transmissions with existing customer equipment (such as routers, PBXs, and integrated access devices).

Microwave Vs. Millimeter Wave

Broadband wireless services can be classified into two groups: microwave, which refers to all spectrum below the 15 GHz range; and millimeter wave, which refers to all spectrum above the 15 GHz range.

Microwave: Spectrum allocated in the microwave band for broadband applications consists largely of MMDS and various unlicensed bands (such as 2.4 GHz and 5 GHz). As noted, these bands have superior propagation characteristics, with signals reaching as far as 30 miles. Further, the line of sight issue does not affect these bands to as large an extent as it affects the higher-frequency bands. However, these bands contain significantly smaller amounts of spectrum (80 MHz to 200 MHz) than the higher-frequency bands, thereby limiting the available bandwidth per cell. These microwave bands still qualify as a robust broadband delivery platform, and firms using microwave technology have successfully demonstrated broadband services over their networks, with throughputs ranging from fractional T1 speeds up to multiple T1s. By comparison, cellular and PCS carriers, which also operate in the microwave band, typically have no more than 25-40 MHz of spectrum, largely limiting their capability to basic voice or specialized narrowband services.

Exhibit 6-4 ◆ Representative Unit Economic Analysis for Microwave-Based Deployment

Assumptions:	
Homes/buildings per base hub	10,000
Customers per home or building	1
Fixed costs	
Base station/hub cost (one-time)	$30,000
Semi-fixed costs	
Installation cost/incremental capex (per sub or building)	$400
Customer acquisition cost (one-time)	400
Customer premise equipment (one-time)	600
Gross semi-fixed costs (subscriber acquisition cost)	**$1,400**
Revenue from customer premise equipment (one-time)	(300)
Revenue from installation fee (one-time)	(100)
Net semi-fixed costs (subscriber acquisition costs)	**$1,000**
Variable costs	
Backhaul (monthly)	$1,700
Heating, lighting and power cost per colo (monthly)	$450
Total variable costs per sector (monthly)	**$2,150**
Recurring monthly revenue per customer	**$100**
Customer revenue margin	**$99**
Breakeven (customers)	**429.9** *
Breakeven (penetration)	**4.3%** *

* capital expenditures amortized over 36 months

Source: Dain Rauscher Wessels

Millimeter Wave: As discussed previously, there are three bands currently used commercially in the millimeter wave band—24 GHz, 28 GHz (LMDS), and 39 GHz, with Teligent, NEXTLINK, and WinStar as the respective "anchor tenants" at each frequency. Each of these bands is subject to far greater propagation limitations than microwave (three miles compared to 30 miles) and is highly influenced by physical objects such as buildings, trees, and even rain drops. Nevertheless, as the signals in this band travel more directly, individual transmissions are less likely to interfere with each other, and therefore frequency re-use can achieve significant increases in capacity, providing transmission speeds of up to OC-3 (155 Mbps) with carrier-grade reliability. This implies the use of millimeter wave frequencies as viable competitors to fiber in certain applications.

Exhibit 6-5 ◆ Representative Unit Economic Analysis for Millimeter-Wave System (Point-to-Multipoint)

Assumptions	
Buildings per hub	30
Prospects per building	30
Data penetration (as percentage of core voice customers)	30%
Fixed costs	
Hub Cost:	$398,600
Semi-fixed costs	
Receiver radio cost per building	$5,000
Installation cost per building	18,500
Customer acquisition cost (one-time)	800
Customer premise equipment (one-time)	600
Gross semi-fixed costs (subscriber acquisition cost)	**$24,900**
Revenue from installation fee (one-time)	(400)
Net semi-fixed costs (subscriber acquisition cost)	**$24,500**
Variable costs	
Backhaul (monthly)	$400
Roof Right Cost (monthly)	2,000
Heating, lighting and power cost per colo (monthly)	500
Total variable costs	**$2,900**
Total variable costs per customer	**$21**
Revenues:	
Recurring monthly voice revenue per customer	$70
Recurring monthly data revenue per data customer	500
Recurring monthly revenue per building	990
Recurring monthly revenue per customer (weighted average)	220
Customer revenue margin	**$199**
Breakeven (customers)	**71.2** *
Breakeven (penetration)	**7.9%** *

* assumes capital expenditures amortized over 36 months.

Source: Dain Rauscher Wessels

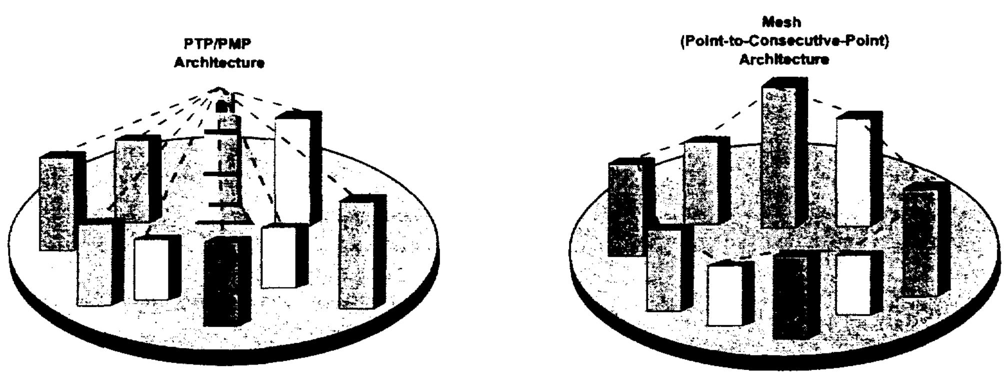
Broadband Wireless Architectures: Point-to-Point, Point-to-Multipoint, and Mesh

The following three primary system architectures are currently in use for millimeter-wave systems: point-to-point, point-to-multipoint, and mesh. Each architecture entails tradeoffs between bandwidth capacity and capital efficiency.

To date, the majority of broadband wireless systems have used point-to-point (PTP) technology. PTP systems require two transceivers for each connection—one at the hub and one at the customer site. Newer point-to-multi-point (PMP) technology enables a single hub radio to communicate with multiple customers, thereby reducing capital requirements. In practical terms, a PTP system serving 50 customers would require 100 transceivers, while an equivalent PMP system would require only 51 transceivers.

The mesh architecture works around the line of sight issue as each building radio performs most of the functions of a hub radio to form a virtual ring connecting multiple buildings. This architecture is handicapped in terms of scalability since it increases the cost of each customer radio. Mesh-based systems are initially oriented towards higher-bandwidth applications.

Exhibit 6-6 ◆ PTP/PMP vs. Mesh Architecture

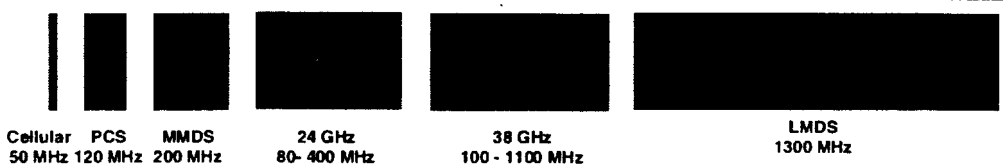


Source: Dain Rauscher Wessels

◆ Spectrum-Specific Considerations

Each of the four licensed bands considered in this report is subject to its own licensing rules. In general, each of the four bands is now authorized for the provision of any voice, data, or video service. The amount of spectrum licensed for each band varies dramatically. LMDS carriers have significantly more spectrum (typically 150-1,300 MHz) than any other frequency band, and MMDS carriers typically have the least (approximately 120-200 MHz). WinStar, which operates in the 39 GHz band, has obtained through acquisition an average of 1,000 MHz per market, while other 39 GHz carriers, such as ART and AT&T, have approximately 100-400 MHz per market. Teligent, the only operator at 24 GHz, holds approximately 80-400 MHz per market. As mentioned earlier, cellular and PCS carriers typically have no more than 25-40 MHz of spectrum per market, limiting their throughput potential.

Exhibit 6-7 ◆ Comparison of Available Spectrum per Market



Source: FCC

MMDS Spectrum

Initially licensed for one-way video services, the FCC authorized MMDS to provide two-way communications services in 1998. There are several wireless spectrum blocks in the 2.1 to 2.7 GHz band that can be used for cable television and Internet services, including multi-point distribution service (MDS), multi-channel multi-point distribution service (MMDS), and instructional television fixed service (ITFS). Many MMDS operators have aggregated available MDS, MMDS, and ITFS spectrum in a given market, providing up to 200 MHz of bandwidth.

Exhibit 6-8 ◆ MMDS Spectrum in the 2.1-2.7 GHz Band

Frequency Range	Service Type	Number of Channels	Channel Width
2.15-2.162	MDS	2	6 MHz
2.305-2.32	WCS	2	5 & 10 MHz
2.345-2.36	WCS	2	5 & 10 MHz
2.5-2.596	ITFS	16	6 MHz
2.596-2.644	MMDS	8	6 MHz
2.644-2.686	ITFS	4	6 MHz
2.686-2.689	MMDS	31	125 KHz

Source: FCC

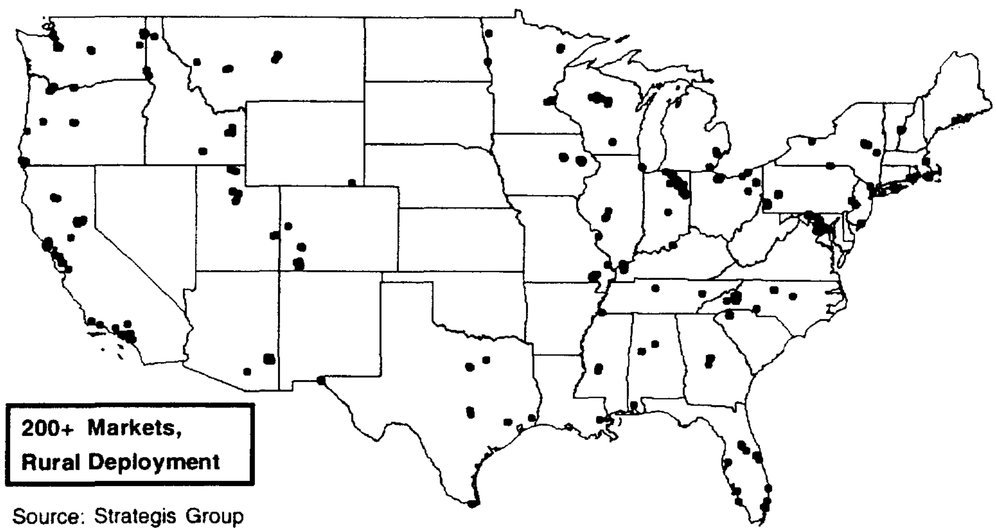
Due to its long signal reach, MMDS may well be deployed in areas that are not reachable via DSL or cable-based approaches. We expect the primary growth in MMDS-based services to be in the delivery of high-speed Internet services at DSL-like speeds of 384 kbps to 1.5 Mbps. Despite its long reach compared with other frequencies, MMDS spectrum comes with certain challenges, including an obligation to coordinate with educational facilities in the case of the ITFS band.

Following a series of acquisitions in 1999, Sprint and Worldcom have emerged as the largest MMDS spectrum holders. Each carrier has numerous pilot markets deployed and intends to roll out two-way MMDS-based services on a broad commercial scale later this year and during 2001. WorldCom, with MMDS spectrum covering some 58 million households, is holding commercial trials in Memphis, Jackson, and Baton Rouge, while Sprint, which is expected to tap into the tower assets of the Sprint PCS group, is testing MMDS in Phoenix, Arizona, Detroit, Michigan, and the San Francisco Bay Area in California. BellSouth and Nucentrix are also significant MMDS spectrum holders.

Unlicensed Bands: 2.4 GHz and 5 GHz

Service providers have the option of using unlicensed frequency to provide voice and data services to end users. The two primary unlicensed bands used for last-mile broadband applications are the 2.4 GHz ISM (industrial, scientific, and medical) band, which contains about 80 MHz of spectrum, and the 5 GHz U-NII (unlicensed national information infrastructure) band, which contains about 200 MHz of spectrum suitable for last-mile services. There are more than 200 current deployments of unlicensed spectrum for last-mile services, primarily by regional ISPs.

Exhibit 6-9 ◆ Unlicensed Spectrum



Source: Strategis Group

The benefits of using unlicensed frequency are immediate availability and "free" frequency, which reduces service provider costs. Potential drawbacks include the possibility of interference with other users in the same frequency band, although this has yet to become a serious issue. As with MMDS, the long signal propagation of fixed wireless systems that utilize the unlicensed spectrum bands make them suitable for delivering services to customers that are beyond the reach of DSL or cable-based services. Alternatively, unlicensed spectrum may be used as an interim solution prior to installation of landline facilities, or as backup capacity.

2.4 GHz

The 2.4 GHz band has been used for several years for last-mile applications. Equipment operating in this band must operate in spread-spectrum mode in order to minimize interference with other devices. Privately held Clearwire Technologies, which operates commercial data services in Dallas, Texas, Buffalo, New York, and Albuquerque, New Mexico, is one of several providers using this band. In addition, Bell Atlantic has announced that it intends to use this band, in conjunction with its WCS spectrum holdings at 2.3 GHz, to provide high-speed services to locations that are not readily accessible using DSL technology. 2.4 GHz services can be used for high-speed (fractional T1 to T1 or even greater, depending on the technology) applications and reach customers 15-20 miles or more from a given hub site. Some deployments we have seen of this technology indicate that the signals are able to propagate through windows—this suggests potentially quicker and less complicated deployment of customer-premise equipment compared to placing devices on rooftops or on the sides of buildings, which requires access to in-building wiring.

5 GHz
Use of the U-NII band, although unlicensed and free of charge, is restricted in the sense that equipment operating in this frequency range is limited in the power it can transmit. This confines the effective range to roughly three miles, but because of the limited cell size, enables throughputs on the order of multiple T1s. Operators using this band include Fuzion Wireless Communications.

24 GHz Band (DEMS)
The only commercial provider currently holding spectrum in the 24-GHz band is Teligent, which holds between 80 and 400 MHz in tier 1 and tier 2 markets. Like other broadband wireless carriers, Teligent is authorized to use its spectrum for any commercial or private use. These licenses, categorized by the FCC as Digital Electronic Messaging Service, were obtained free of charge without auction. Teligent originally held similar licenses in the 18-GHz band, but the FCC, to protect certain government satellite communications services, transferred these to the 24-GHz band. As part of the order that moved the licenses from 18 GHz to 24 GHz, Teligent was granted additional spectrum (100-400 MHz) in several markets.

LMDS—28 GHz
With a total of 1,300 MHz of spectrum in any given market, the LMDS bands contain more spectrum than any other single commercial wireless service. Two licenses in each of 493 "basic trading areas" were auctioned by the FCC in 1998. The LMDS A license, 1,150 MHz, consists of the following two parts: 850 MHz in the 28 GHz band, and 300 MHz in the 31 GHz band. The B license, 150 MHz in the 29 GHz band, is provided on a shared basis to accommodate both LMDS providers and certain satellite service providers.

Exhibit 6-10 ◆ Major LMDS Licensees

Carrier	A Pops	B Pops	Total Paid	Price Per Pop	Price Per GHZ-Pop
1 NEXTLINK	116,899,138	84,473,332	$900,053,588	$4.47	$6.12
2 Adelphia Bus.	2,585,945	88,229,857	$46,602,533	$0.51	$2.88
3 WinStar	14,673,277	2,165,646	$43,372,050	$2.58	$2.52
4 Eclipse	2,514,596	8,950,977	$14,330,559	$1.25	$3.38
5 Actel	7,797,465	2,820,780	$9,728,690	$0.92	$1.04
6 Cortelyou	10,573,982	-	$25,241,133	$2.39	$2.08
7 ARNet	5,971,882	3,122,799	$11,566,685	$1.27	$1.58
8 Telecorp	852,056	7,303,200	$3,824,700	$0.47	$1.84
9 CoServ	-	7,519,988	$10,293,750	$1.37	$9.13
10 Vanguard	7,121,234	-	$8,884,527	$1.25	$1.08
11 ALTA	6,846,284	-	$15,152,500	$2.21	$1.92
12 U S WEST	[illegible]	6,846,072	$9,923,000	$1.45	$9.66
13 HighSpeed	3,988,067	2,001,209	$3,982,424	$0.66	$0.81
14 Blackwater	[illegible]	[illegible]	$3,114,260	$0.68	$0.59
15 Touch America	2,138,153	2,219,741	$7,021,055	$1.61	$2.51
16 BTA Assoc	[illegible]	675,483	$16,996,500	$4.84	$4.80
17 PCTV Gold	107,714	2,404,760	$3,221,400	$1.28	$6.65
18 LMDS Ltd	2,284,569	[illegible]	$1,651,650	$0.72	$0.63
19 Command Connect	1,835,008	324,397	$1,958,670	$0.91	$0.91
20 ABS LMDS Ventura	291,811	1,606,729	$772,750	$0.41	$1.34

Source: FCC and Company reports

The major carriers planning to deploy LMDS-based systems include a number of fiber competitors such as NEXTLINK Communications, Adelphia Business Solutions, and Touch America, as well as Highspeed.com and several independent telephone companies.

39 GHz Band

Licensing for the 39 GHz band was historically administered on a site-by-site basis, rather than the geographic basis (BTAs) followed for the LMDS spectrum allocation. However, the FCC has allowed license holders to aggregate site licenses into regional block licenses. Further, the FCC slated BTAs as the licensing designation for the recently concluded auctions of additional 39 GHz licenses. During these auctions, WinStar, Advanced Radio Telecom, and other carriers enhanced their spectrum assets in existing markets, with relatively little bidding by new entrants.

WinStar, Advanced Radio Telecom, and other 39 GHz licensees have aggregated multiple licenses in markets to gain as much as 1,200 MHz per market. The FCC has ordered that there are no restrictions on the aggregation of 39 GHz licenses. Many of the 39 GHz licenses that were granted prior to this year's auction are slated for expiration during 2001. However, it has been the FCC's practice to renew licenses when the current holder is shown to be providing "substantive service." In the past, substantive service has come to mean a mere four hub sites operational for a given one million in population.

Non-RF Wireless Approaches: Free Space Lasers

Free space laser technology uses invisible light, rather than radio frequencies, and can transmit fiber-like (1 Gbps or greater) capacities over distances of one to two miles, subject to stringent line of sight restrictions. Similar to RF-based wireless approaches, this technology offers the potential for the highly cost effective deployment of high-capacity links without relying on incumbent or other wireline infrastructure over the last mile. However, like unlicensed spectrum, it avoids licensing procedures and even has the potential to penetrate windows, thereby alleviating potential deployment headaches associated with building access rights. We believe this technology is still in its relative infancy and probably will not see commercialization for some time. Once commercialization nears, however, we see no reason why established competitors, including most likely broadband wireless operators, would not be able to leverage free space laser technology for existing and new uses.

◆ Broadband Wireless Regulation

Broadband wireless competitors are regulated in the same manner as other carriers. Any prospective entrant with the appropriate wireless license may offer a full range of voice and data communications and is entitled to the same rights as other competitors under the 1996 Telecommunications Act, such as interconnection, collocation, number portability, and access to unbundled network elements. To the extent that competitors use their own wireless links to connect customers, they are unaffected by problems typically associated with access to ILEC copper loops. Further, broadband wireless carriers offering exclusively data/Internet services over their own facilities are entirely free from the need to establish interconnection agreements with the incumbent carrier.

Access to rooftops is a point of contention between wireless operators and building owners.

Rooftop Rights

Most wireless operators must obtain access to building rooftops as well as inside wiring and phone closets in order to deploy their networks. While access to building wiring and telephone closets does not present any issues that are unique to wireless carriers (see chapter on Building-Centric Service providers), building owners are not subject to any law requiring them to allow wireless providers access to their rooftops. This has led to several disputes between commercial building owners and wireless operators concerning licensing, antenna siting, and rights of way. Although the FCC has ruled in favor of non-discriminatory access to buildings in order to promote competition, commercial building owners have asserted their rights as private property owners and resisted legal attempts to force access to their facilities. The FCC is currently conducting proceedings on competitive access to buildings. In practice, wireless operators usually gain rooftop and building access through direct, private negotiations with building owners at the local level, and we expect this to continue regardless of how the issue gets settled in Washington.

Future Auctions and Spectrum Allocations

Standing FCC spectrum policies make it likely that the agency will continue to seek out for public comment and propose rules for the allocation of additional spectrum for broadband and narrowband applications. Three areas of particular interest to broadband investors in the near and medium terms are the 700 MHz auctions, the 4.9 GHz auctions, and the allocation of spectrum for so-called "3G" (third-generation) mobility services.

4.9 GHz: The FCC recently proposed rules for spectrum auctions in the 4940-4990 MHz (4.9 GHz) band, which is intended for fixed and mobile services. This band was approved for transfer from government to private use, but auction plans in 1998 were abandoned due to concerns over interference with U.S. Navy systems. The commission is currently evaluating proposals on the geographic and spectrum blocks that should be used in licensing this band.

700 MHz: The FCC recently adopted auction and service rules governing spectrum that currently occupies channels 60-69 of the television UHF band. This spectrum is slated to be vacated by broadcasters by 2006 as they roll out digital television services, but the FCC may allow new licensees to offer payments to the broadcasters to speed the relocation of their stations. The 30 MHz of spectrum between 747-762 MHz and 777-792 MHz is to be split into the following 12 licenses nationwide: one 20-MHz license and one 10-MHz license, each to be auctioned across six regions nationwide. Another 6-MHz of spectrum, known as the 700-MHz "guard band," is slated to be auctioned in 4-MHz and 2-MHz blocks across 52 regions nationwide. Parties that obtain rights to the guard-band spectrum (so-called "guard band managers") will be able to lease the spectrum to third parties. Auctions are currently scheduled for September 2000.

3G Spectrum: Although spectrum has been allocated for "third generation" (3G) broadband mobility services in several international markets, the FCC has not formally set aside a band dedicated to 3G The United States is advocating a flexible approach on this issue, with the following three possible bands proposed thus far: the 1.7 GHz band, portions of which are currently used by the military; the 2.5 GHz band, partially occupied by MMDS operators; and the 690 MHz band. We do not expect 3G spectrum allocation issues in the United States to be resolved for some time.

◆ Satellite-Based Services

No discussion of broadband wireless is complete without mention of satellite-based services. While traditional satellite networks have been limited to video or narrowband services (at least as a local-loop bypass), several newly proposed broadband satellite systems may have the potential for wider commercial applications. Although many of these services will be more oriented toward developing markets with less developed terrestrial alternatives, some may gain traction in the United States in regions that are underserved by fiber, cable, DSL, or fixed wireless services. In addition, as exhibited by the initial market acceptance of such firms as iBeam Broadcasting and Cidera, satellite-based services are gaining ground as a delivery mechanism for Internet content.

A major force behind the proposed satellite systems is Internet access (carrier-grade telephony services are not as well suited to the latency and complexity associated with sending signals to, from, and possibly between satellites). Two of the more likely near-term satellite-based entrants for two-way broadband services are iSky and Gilat-To-Home, which leverage existing relationships with DBS-based video networks DirectTV and Echostar. AOL's announced $1.5 billion investment in Hughes (the backer of DirecTV and DirecPC) in 1999, coupled with EchoStar's investments of $50 million in both iSky and Gilat-To-Home and Microsoft's investment of $50 million in Gilat-To-Home, have brought visibility to the prospect of consumer access to Internet at high speeds, without the need for terrestrial connections.

The **Exhibit 6-11** describes several proposed two-way broadband satellite projects. While we do not purport to provide a detailed description of satellite technology, the following key points should be kept in mind:

- LEO (low-earth orbit) systems have many potential advantages, including lower orbital altitude (and therefore less latency).
- The complexity and investment required for the LEO projects make them medium to longer term possibilities.
- GEO (geostationary earth orbit) systems employ less costly equipment and fewer satellites and are the basis for many of today's commercial one-way applications.
- With respect to spectrum usage, Ku-band architectures are generally more bandwidth constrained than Ka-band.

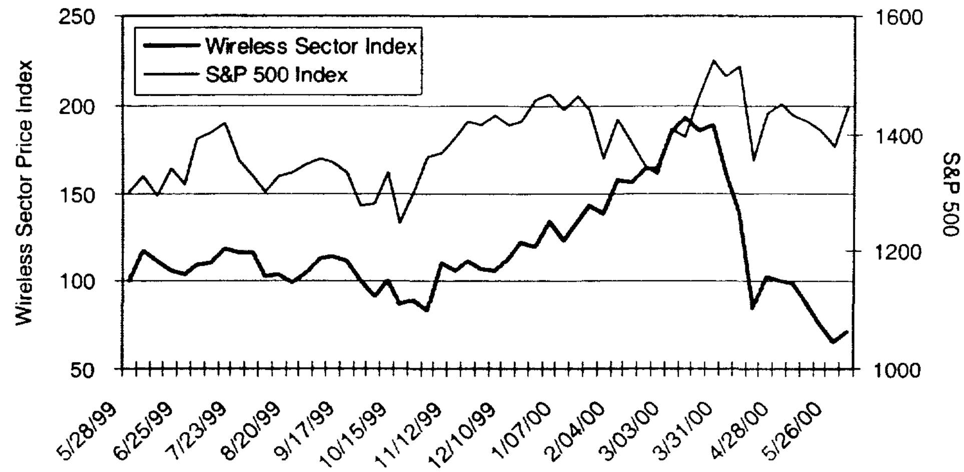
Exhibit 6-11 ◆ Proposed Broadband Satellite Systems

System	Operator	Number of Satellites	Estimated Service Date	Frequency	Cost	Orbit	Coverage
Gilat-To-Home	Gilat-To-Home	uses existing capacity	2001	Ku	N/A	GEO	Regional
Skybridge	Alcatel	80	2002	Ku	$6.1 billion	LEO	Global
GE*Star	GE Americom	9	after 2002	Ka	$4 billion	GEO	Global
Spaceway	Hughes	8	2002	Ka	$5.1 billion	GEO	Global
iSky	iSky	2	2001	Ka	$750 million	GEO	Regional
Astrolink	Lockheed Martin	9	2003	Ka	$3.6 billion	GEO	Global
Cyberstar	Loral	3	2003	Ka	$1.6 billion	GEO	Regional
Teledesic	Teledesic	288	2003/4	Ka	$10 billion	LEO	Global

Source: Company reports, Pioneer Consulting, and Dain Rauscher Wessels

As with competing broadband services, the success of these projects will come down in large part to achieving competitive price points for customer premise equipment and monthly subscriptions. That said, it remains an open question as to how many broadband subscribers these services can accommodate simultaneously given the shared, not dedicated, nature of their spectrum resources and limits on transponder capacity. Therefore, we believe pricing and customer expectation setting will be critical success factors.

Exhibit 6-12 ◆ Broadband Wireless Sector Price Index vs. S&P 500



Source: Company reports, Pioneer Consulting, and Dain Rauscher Wessels

Exhibit 6-13 ◆ Publicly Traded Broadband Wireless Competitors

(Amounts in millions, except per share figures)

(Amounts in millions, except per share figures)

			Stock Price Information										Revenue			
			Price	52 Week Range		FD Shares	Market	Long Term	Preferred		Enterprise				Enterprise Value / Rev.	
Company	Symbol	FYE	06/01/00	High	Low	Out.	Cap.	Debt	Stock	Cash	Value	CY 99	CY 00E	CY 01E	CY 00E	CY 01E
Advanced Radio Telecom Corp.	ARTT	Dec	$10.38	$49.25	$7.50	29.18	$303	$109	$244	$193	$462	$1	$2	$16	288.7 x	29.8 x
Nucentrix Broadband Networks, Inc.	NCNX	Dec	22.50	36.00	18.63	10.15	228	15	0	29	214	70	NA	NA	NM	NM
Teligent, Inc.	TGNT	Dec	21.25	100.00	18.38	59.38	1,262	809	479	595	1,954	31	159	391	12.3 x	5.0 x
WinStar Communications, Inc.	WCII	Dec	30.25	66.50	24.00	89.28	2,701	2,324	431	246	5,210	356	703	1,008	7.4 x	5.2 x

Source: FactSet

Section 6: Broadband Wireless Services

Broadband Services Companies	Hyperlink	Description	Address	[illegible]	Ticker
Advanced Radio Telecom	www.artelecom.com	Advanced Radio Telecom is a broadband wireless provider of high-speed, IP-based services. The company's customers include Internet service providers, long-distance carriers, building-centric service providers, hosting companies, and applications service providers. ART plans to deploy its 100 Mbps metro-area networks in 40 markets over the next several years.	500 108th Avenue, NE Bellevue, WA 98004	Qwest Communications, Oak Capital Partners, Columbia Capital, Meritech, Adams Capital Management, Advent International, Accel Partners, Brentwood Venture Partners, Worldview Technology Partners, Bessemer Venture Partners	ARTT
iBeam	www.ibeam.com	iBEAM provides an Internet broadcast network that delivers streaming media directly to ISP points of presence using satellite technology. The company's customers include media, technology and entertainment companies.	645 Almanor Avenue Sunnyvale, CA 94086	Sony Corporation, Microsoft Corporation, Intel Corporation, Covad Communications, Standford University, Liberty Media, Media Technology Ventures, Accel Partners, Crosspoint Venture Partners	IBEM
Nucentrix Broadband Networks	www.nucentrix.com	Nucentrix is a broadband wireless provider with MMDS spectrum in over 90 tier 2 and tier 3 markets in the Southwest and Midwest. The company currently provides multi-channel video services in 58 of these markets and plans to launch two-way, high-speed data services in 20 markets by 2001. The company is partnering with Cisco for its MMDS network deployment.	200 Chisholm Place Plano, TX 75075		NCNX
Teligent	www.teligent.com	Teligent provides local, long-distance, high-speed data, Internet access, and hosting services to small and medium-sized business over its broadband wireless network as well as landline facilities. The company has deployed its network in all major U.S. markets and is pursuing joint venture opportunities in numerous international markets.	8065 Leesburg Pike Vienna, VA 22182	Microsoft, Hicks Muse Tate & Furst, DB Capital Partners, Olympus Partners.	TGNT
WinStar Communications	www.winstar.com	WinStar provides telecommunications services directly to business customers in more than 35 major U.S. markets and several international markets. The company provides several services over its broadband wireless and leased network facilities, including local and long distance voice services, high-speed data transport, Internet access, Web hosting, and a growing set of Internet content-related services.	230 Park Avenue New York, NY 10169	Microsoft, CS First Boston, Welsh Carson Anderson & Stowe, Cascade Investments, Lucent, Williams, Metromedia Fiber Network, Hicks Muse Tate & Furst	WCII
BroadlLink Communications	www.broadlink.com	BroadLink Communications provides wholesale, broadband access to ISP and CLEC customers using unlicensed-band spectrum. The company is operational in Northern California and is planning to expand to additional markets during the coming quarters. BroadLink partners with other carriers for transport services and with major collocation providers to interconnect with other carriers.	1300 N. Dutton Ave. Santa Rosa, CA 95401-4610	numerous private sponsors	private
Cidera	www.cidera.com	Cidera is building and operating a global satellite broadcast overlay network that delivers Internet, audio/video, and streaming media content to the edge of the Internet. Cidera serves several hundred POPs in North America and Europe, and plans to open service in Latin America and Asia by the end of 2000.	8037 Laurel Lakes Ct. Laurel, MD 20707	Carlyle Venture Partners, Intel, Institutional Venture Partners, New Enterprise Associates	private
Clearwire Technologies	www.clearwire.com	Clearwire Technologies is a developer and manufacturer of fixed wireless local access products as well as a provider of broadband wireless connectivity using unlicensed-band spectrum. The company's services arm provides high-speed, IP connectivity to carrier customers as well as business end users. Clearwire typically partners with local ISPs to enable them to provide high-speed access to their customers. The company's services have been commercially launched in three markets, with expansions planned to additional markets.	2000 East Lamar Arlington, Texas 76006	numerous private sponsors	private

Section 6: Broadband Wireless Services

Broadband Services Companies	Hyperlink	Description	Address	Financial & Strategic Partners	Ticker
Fuzion Wireless Communications	www.gofuzion.com	Founded in early 1999, Fuzion offers an array of Internet and data connectivity services using unlicensed 5-GHz spectrum.	5255 North Federal Hwy. Boca Raton, Florida 33487	numerous private sponsors	private
HighSpeed.com	www.highspeed.com	HighSpeed.Com is a CLEC and LMDS licensee in five Western states. The company provides an array of Internet access and data connectivity services.	1520 Kelly Place Walla Walla, WA 99362		private
iSky	www.isky.netflash.htm	iSKY intends to deliver affordable high-speed Internet access services via satellite to homes and small offices in North America and Latin America during 2001. The company is targeting users that are under-served by terrestrial broadband	9137 East Mineral Circle Englewood, CO 80112	Kleiner Perkins Caufield & Byers, TV Guide, Liberty Media	private
LMA Systems	www.lmasys.com	LMA Systems is a provider of broadband wireless services. The company has deployed high-speed data services primarily in the MMDS band, and is targeting tier 3 and tier 4 markets along the East Coast.	14 Commerce Street Flemington, NJ 08822		private
Netbeam, Inc.	www.netbeam.net	Netbeam provides high-speed network access for businesses and individuals in small population centers and rural markets using unlicensed-band spectrum. The company typically partners with local ISPs to enable them to provide high-speed access to end users.	325 South Main Street Breckenridge, CO 80424	numerous private sponsors	private
SPEEDUS.COM	www.speedus.com	SPEEDUS.COM is a facilities-based broadband wireless carrier. The company also provides standard direct dial-up and ISDN service, as well as web hosting and e-mail.	140 58th Street Brooklyn, NY 11220		private
TeraBeam Networks	www.terabeam.com	Founded in 1997, TeraBeam Networks is developing a high-bandwidth service based on free-space-laser technology. The company is trialing its technology in several markets and plans to launch commercial service during 2000-2002.	2300 Seveth Avenue Seattle, WA 98121	Softbank Venture Partners, Oakhill Venture Partners, Madrona Investments, Morgan Stanley, Merrill Lynch, Fidelity Management and Research, T. Rowe Price, Capital Research and Management Co., and five other major telecommunications strategic partners	private

Section 7:
Cable Modem-Based Internet Access