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Digital Subscriber Line Technology

INTRODUCTION

Digital subscriber line (DSL) is one of several access methods competing to bring broadband connectivity to the small office/home office (SOHO) market. As demand for access to the Internet soars, demand for faster access has also increased. Today, the typical SOHO user reaches the Internet via a dial-up analog modem with a maximum access speed of 56 kilobits per second (kbps). DSL, on the other hand, promises connection speeds up to 100 times faster by using a digital modem (or splitter) instead of an analog modem.

HOW DOES DSL WORK?

DSL travels over the twisted-pair copper telephone lines that already link the public switched network (PSN) central office (CO) and the SOHO premises. It works by exploiting unused bandwidth in these copper wires. Voice traffic over copper uses only the lower end of the wire's frequency range (300 Hertz [Hz] to 3.4 kilohertz [kHz]). DSL takes advantage of the fact that copper telephone lines can carry broadband signals at a much higher frequency (between 5 kHz and 1.4 megahertz [MHz]). However, the distance that DSL can travel over copper wires is limited to 18,000 feet from a CO.

Although the DSL distribution path subsists in existing twisted pair copper, DSL does require the addition of new equipment at the CO and the SOHO premises. Like the analog solution, DSL requires modems at the SOHO. At the CO, DSL access multiplexers (DSLAM) are the key pieces of equipment for providing DSL service to multiple users. (In the near future, DSLAMs will provide not only DSL service, but also "edge" services and management controls to Internet service providers [ISP] and their customers.)

The modem and the DSLAM split the voice and data signals using frequency division multiplexing. Because voice and data are transmitted over different frequency ranges, DSL can operate independently of voice services. If the DSL modem or the DSLAM fail, voice services should remain unaffected. As shown in Figure 1, DSL allows data traffic to completely bypass the CO switch. Once data signals have been separated from voice signals, voice calls can be carried over the circuit-switched PSN, and data traffic can be

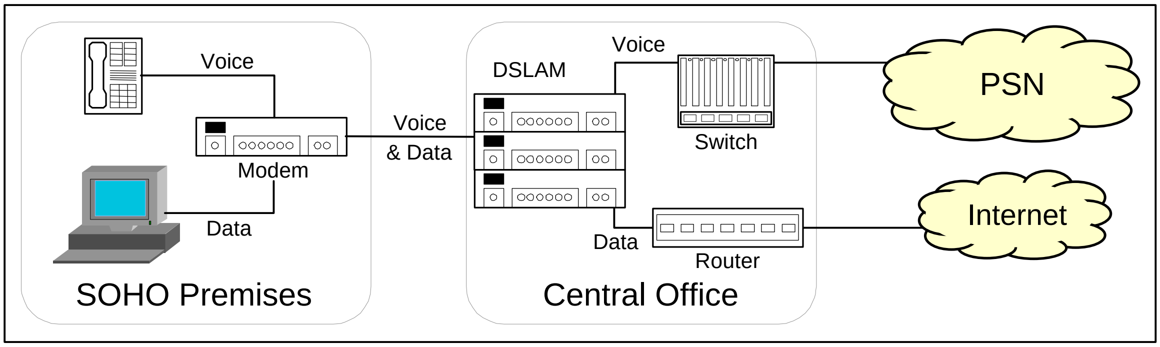

Figure 1. Typical DSL Configuration

aggregated with other incoming data traffic to be routed to the Internet.

xDSL

Many companies are developing alternative "flavors" of DSL, known collectively as xDSL. xDSL types include asymmetric DSL (ADSL), rate adaptive DSL (RADSL), and symmetric DSL (SDSL).

ADSL is by far the most common version of DSL and is perhaps the simplest and least expensive way to provide DSL to the end user. "Asymmetric" refers to the asymmetric rates for upstream (SOHO to CO) and downstream (CO to SOHO) data. ADSL takes advantage of the fact that most customers receive more data (Web pages, graphics, e-mail attachments) than they send; therefore, it is much cheaper and easier to push data downstream to the customer than it is for the data to be sent upstream from the customer. Upstream rates for ADSL tend to peak at around 128 kbps, whereas downstream rates can reach as high as 6 megabits per second (Mbps), or roughly 100 times faster than a typical download using an analog modem.

Competing Technologies

Broadband access for the SOHO market is not restricted to telephony access. DSL is only one choice among many for providing broadband data access. Other competing technologies include cable modems and wireless broadband.

Cable Broadband

Broadband access via cable television wiring, commonly known as cable modem service, is a nearly direct competitor to DSL. Cable service providers are pursuing the same SOHO market as DSL, but with two notable differences. First, cable has not traditionally been installed in office buildings, therefore limiting its use for business. Second, unlike DSL, cable signals do not dissipate over distances; therefore, theoretically, anyone with cable TV could purchase cable modem service if his or her cable company offers the service.

How Do Cable Modems Work?

Cable modem service provides bidirectional Internet access via asymmetric cable modems and cable coaxial wires. Previously, first-generation cable modem service required the use of a telephone line for the upstream data connection. However, today's cable modem services use cable coaxial wires to carry data downstream and upstream.

Broadband access speeds can reach up to 3 Mbps upstream and 2.5 Mbps downstream. Like DSL, cable modem service uses a combination of existing wiring and new equipment. Downstream data is modulated and sent via a 6-MHz-wide television channel, in the frequency range from 50 MHz to 750 MHz. Theoretically, this will allow for a downstream speed of 27 Mbps. However, because most computers are incapable of connecting at this speed, most service providers will limit downstream data rates to 1 to 3 Mbps. Upstream data is transmitted in the range of 5 to 42 MHz, with data rates as high as 10 Mbps. However, because most users do not require access at this high rate, most cable modems are manufactured to provide service at 0.5 to 2.5 Mbps.

Like DSL, cable modem service requires investment in new equipment. At the SOHO premises, a cable modem is required, which is typically leased from the service provider. At the cable plant, the service provider must install a cable modem termination system (CMTS). The CMTS is the key hardware for connecting the cable TV network to the Internet or other data networks.

WIRELESS BROADBAND

Many wireless equipment vendors and service providers are moving aggressively to offer wireless broadband to the SOHO market. Like wired broadband, wireless broadband (also known as fixed wireless, broadband wireless local loop, and wireless digital subscriber) is a network access alternative for the delivery of data, Internet, voice, video, and multimedia applications. Broadband wireless access uses licensed spectrum to transmit signals within cells that are several kilometers wide. It is a short-haul, line-of-site (LOS) technology.

Among the technologies being developed for this market are local multipoint distribution service (LMDS) and multichannel multipoint distribution service (MMDS). LMDS operates in the 28 gigahertz (GHz) and 31 GHz bands. MMDS operates in the 2.5 GHz band. Other frequencies also in use are the 24 GHz, 26 GHz, 38 GHz, and 39 GHz bands. Generally speaking, frequencies above 10 GHz are known as LMDS. Unli-

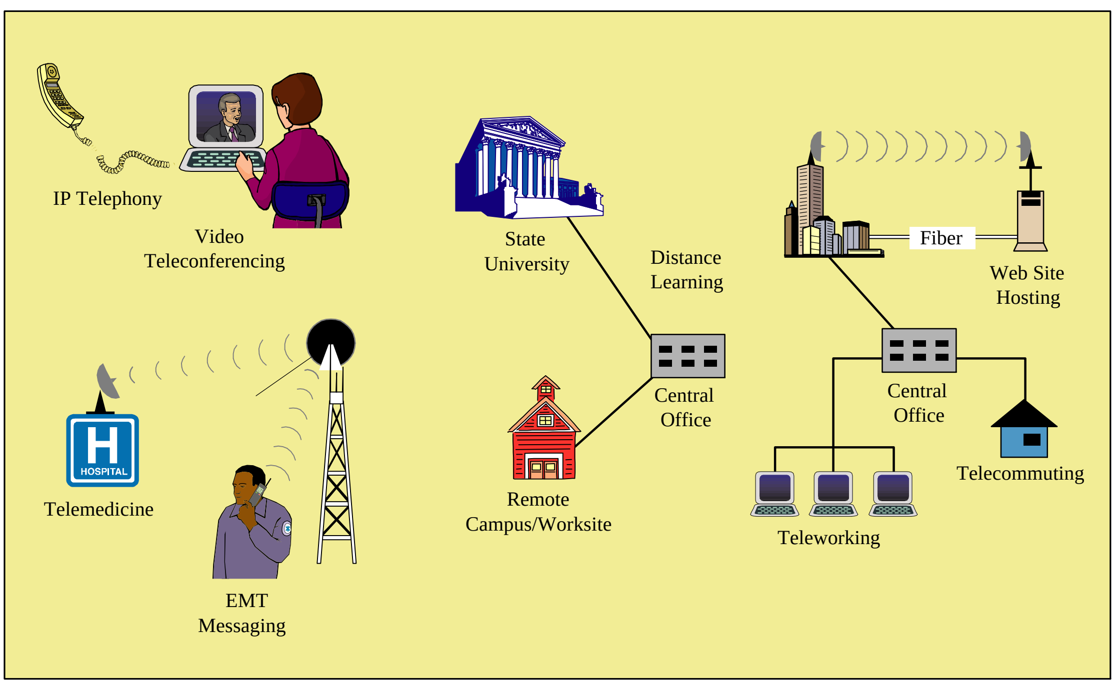

Figure 2. Potential Broadband Applications

ADVANTAGES	DISADVANTAGES
? High bandwidth service ? Low cost for medium number of users ? Voice, data, and video support ? An "always on" service	? Not ubiquitous ? Expensive for small number of users ? Sometimes difficult to install ? Not portable ? Security issues

Table 1. Advantages and Disadvantages of Broadband Access

censed spectrum also exists in the 2.4 GHz and 5.8 GHz bands.

The wireless broadband technology uses fixed wireless antennas that are highly directional and bolted to rooftops. These antennas possess large data capacities and do not support roaming. The narrowband antennas do not use satellites. To deliver wireless broadband Internet, a combination of technology platforms is used, from fixed wireless for the first mile connection to fiber rings that connect hub site buildings, to long-haul fiber that connects cities. Wireless broadband connections and other fixed-wireless connections deliver data rates from T1 to 155 Mbps. These wireless connections serve the same function as a wireline, interconnecting private networks, bypassing a local exchange carrier, or connecting to the Internet.

How Does Wireless Broadband Work?

When a user sends data, data packets stream to an antenna. The antenna then uses the spectrum to transmit the packets in a tight beam aimed at another antenna within LOS. This second antenna is co-located with a hub that receives transmissions (e.g., voice, video, and data) simultaneously from many customers, aggregates the transmissions, and pushes them out onto a backbone for network distribution. Data going from the backbone to the customer is received at the hub. The hub sorts the packets and distributes them as transmissions aimed at the rooftop antennas on surrounding buildings. A combination of point-to-point and point-to-multipoint radios (or transceivers) carry the signals, but only if the service supports point-to-multipoint (most do not at this time). Audio signals can be digitized and sent as data packets; therefore, industry hopes to combine data and voice communications within a single transmission within this decade.

Applications, Advantages, and Disadvantages

The "always on" nature of DSL and its high bandwidth capabilities make it a good candidate for several applications. From support of a SOHO to advanced video teleconferencing, Figure 2 highlights some of the many potential uses for DSL and other broadband applications.

Although DSL and other broadband technologies offer greater data access rates at a relatively low cost per user, drawbacks to broadband access also exist. Table 1 summarizes the advantages and disadvantages of broadband access. Table 2 compares various characteristics for competing broadband access technologies.

Security

One selling point of broadband is that a connection always exists on the Internet. Continuous access eliminates the downtime associated with dialing in via an analog modem. However, the convenience of a con-

xDSL	Description	Provider/ Developer	Data Rates	Availability/ Range	Target Services	Cost	Pros
ADSL	Asymmetric DSL	Various	Down:6 Mbps Up: 640 kbps	12,000-18,000 feet	Home/small business	$50-$360/month	Quick downloads, always on, dedicated connection
ADSL Lite	A low data rate version of ADSL	Various	Down: 6 Mbps Up: 640 kbps	<12,000 feet	Home/small business	$30/month	Quick downloads, always on, dedicated connection
CDSL	Consumer DSL	Rockwell International	Down: 1 Mbps Up: 128 kbps	~12,000 feet	Home	NA	Quick downloads, always on, dedicated connection
HDSL	High bit-rate DSL	Various	1.544 Mbps	~12,000 feet	Substitute for T1/E1	NA	T1 performance at lower cost (1 pair cable), always on, dedicated connection
IDSL	ISDN DSL	Ascend	128 kbps	~12,000 feet	Home	$50-$150/month	Always on, dedicated connection
RADSL	Rate adaptive DSL	Globespan	Down: 6 Mbps Up: 640 kbps	~12,000 feet	Small business	$70/month	Quick downloads, always on, dedicated connection
SDSL	Symmetric DSL	Various	2 Mbps	~11,000 feet	Small business	$60-$400/month	T1 performance at lower cost (1 pair cable), always on, dedicated connection
VDSL	Very high bit-rate DSL	Various	Down: 51 Mbps 2.3 Mbps	< 3,000 feet	Small business	NA	High performance, always on, dedicated connection
OTHERS	**Description**	**Provider/ Developer**	**Data Rates**	**Availability/ Range**	**Target Services**	**Cost**	**Pros**
POTS	Analog modem	Various	Less than 56 kbps	Universal	Home	$30-40 month	Simple installation, low cost
Cable	Cable modem	Various	Up to 38 Mbps	Widely available	Home	$40/month	Fast speed, always on
Wireless	Wireless broadband	Teligent/ Winstar	Up to 50 Mbps	Limited/35 miles	Small business	$90/month	Quick deployment
Strato-spheric	High Altitude Platform Stations	Skystation	2-10 Mbps	NA	Small business	NA	Not in service yet
Orbiting	Satellite	Comsat, ICO, Globalstar, Teledesic	9.6 kbps to 155 Mbps	Available currently	Small business, VIP traveler, remote villages w/o existing POTS	$100/month plus 1.59 per minute	Possibility of global coverage
T1/T3	Leased line from LEC	LECs	1.54 Mbps	Most areas unlimited	Small business	$1,500/ month	Mature technology, good security
EtherLoop	Ethernet local loop	NORTEL	4 Mbps	21,000 feet	Home	NA	Looks like Ethernet to LAN devices, higher speed
ISDN	Integrated Services Digital Network	LECs	128 kbps	Most areas unlimited	Home/ business	Varies widely	Mature technology, nationwide STDs
Satellite Internet	Internet/TV via satellite dish	Hughes Network Systems	Upstream: 128 to 256 kbps Downstream: 40 Mbps	Universal/ unlimited	Residential/ business	$110/month	Independent of PSTN and no local infrastructure required

Table 2. DSL and Comparative Technologies

tinuous connection does not come without a price. Unfortunately, that price is a lack of security.

Continuous connections make computers vulnerable to hackers and snoopers. For the typical analog modem-to-ISP connection, the ISP will assign a dynamic Internet Protocol (IP) address at random with each new Internet session. However, because broadband connections are continuous, they tend to use static IP addressing. Static IP addressing makes it easier for hackers and snoopers to target and track an individual's personal computer (PC).

Cable modems have an additional vulnerability. Using a cable modem is analogous to using a local area network, in which many users share common cabling. This means that "neighbors" who are using the same cable modem networks theoretically can intercept data packets sent between the end user and the ISP.

Several steps can be taken to address these security concerns. A good place to start is with the ISP. End users should ask their ISP if any security systems are currently in place to detect or prevent hackers and snoopers (e.g., dynamic IP addresses, protective software to encrypt data, or a firewall).

If the ISP does not provide dynamic IP addressing, the best protection is to disconnect the computer from the Internet when it is not in use. This can be accomplished either by disconnecting the cable or telephone line or by turning off the system. In addition, if the ISP does not provide encryption, a firewall, and antihacking software, the end user can purchase these for self-installation.

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