This chapter covers the following topics:

- Digital Subscriber Line
- Cable Access Technologies

CHAPTER 7

DSL and Cable Modem Networks

DSL and cable modem network access are two alternative ways to connect to a network service provider without the use of more expensive dedicated service, such as Frac-T1/T1. DSL and cable modem networks achieve the same result of providing dedicated access to a network service, often the Internet, but each do so using differing technologies. This chapter discusses what DSL and cable modem technologies do and how they do it.

Digital Subscriber Line

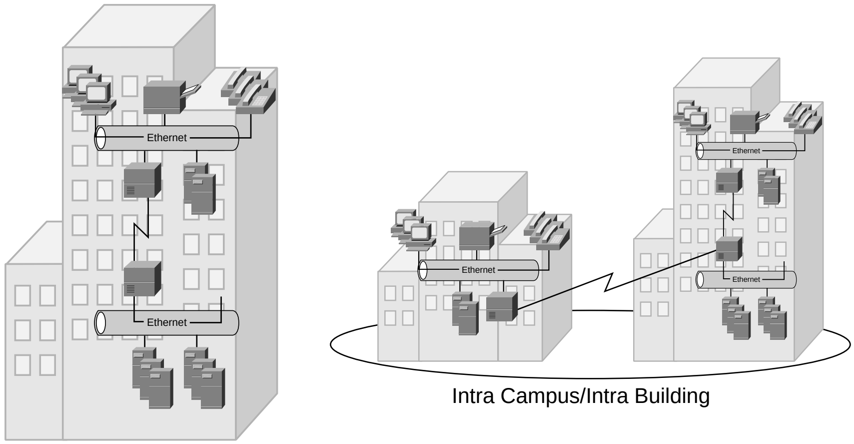
Digital subscriber line (DSL) technology is a modem technology using existing twisted-pair telephone lines to carry high-bandwidth applications, such as multimedia and video. The term *xDSL* covers a number of DSL technologies, such as Asymmetrical Digital Subscriber Line (ADSL), Symmetrical Digital Subscriber Line (SDSL), Hi-Speed Digital Subscriber Line (HDSL), HDSL-2 (HDSLv2), ITU DSL standard (G.SHDSL), ISDN Digital Subscriber Line (IDSL), and Very-High-Data-Rate Digital Subscriber Line (VDSL).

xDSL services are dedicated point-to-point network access over twisted-pair copper wire on the local loop (last mile) between a network service provider's (NSP) central office (CO) and the customer site. xDSL also can be deployed in intra-building and intra-campus environments, as illustrated in Figure 7-1.

xDSL offers two chief benefits over dial-up service:

- Dial-up service is limited to 53.3 Kbps, whereas xDSL service can enable up to 6.122 Mbps.
- Dial-up service is initiated "on-demand" by the end-user, but xDSL service is a dedicated connection, meaning that it is "always on."

Figure 7-1 *Intra-Building and Intra-Campus/Inter-Building*

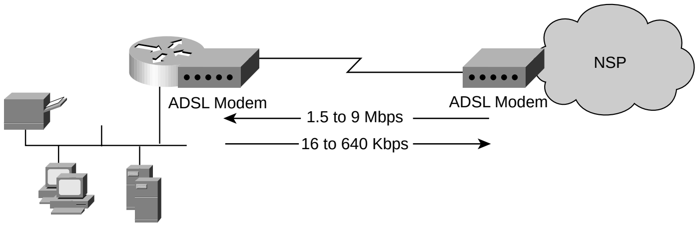


The following sections discuss ADSL. ADSL is often deployed in the small office/home office (SOHO) environment and is the traditional DSL service for residential deployment. The asymmetry is ideal in these environments because the majority of upstream bandwidth is consumed by Internet requests; for example, users navigating through web sites. These upstream requests are small compared to the downstream response, such as the web site fulfilling the user's request.

ADSL

ADSL technology makes more bandwidth available downstream, from a NSP central office (CO) to the customer site, than it makes available upstream, from the customer site to the CO. Figure 7-2 illustrates an example of an ADSL connection.

Figure 7-2 *ADSL Connection*



The asymmetry of ADSL, combined with always-on access (which eliminates call setup), makes ADSL another solution for Internet/intranet surfing, video-on-demand, and remote LAN access because users of these applications often download more data than they upload.

ADSL Architecture

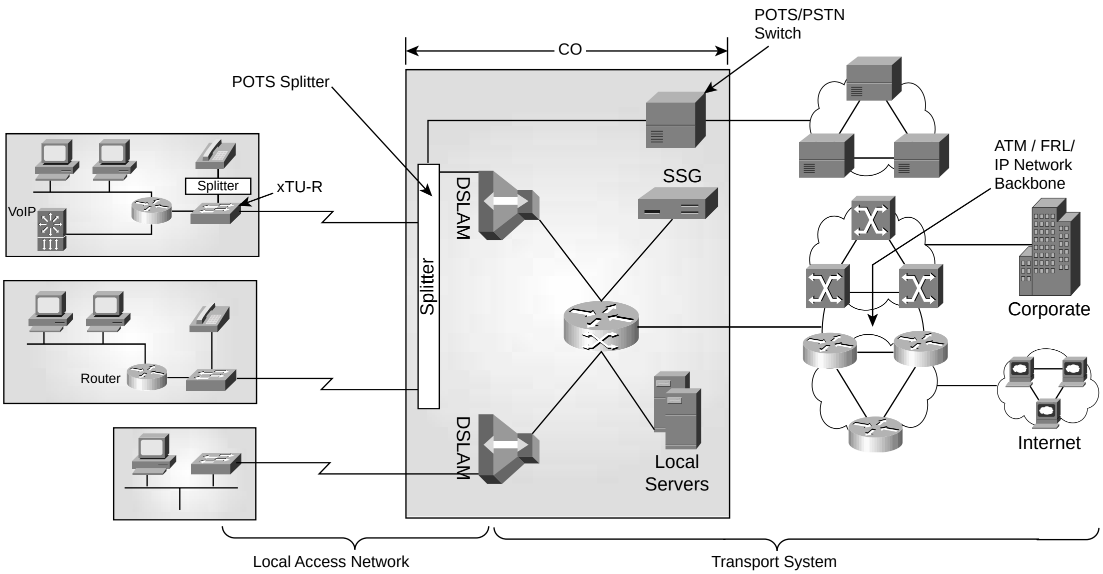
ADSL circuits connect ADSL modems on each end of a twisted-pair telephone line, creating three data channels:

- **A high-speed downstream channel**—Ranges from 1.5 to 9 Mbps.
- **A low-speed upstream channel**—Ranges from 16 to 640 Kbps.
- **A basic telephone service channel**—The basic telephone service channel is split off from the digital modem by filters or plain old telephone service (POTS) splitters, providing uninterrupted basic telephone service.

NOTE The upstream and downstream bandwidth ranges depend upon the distance between the customer site and the DSL provider's CO; the greater the distance, the lower the bandwidth capacity.

Figure 7-3 illustrates the architecture of an ADSL network.

Figure 7-3 *ADSL Architecture*



ADSL architecture is made up of the following components:

- **Transport System**—Provides the carrier backbone transmission interface for the DSLAM system. This device can provide service specific interfaces such as T1/E1, T3/E3, OC-1/3, and STS-1/3.
- **Local Access Network**—Uses the local carrier Inter-CO network as a foundation, providing connectivity between multiple service providers and multiple services users, often with Frame Relay or ATM switches.
- **Digital Subscriber Line Access Multiplexer (DSLAM)**—Concentrates data traffic from multiple DSL loops onto the backbone network for connection to the rest of the network.
- **DSL Transceiver Unit-Remote (xTU-R)**—The customer site equipment for service connection to the DSL loop.
- **POTS Splitters**—Optional device at both CO and service user locations, enabling the copper loop to be used for simultaneous DSL and transmission and single line telephone service. POTS splitters come in two configurations:
  - Single splitter version for mounting at the residence
  - Multiple splitter version for mass termination at the CO

  POTS splitters are either passive or active. *Active* splitters require an external power source, and *passive* splitters require no power and often have a higher mean time between failure (MTBF) than the active splitter. Passive splitters enable lifeline services, such as 911, in the event of a DSLAM or xTU-R power loss; active splitters require backup power.

ADSL Data Rates

Downstream bandwidth depends on a number of factors:

- Length of the copper line
- Wire gauge of the copper line
- Presence of bridged taps
- Presence of cross-coupled interference

NOTE *Bridged taps* are any cable pair spliced into the main pair. Many unused bridged taps remain from the early days when party lines were the norm and two or more taps were made on every line. Bridged taps cause undesirable reflection that can distort the high-frequency signals in modern transmission technologies.

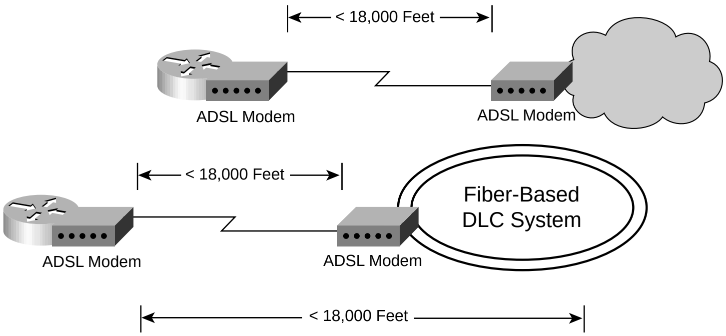
Line attenuation increases with line length and frequency, and decreases as wire diameter increases. Ignoring bridged taps, ADSL performs as shown in Table 7-1.

Table 7-1 *ADSL Rates (Ignoring Bridged Taps)*

Rate (Mbps)	Wire Gauge (AWG)	Distance (feet)	Wire Size (mm)	Distance (km)
1.5 or 2	24	18,000	0.5	5.5
1.5 or 2	26	15,000	0.4	4.6
6.1	24	12,000	0.5	3.7
6.1	26	9000	0.4	2.7

Customer sites beyond the previously listed distances can be reached with fiber-based digital loop carrier (DLC) systems, as illustrated in Figure 7-4.

Figure 7-4 *ADSL with and Without Fiber-based DLC*



NOTE xDSL service will not work over fiber-to-the-curb (FTTC) implementations. *FTTC* is the installation of optical fiber to within a thousand feet of the home or office. Fiber-to-the-home (FTTH) is the installation of optical fiber from the carrier directly into the home or office.

ADSL Standards and Associations

The American National Standards Institute (ANSI) Working Group T1E1.4 approved an ADSL standard at rates up to 6.1 Mbps (DMT/ANSI Standard T1.413). The European Technical Standards Institute (ETSI) contributed an annex to T1.413 reflecting European requirements including a single terminal interface at the premise side of the access circuit.

The ATM Forum and the Digital Audio-Visual Council (DAVIC) have both recognized ADSL as a physical layer transmission protocol for unshielded twisted pair (UTP) media.

NOTE UTP is a popular type of cable consisting of two unshielded wires twisted around each other. Because UTP cabling is cost efficient, it is used extensively for local-area networks (LANs) and telephone connections. UTP cabling does not offer the high bandwidth or protection from interference that is found with coaxial or fiber optic cables; however, UTP is less expensive and easier to work with than coaxial or fiber-optic.

Other xDSL Technologies

There are several xDSL implementations in addition to ADSL. These are as follows:

- **Single-lined digital subscriber line (SDSL)**—A rate-adaptive version of Hi-speed digital subscriber line (HDSL) which like HDSL is symmetric. SDSL enables equal bandwidth downstream from a network service provider CO to the customer site as upstream from the customer site to the CO. SDSL supports data only (maximum of 1.544 Mbps) on a single line and does not support analog calls.
- **High-data-rate digital subscriber line (HDSL)**—Developed by Bellcore, high bit-rate DSL (HDSL)/T1/E1 technologies have been standardized by ANSI in the United States and by ETSI in Europe. HDSL is a more cost-efficient method of installing T1 service to a customer site than traditional dedicated DS1 service.
- **HDSL 2**—Standard enabling symmetric service at T1 speeds using a single-wire pair rather than the two pairs of HDSL service. HDSL-2 also was developed as a standard by which different vendors' equipment can interoperate.
- **G.SHDSL (ITU HDSL Standard)**—A standards-based, multirate version of HDSL-2, which offers symmetrical service.
- **Integrated services digital network (ISDN) digital subscriber line (IDSL)**—A cross between ISDN and xDSL, using a single-wire pair to transmit full-duplex data at 128 kbps.
- **Very-high-data-rate digital subscriber line (VDSL)**—Transmits high-speed data over short reaches of twisted-pair copper telephone lines, with a range of speeds depending on actual line length. The maximum downstream rate under consideration is between 51 and 55 Mbps over lines up to 1000 feet (300 m). Downstream speeds as low as 13 Mbps over lengths beyond 4000 feet (1500 m) also are in consideration.

Cable Access Technologies

Cable television (CATV) is a unidirectional medium carrying broadcast analog video channels to the most customers possible at the lowest possible cost to the CATV service provider. Since the introduction of CATV more than 50 years ago, little has changed beyond increasing the number of channels supported.

Fearing loss of market share when DSL was introduced (in the 1990s) and recognizing the need to offer advanced services to remain economically viable, key multiple system operators (MSOs) formed the Multimedia Cable Network System Partners, Ltd. (MCNS). The goal of the MCNS was to define a standard product and system capable of providing data and future services over the CATV infrastructure. MCNS partners included Comcast Cable Communications, Cox Communications, Tele-Communications Inc., Time Warner Cable, MediaOne, Rogers CableSystems, and Cable Television Laboratories (CableLabs).

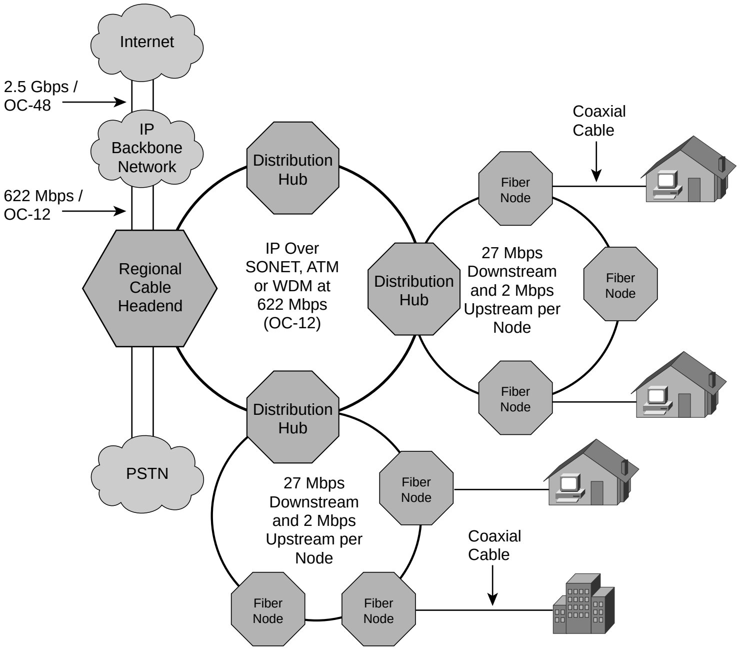
The MCNS defined the Data Over Cable Service Interface Specification (DOCSIS) 1.0 standard, which was in turn accepted as the North American standard. These key MSOs defined upgrade and construction programs to provide two-way functionality to the end-user over the CATV infrastructure.

Cable Access Architecture

To deliver data services over a cable network, one television channel (50 to 750 MHz range) is allocated for downstream traffic to homes and another channel (5 to 42 MHz band) is used to carry upstream signals.

Figure 7-5 illustrates the architecture of a cable access network for both CATV and cable modem services.

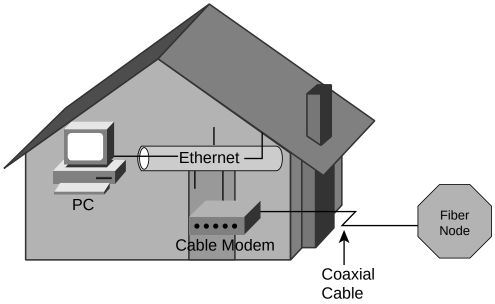
Figure 7-5 *Cable Access Architecture*



The following list details the cable access network architecture:

- Residential and business end-users are connected to fiber nodes by coaxial cables. Users attach to this cable through an Ethernet network interface card (NIC) installed in the PC, in turn connected to a cable modem, as illustrated in the Figure 7-6.

Figure 7-6 *Cable Modem Access*



- The fiber nodes house the cable modem termination system (CMTS) at the head-end, communicating with the cable modems at the end-user premise. This communication creates a LAN connection between the end-user and the cable modem service provider.
- Most cable modems are external hardware devices connecting to a PC through a standard 10Base-T Ethernet card or Universal Serial Bus (USB) connection.
- These fiber nodes are connected by fiber rings (such as SONET) to the distribution hubs, which are in turn connected by fiber rings to a regional cable head-end.
- The cable head-end then forwards the traffic to the appropriate network—the PSTN for VoIP applications and the public Internet for all other IP traffic.

A single downstream 6 MHz television channel can carry up to 27 Mbps of downstream data throughput from the cable head-end; upstream channels can deliver 500 Kbps to 10 Mbps from home and business end-users. This upstream and downstream bandwidth is shared by other data subscribers connected to the same cable network segment, which is often 500 to 2000 homes on a modern network.

An individual cable modem subscriber can reach speeds from 500 Kbps to 1.5 Mbps or more, depending on the network architecture (for example, oversubscription ratio) and traffic load.

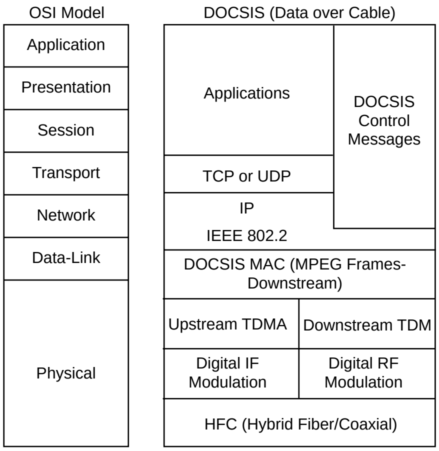
NOTE Although other users on the network segment affect cable modem speed, the CATV-signal does not affect this speed because each signal (CATV and cable modem) uses a different frequency on the line. This means that your cable modem connection will not be slower if you are watching TV.

NOTE When you are surfing the World Wide Web, your system's performance can be affected by Internet backbone congestion. The local access provider has no direct management control over this backbone congestion; it's the Internet.

DOCSIS Standards, Signaling Protocols, and Applications

Data Over Cable Service Interface Specification (DOCSIS) is a set of standards for transferring data by CATV and cable modems. The DOCSIS interface specifications enable multivendor interoperability for transporting Internet Protocol (IP) traffic. The DOCSIS layers are compared with the OSI Reference Model layers in Figure 7-7.

Figure 7-7 *OSI Layers and DOCSIS Layers*



The following list details the correlation between the OSI Reference Model and the DOCSIS standard:

- TCP/IP support:
  - — IP services at the network layer (OSI Layer 3)
  - — TCP/UDP services at the transport layer (OSI Layer 4)
- Data-link layer:
  - — Logical Link Control (LLC) sublayer conforming to Ethernet standards
  - — Link security sublayer for basic privacy, authorization, and authentication
  - — Media Access Control (MAC) sublayer supporting variable-length protocol data units (PDU)
- Physical (PHY) layer comprised of the following:
  - — Downstream convergence layer conforming to MPEG-2
  - — Physical Media Dependent (PMD) sublayer for downstream and upstream data transmission; through Time Division Multiplexing (TDM).

Summary

DSL and cable modem network access are two alternate ways to connect to an NSP without the use of more expensive dedicated service. DSL technology is a modem technology using existing twisted-pair telephone lines capable of carrying high-bandwidth applications.

There are several forms of xDSL, each designed around specific goals and needs of the marketplace. Each of these is summarized in Table 7-2.

Cable systems originally were designed to deliver broadcast television signals efficiently to subscribers' homes. Downstream video programming signals begin around 50 MHz, the equivalent of channel 2 for over-the-air television signals. The 5 MHz to 42 MHz portion of the spectrum is usually reserved for upstream communications from subscribers' homes.

Each standard television channel occupies 6 MHz of the Radio Frequency (RF) spectrum. Traditional cable systems have 400 MHz of downstream bandwidth, capable of carrying the equivalent of 60 analog TV channels. Modern hybrid fiber/coax (HFC) systems have 700 MHz of downstream bandwidth, with the capacity for approximately 110 channels.

The MCNS defined the DOCSIS 1.0 standard, which in turn was accepted as the North American standard.

Table 7-2 *DSL Service Summary*

DSL Type	Description	Data Rate Downstream; Upstream	Distance Limit	Application
ADSL	Asymmetric digital subscriber line	1.544 to 6.1 Mbps downstream; 16 to 640 Kbps upstream	1.544 Mbps at 18,000 feet; 2.048 Mbps at 16,000 feet; 6.312 Mbps at 12,000 feet; 8.448 Mbps at 9,000 feet	Used for Internet and web access, motion video, video on demand, remote LAN access.
HDSL	High-data-rate digital subscriber line	1.544 Mbps duplex on two twisted-pair lines; 2.048 Mbps duplex on three twisted-pair lines	12,000 feet on 24-gauge wire	T1/E1 service between server and phone company or within a company; WAN, LAN, server access.
SDSL	Single-line digital subscriber line	1.544 Mbps duplex (U.S. and Canada); 2.048 Mbps (Europe) on a single duplex line downstream and upstream	12,000 feet on 24-gauge wire	Same as for HDSL but requiring only one line of twisted-pair.
VDSL	Very-high digital subscriber line	12.9 to 52.8 Mbps downstream; 1.5 to 2.3 Mbps upstream; 1.6 Mbps to 2.3 Mbps downstream	4500 feet at 12.96 Mbps; 3000 feet at 25.82 Mbps; 1000 feet at 51.84 Mbps	ATM networks; Fiber to the Neighborhood.

DSL and cable modem network access is not available in all parts of the country or even to every house and business within a city. Before planning on deploying either of these services, it is imperative to discuss these plans with the local DSL/Cable NSP. In the event these services are not available for connectivity, you need to consider the more traditional Frac-T1/T3, ISDN, or dial-up services.

Frequently Asked Questions (FAQ)

1 Which is better: DSL or cable modem?

There is no clear choice between the two because each service offers its own advantages and disadvantages.

The main disadvantages of cable modems, when compared to DSL service, is the shared bandwidth to the cable head-end; end-users and their neighbors share the same cable. The Internet access point tends to be the congestion point, as well as the Internet itself. Another disadvantage is the end-user cannot choose the Internet Service Provider (ISP). Cable TV lines do not have "common-carrier" status as do phone lines.

DSL solutions provide the end-user with a dedicated line to the ISP; there is no bandwidth sharing with other users on the same access network. Like cable modem implementations, the Internet access point tends to be the congestion point, as well as the Internet itself.

2 Does Cisco manufacture or sell xDSL solutions?

Yes, Cisco provides DSL equipment for NSP and enterprise environments, as well as network management for a DSL platform. More information regarding Cisco's product and solution offering can be found at `www.cisco.com/warp/public/44/solutions/network/dsl.shtml`.

3 Does Cisco manufacture or sell cable solutions?

Yes, Cisco provides cable equipment for head-end and customer premise environments, as well as network management for a cable platform. More information regarding Cisco's product and solution offering can be found at `www.cisco.com/warp/public/44/jump/cable.shtml`.

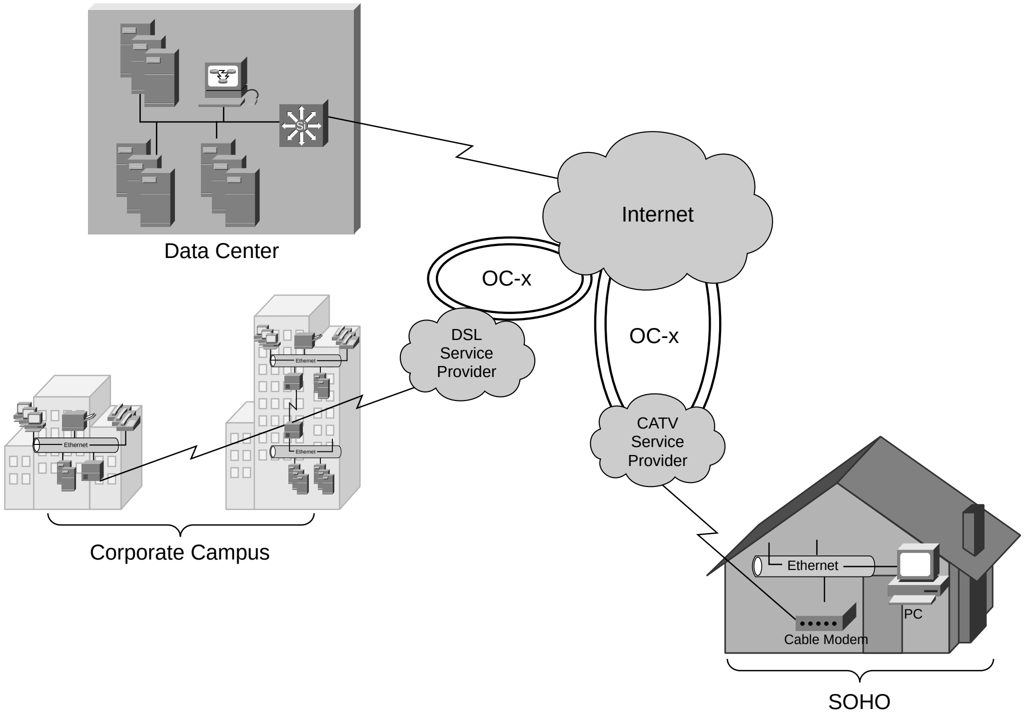
4 Can a television be connected to the cable modem line?

Yes. In most cases this configuration will work as long as a splitter is used to "split" the television signal apart from the cable modem (data) signal. It is imperative to discuss this configuration with the CATV provider to ensure that no adverse effects to the TV or data signal are experienced by the end-user.

Case Study

HB & J, Inc. is an organization with a corporate campus and several remote SOHO users. HB & J, Inc. has outsourced file storage to a server farm hosted by an off-site data center company. HB & J, Inc. decided to forego traditional Frame Relay service and implemented an IP-VPN, with the public Internet as the transport medium. The topology of the HB & J, Inc. network is illustrated in Figure 7-8.

Figure 7-8 *HB & J, Inc.*



HB & J, Inc. is using SDSL between their two campus buildings—the main building and the annex building. SDSL is implemented by the deployment of a pair of SDSL modems on each side of an existing copper facility. The main building of the HB & J, Inc. campus is using HDSL, provided by the local NSP, to connect to the Internet.

HB & J, Inc.'s SOHO users have deployed cable modem access (where available) for connectivity to the Internet. These SOHO users are using a virtual private network (VPN) client to establish a secure communications tunnel across the Internet to the HB & J, Inc. Corporate Campus and the Data Center server farms. The VPN client must interoperate and be supported by the Corporate Campus and the Data Center in order to establish the secure tunnel across the Internet.

The Data Center has deployed a dedicated service to the Internet (likely DS3 or higher) to meet the demands of their large, high-volume customer base.

DSL and cable modem service provide HB & J, Inc. a more cost-efficient connectivity method than traditional dedicated service. For new locations where DSL or cable modem service may not be available, HB & J, Inc. will need to install dedicated Internet service.

If HB & J, Inc. decides at some time to add traditional Frame Relay or ATM service to support remote users, the Corporate Campus also will need to implement a Frame Relay/ATM connection so that connection can be established with these users as well.