

Voice & Data Communications Handbook

Fourth Edition

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- Provides an up-to-date overview of the telecommunications industry
- Explains voice over IP, xDSL, VPNs and other key topics in clear, jargon-free terms
- Contains practical implementation techniques in addition to basic concepts

REGIS J. "BUD" BATES AND DONALD W. GREGORY

Best-selling authors and data communications experts

VOICE AND DATA
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Fourth Edition

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ACKNOWLEDGMENTS

Well, here I am again, finalizing the latest book for McGraw-Hill. This one is special because it is the fourth edition of the *Voice and Data Communications Handbook*! The original book came out in 1995 but has blossomed quite a bit since then. It is hard to believe that so much has happened over these few years.

This book deals with the issues surrounding the telecommunications industry on voice and data topics as the two converge. As always, I chose to write the way I think, that is, in a non-technical fashion. I hope that this is consistent with you, the reader, because there is little published that is geared for the novice and business professional. Besides the new chapters, we added something new this time in response to many professors around the country. In the beginning of each chapter, we have an objectives section and at the end of the chapter we have added some questions. We hope this adds and rounds off the information based on this new information. We can thank the educators for their interest and requests.

To be fair about this production, we owe a lot of credit to many people. Some of the people interacted with us regularly, and others only occasionally. First, we must thank Steve Elliot, McGraw-Hill's executive editor on this book, who prodded me to keep going. In addition to Steve is Alex Corona who e-mailed us weekly, keeping the project on schedule.

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Two people in my office deserve the lion's share of the credits for the ultimate graphical representation and production of this book. The first is Gabriele my wife and partner of more than three decades. She is the silent contributor of this production. Gabriele really deserves to have her name on the cover of this book. Second is a young lady whose energy and enthusiasm never seem to cease. Amber Hartmann and Gabriele worked dauntlessly to keep the graphics accurate and readable, while at the same time creating interesting renderings. Amber's age belies her maturity and

ability to jump right in and get things done quickly, even though we change them constantly.

This team of people all pulled together to make this fourth edition of the *Voice and Data Communications Handbook* a reality. They deserve the credit.

Finally, I want to thank you the reader for giving up your time to read this book. I receive many calls and e-mails from readers who just want to let me know that they enjoyed my opinion or the way I present an idea. I hope I can continue to win your support. My best wishes to you all!

Thank you all,

Regis J. (Bud) Bates

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CHAPTER 29

Digital Subscriber Line (DSL)

After reading this chapter and completing the questions, you will be able to:

- Describe the benefits of using xDSL
- Understand the capabilities of the various types of xDSL
- Discuss the limitations of the local loop
- Describe the modulation techniques used
- Understand why the telcos have been reluctant to offer DSL services over the long run

Although the industry has been scurrying around looking for new ways of transmitting data from the consumer's door, the Incumbent Local Exchange Carriers (ILECs) found new life in their copper cable plant. Clearly, the telcos had a personal stake in finding something that would enable them to continue to use unshielded twisted pairs of wire at everyone's door. The movement to a data communications driver gave them the impetus they needed.

What Is xDSL?

One of the major problems facing the ILECs was the ability to maintain and preserve their installed base. Ever since the Telecommunications Act of 1996, the ILECs have faced mounting pressure to provide faster and more accurate Internet access. Therefore, a new form of communications was needed to work over the existing copper cable plant. One of the technologies selected was the use of xDSL. The DSL family includes several variations of what is known as *digital subscriber line* (DSL). The lowercase *x* in front of DSL stands for the many variations. These will include

- Asymmetric digital subscriber line (ADSL)
- ISDN-like digital subscriber line (IDSL)
- High-bit-rate digital subscriber line (HDSL)
- Consumer digital subscriber line (CDSL)
- Rate-adaptive digital subscriber line (RADSL)
- Very high-speed digital subscriber line (VDSL)
- Symmetric or single digital subscriber line (SDSL)
- Single-pair high-speed digital subscriber line (SHDSL)

One can see that many variations are available. Each digital subscriber line (DSL) capability carries with it differences in speed, throughput, and facilities used. The most popular of this family under today's technology is asymmetrical digital subscriber line (ADSL).

ADSL is a technology primarily provided by the ILECs because the existing cable plant can support the speeds, which can vary depending on the quality of the copper. The Competitive Local Exchange Carriers (CLECs) are quickly becoming involved in providing xDSL now. However, the most important and critical factor in dealing with ADSL technology is the capability to support speeds from 1.5 up to 8.192 Mbps. The ILECs can also support POTS for voice or fax communications on the same line. This means that the ILECs do not have to install all-new cabling to support high-speed communications access to the Internet, which is burning up the wires today.

Asymmetric Digital Subscriber Line (ADSL)

Asymmetric digital subscriber line is the new modem technology that converges the existing twisted-pair telephone lines into the high-speed communications access capability for various services. Most people consider ADSL as a transmission system instead of a modification to the existing transmission facilities. In reality, ADSL is a modem technology used to transmit speeds of 1.5 to 6 Mbps under current technology. In the future, ADSL is expected to support speeds up to 8.192 Mbps. This definition of the higher range of ADSL speeds is one that is yet to be proven; however, with changes in today's technology, one can only imagine that the speeds will be achievable.

ADSL Capabilities

Many of the capabilities being considered with the DSL family are the services for converging voice, data, multimedia, video, and Internet streaming protocols services. The carriers see their future in the rollout of products and services to the general consuming public so they can access the Internet. Table 29-1 shows the theoretical speeds and distances of various ADSL technologies.

Remember that the speeds and distances shown in this table are theoretical. If the copper has been damaged or impaired in any way, the speed and distances will change accordingly (downward), and we all know what condition the wiring is in from earlier discussions in this book. Reality and the actual distances and speeds will most likely be less than those shown in this table. What is most important is the assumption that these speeds can

Table 29-1

Data Rates
for ADSL

Current Data Rate (Mbps)	Wire Gauge	Distance (ft)	Distance (km)
1.5-2.048	24	18,000	5.5
1.5-2.048	26	15,000	4.6
6.3	24	12,000	3.7
6.3	24	9,000	2.7

be established and maintained on the installed base of unshielded twisted pair (UTP) wire. As long as the ILECs can approximate these speeds today, the consumer will most likely not complain.

Modem Technologies

Before proceeding too far in this discussion, a quick review of modem technology is probably in line. Modems, or modulator/demodulators, were designed to move data across the voice communications network. Users still struggle to transmit data across the voice networks at speeds up to 33,600 bps. Even with the newer modems called the *V.90*, which are supposed to operate at 56 Kbps, we still see significant reductions in speed. Although this may seem like high-speed communication, our demands and needs for faster communications have quickly outstripped the capabilities of our current modem services, making the demand for newer services more evident. High-speed modems could be produced, but the economics and variations on the wiring system prove this somewhat impractical. Instead, the providers looked for a better way to provide data communications that mimic the digital transmission speeds we readily accept.

Using the telephone company's voice services, the end user installs a modem on the local loop. This modem is the data circuit-terminating equipment (DCE) for the link. A modem is used to communicate across the wide-area networks, as shown in Figure 29-1. The ILEC installs a voice-grade line on the copper cable plant and allows the end user to connect the modem. The modem then converts the data into an analog signal. There is no magic in modem communications today, but in the early days of data communications, this was considered voodoo science. The miracle of data compression and other multibit modulation techniques quickly expanded the data rates from 300 bps to today's 33.6 Kbps. Newer modems are touted to handle data at speeds of up to 56 Kbps, but few come close to these rates. So, the reality of all the pieces combined still has the consumer operating at approximately 33.6 Kbps.

ISDN-Like Digital Subscriber Line (IDSL)

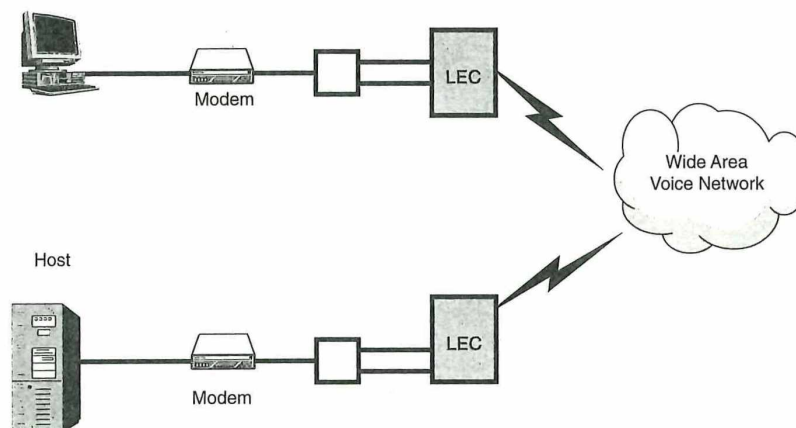
DSL refers to a pair of modems installed on the last mile of line, which facilitate high data speeds. Network providers use the existing wires and add

Digital Subscriber Line (DSL)

803

Figure 29-1

Modems are installed at the customer's location and use the existing telephone wires to transmit data across the voice network.

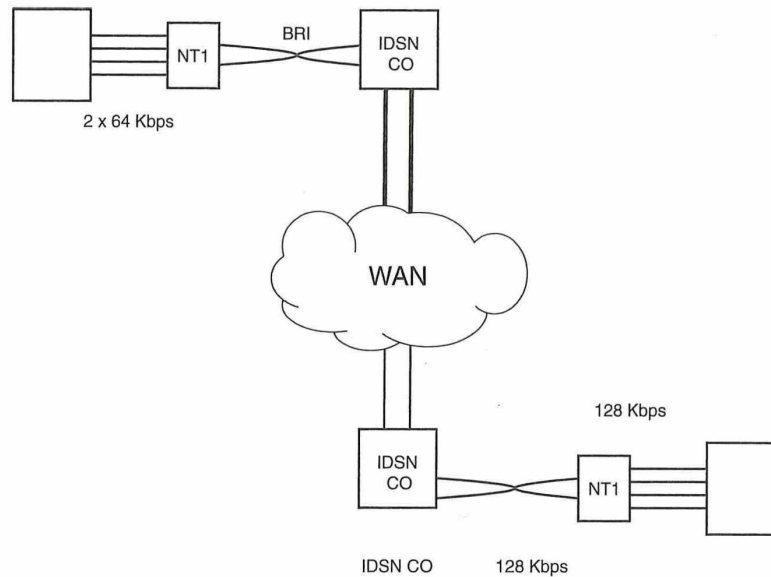


the DSL modems to increase the throughput. DSL modems offer duplex operations. The speed of a DSL modem may be 128 Kbps on copper at distances up to 18,000 feet using the twisted pair wires. The bandwidth used is from 0 to 80 kHz. IDSL uses the 128-Kbps full-duplex basic rate interface (BRI). As shown in Figure 29-2, the IDSL technique is all digital, operating at two channels of 64 Kbps for voice or nonvoice operation and a 16-Kbps data channel for signaling, control, and data packets. ISDN was very slow to catch on, but the movement to the Internet created a whole new set of demands. Now more ILECs and the CLECs offer ISDN services. As the deployment of IDSL was speeding up on the local loop, the providers developed a new twist, called *always on ISDN*, mimicking a leased set of channels that are always connected. Bonding the channels together, users can surf the Net at speeds of 128 Kbps. Note that this is a *symmetrical* digital subscriber line.

High-Bit-Rate Digital Subscriber Line (HDSL)

In 1958, Bell developed a voice multiplexing system that uses the 64-Kbps pulse code modulation (PCM). Using the PCM techniques, voice calls were sampled 8,000 times per second and coded using an 8-bit encoding. These samples were then organized into a framed format, using 24 time slots to bundle and multiplex 24 simultaneous conversations onto a single four-wire circuit. Each frame carries 24 samples of 8 bits and 1 framing bit,

Figure 29-2
IDSL line connection
allows 128 Kbps.



8,000 times a second. This produces a data rate of 1.544 Mbps. We now refer to this as a Digital Signal Level 1 (DS-1) at the framed data rate. This rate of data transfer is used in the United States, Canada, and Japan.

Throughout the rest of the world, standards were set to operate using an E1 with a signaling rate of 2.048 Mbps. The differences between the two services (T1 and E1) are significant enough to prevent their seamless integration.

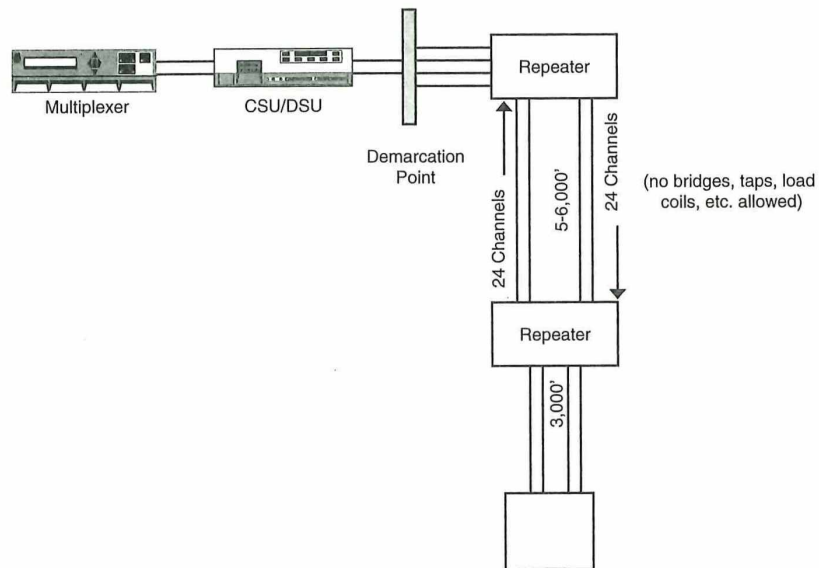
However, in the digital arena, T1 required that the provider install the circuits to the customer's premises. The local provider installs a four-wire circuit. Repeaters are spaced at every 5,000 to 6,000 feet. When installing the T1 on the local loop, limitations of the delivery mechanism get in the way. Alternate mark inversion (AMI) consumes all the bandwidth and corrupts the surrounding cable spectrum quickly. Consequently, the providers can only use a single T1 in a 50-pair cable. Figure 29-3 is a representation of this cable layout. This inefficient use of the wiring makes it impractical to install T1s to small office and residential locations. Further limitations require the providers to remove bridge taps, clean up splices, and remove load coils from the wires to get the T1 to work.

Digital Subscriber Line (DSL)

805

Figure 29-3

The typical layout of the T1

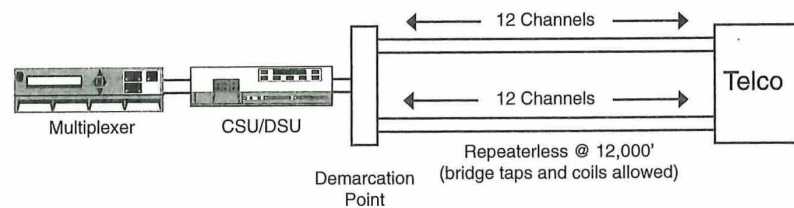


To circumvent these cabling problems, HDSL was developed. HDSL does not require the repeaters on a local loop of up to 12,000 feet. Bridge taps will not bother the service, and the splices are left in place. This means that the provider can offer HDSL more efficiently for 1.544 Mbps. The modulation rate on the HDSL service is more advanced. Sending 768 Kbps on one pair and another 768 Kbps on the second pair of wires splits the T1. This is shown in Figure 29-4.

Originally, HDSL used two pairs at distances of up to 15,000 feet. HDSL at 2.048 Mbps uses three pairs of wire for the same distances. The most

Figure 29-4

HDSL is impervious to the bridge and splices. The T1 is split onto two pairs.



recent version, HDSL-2, uses only one pair of wire and is more acceptable to the providers. Nearly all providers today deliver T1 capabilities on some form of HDSL.

Symmetric or Single Digital Subscriber Line (SDSL)

The goal of the DSL family was to continue to support and use the local cable plant. Therefore, providing high-speed communications on a single cable pair became paramount. Most local loops already employ single cable pair today; thus, it is only natural to assume that providers would want this capability. SDSL was developed to provide high-speed communications on that single cable pair, but at distances no greater than 10,000 feet. Despite this distance limitation, SDSL was designed to deliver 1.544 Mbps on the single cable pair. Typically, however, the providers provision SDSL at 768 Kbps. This creates a dilemma for the carriers because HDSL can do the same things as SDSL.

Asymmetric Digital Subscriber Line (ADSL)

SDSL uses only one pair of wires to provide duplex high-speed communications, but it is limited in distance. Not all users require symmetrical speeds at the same time. ADSL was therefore designed to support different speeds in each direction at distances of up to 18,000 feet. Because the speeds requested are typically to access the Internet, most users look for higher download speeds and lower upload speeds. Therefore, the asymmetrical nature of this service meets those needs.

Rate-Adaptive Digital Subscriber Line (RADSL)

Typically, when equipment is installed, assumptions are made based on minimum performance characteristics and speeds. In some cases, special equipment is used to condition the circuit to achieve those speeds. However, if the line conditions vary, the speed will be dependent on the sensitivity of the equipment. In order to achieve variations in throughput and be sensitive to the line conditions, rate-adaptive DSL was developed. This enables

the flexibility to adapt to changing conditions and adjust the speeds in each direction to potentially maximize the throughput on each line. In addition, as line conditions change, one could see the speeds changing in each direction during the transmission. Many of the ILECs have installed RADSL as their choice given the local loop conditions. Speeds of up to 768 Kbps are the preferred rates offered by the incumbent providers.

Consumer Digital Subscriber Line (CDSL)

Not all consumers need symmetrical high-speed communication to access the Internet. Furthermore, ADSL speeds are more than the average consumer may be looking for. Lower speed communications capability was developed using CDSL. With other forms of DSL, splitters are used on the line. CDSL was designed to eliminate the splitter on the line. Moreover, speeds of up to 1 Mbps in the download direction and 160 to 384 Kbps in the upload direction are provided. It is expected that the speeds and CDSL will meet needs of the average consumer for some time to come. A universal ADSL working group developed what is called ADSL-lite, also called G.lite. This specification was ratified in late 1998, using the working group's specifications for service delivery to the average consumer. An example of this DSL-lite service is provided by the Nortel Networks' 1-Mb modem.

Very High-Speed Digital Subscriber Line (VDSL)

It was only matter of time until some users demanded higher speed communications than was offered by the current DSL technologies. VDSL was introduced to achieve the higher speeds. In fact, speeds ranging from 13 to 52 Mbps are available, but the distance limitations of the local cable will be a big factor. In order to achieve the speeds, one can expect that a fiber feed will be used to deliver VDSL. This technique will most likely carry ATM (cells) as its primary payload. We can expect some hybrid arrangements to deliver this speed to the door for high-speed data at up to 52 Mbps downward and 1.5 to 6 Mbps upward.

Table 29-2 summarizes the speeds and characteristics of the DSL technologies we have discussed. These are the typical installation and operational characteristics; others will certainly exist in variations of installation and implementation.

Table 29-2

Summary of DSL
Speeds and
Operations Using
Current Methods

Service	Explanation	Download	Upload	Mode of Operation
ADSL	Asymmetric DSL	1.5–8.192 Mbps	16–640 Kbps	Different up and down speeds; one pair of wire
RADSL	Rate-adaptive DSL	64 Kbps–8.192 Mbps	16–768 Kbps	Different up and down speeds; many common operations on 768 Kbps. One pair of wire.
CDSL	Consumer DSL	1 Mbps	16–128 Kbps	Now ratified as DSL-lite. No splitters. One pair of wire.
HDSL	High-bit-rate DSL	1.544 Mbps in North America; 2.048 Mbps in the rest of the world	1.544 Mbps 2.048 Mbps	Symmetrical services Two pairs of wire.
ISDL	ISDN DSL	144 Kbps (64 + 64 + 16) as BRI	144 Kbps (64 + 64 + 16) as BRI	Symmetrical operation. One pair of wire. ISDN BRI.
SDSL	Single DSL	1.544 Mbps 2.048 Mbps	1.544 Mbps 2.048 Mbps	Uses only one pair, but typically provisioned at 768 Kbps. One pair of wire.
SHDSL	Single-pair high-bit-rate DSL	2.312 Mbps	192–384 Kbps	Uses one pair, aimed at small residential customers
VDSL	Very high-speed DSL	13–52.6 Mbps	1.5–6.0 Mbps	Fiber needed and ATM probably used.

Single-Pair High-Speed Digital Subscriber Line (SHDSL)

SHDSL is the newest member of the DSL family being currently standardized at ITU (G.shdsl) and ETSI (TM6) in 2001. G.shdsl targets the small business market. Multiple telephone and data channels, videoconferencing, remote LAN Access, and leased lines with customer-specific data rates are among its many exciting characteristics. Spectrally friendly with other xDSLs, it supports symmetric data rates varying from 192 Kbps to 2.321 Mbps across greater distances than other technologies. SHDSL uses a Trellis Coded Pulse Amplitude Modulation (TC PAM)-based modulation

scheme, which is different from the other forms of xDSL. It will operate over a single pair of wires at ranges from 6,000 feet to 20,000 feet (2.3 Mbps to 192 Kbps rates, respectively) on 26 AWG copper. This will produce a 35 to 50 percent improvement in rate at a given range over traditional symmetric DSL and a 15 to 20 percent improvement in distance at a given rate over traditional symmetric DSL. G.shdsl is also known as G.991.2 standard.

The Hype of DSL Technologies

The local providers are extremely excited at the possibility of installing higher speed communications and preserving their local cable plants. No one wants to abandon the local copper loop, but getting more data reliably across the local loop is imperative. Therefore, the ability to breathe new life into the cable plant is an extension of the facilities in place. This also means that they can create a new form of revenue streams from the old copper. Consumers are looking for high-speed access (primarily to access the Internet) for whatever the application. Yet, at the same time, consumers are looking for a bargain. They do not want to spend a lot of money on their communications services.

The providers are trying to bump up their revenues, without major new investments. They would like to launch as many new service offerings on their existing cable plant and increase the costs to the end user. This is a business decision, not a means of trying to rake the consumer over the coals. Yet, a happy medium must be found of providing services and generating revenues with limits on expenses. To do this, the xDSL family offers the opportunity to meet the demands while holding down investment costs. The key ingredient for success is to minimize costs and satisfy the consumer. Make no mistake—if the local provider does not offer high-speed services, someone else will.

xDSL Coding Techniques

Many approaches were developed as a means of encoding data onto xDSL circuits. The more common are carrierless amplitude phase (CAP) modulation and discrete multitone (DMT) modulation. Quadrature phase modulation (QAM) has also been used, but the important part is the standardization. The industry as a rule selected DMT, but several developers

and providers have used CAP. It is therefore appropriate to summarize both of these techniques.

Discreet Multitone (DMT) Modulation

DMT uses multiple narrowband carriers, all transmitting simultaneously in a parallel transmission mode. Each of these carriers carries a portion of the information being transmitted. These multiple discrete bands—or in the world of frequency-division multiplexing, subchannels—are modulated independently of each other, using a carrier frequency located in the center of the frequency being used. These carriers are then processed in parallel form.

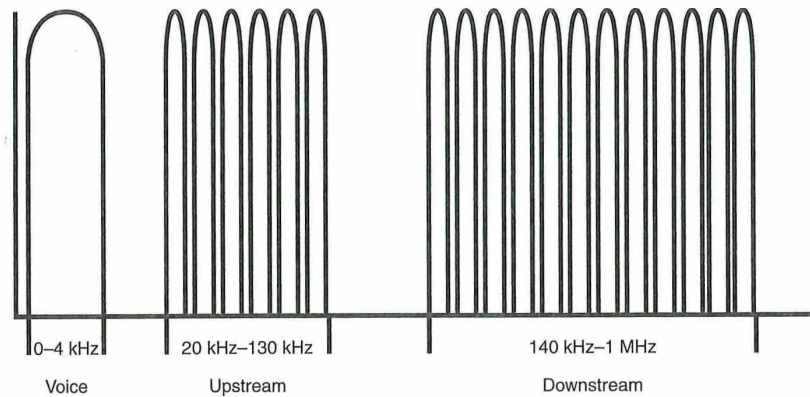
In order to process the multicarrier frequencies at the same time, a lot of digital processing is required. In the past, this was not economically feasible, but integrated circuitry has made this more feasible.

The American National Standards Institute (ANSI) selected DMT with the use of 256 subcarriers, each with the standard 4.3125-kHz bandwidth. These subcarriers can be independently modulated with a maximum of 15 bps/Hz. This allows up to 60 Kbps per tone used. Figure 28-5 shows the use of the frequency spectrum for the combination of voice and two-way data transmission. In this representation, voice is used in the normal 0- to 4-kHz band on the lower end of the spectrum (although the lower 20 kHz are provided). Separation is allowed between the voice channel and the upstream data communications, which operates between 20 and 130 kHz. Then a separation is allowed between the upstream and the downstream channels. The downstream flow uses between 140 kHz and 1 MHz. As shown in Figure 29-5, the separation allows for the simultaneous up and down streams and the concurrent voice channel. It is on this spectrum that the data rates are sustained. Each of the subchannels operates at approximately 4.3125 kHz, and a separation of 4.3125 kHz between channels is allocated.

Using DMT for the Universal ADSL Service (G.Lite)

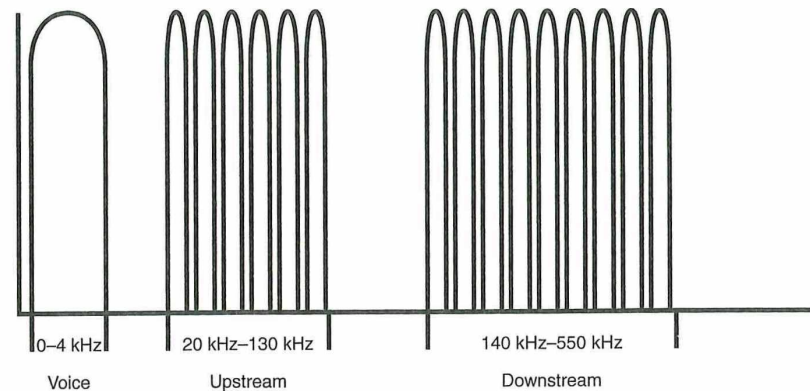
Provisions for the high-speed data rates of full ADSL are good, but not every consumer is looking for the high data rates afforded on ADSL. Therefore, the Universal ADSL Working Group decided to reevaluate the need for the end user. They determined that many consumers need downloads of

Figure 29-5
The ANSI DMT
specification



1 to 1.5 Mbps and uploads of 160 to 640 Kbps. Consequently, ADSL-lite specification was designed with these speeds for the future. Initially introduced in early 1998, the specification was ratified in late 1998 to facilitate the lower throughput needs of the average consumer. DMT is the preferred method of delivering G.lite service. There is no way to know if the network providers can support hundreds of multimegabit ADSL up- and download speeds on their existing infrastructure. However, using the G.lite specification can support low-demand users more efficiently. Similar to the DMT used in the ANSI specification, the carriers are divided as shown in Figure 29-6. Note that in this case, the high end of the frequency spectrum tops out at approximately 550 kHz instead of the 1-MHz range with ADSL.

Figure 29-6
The ANSI and UAWG
G.lite spectrum



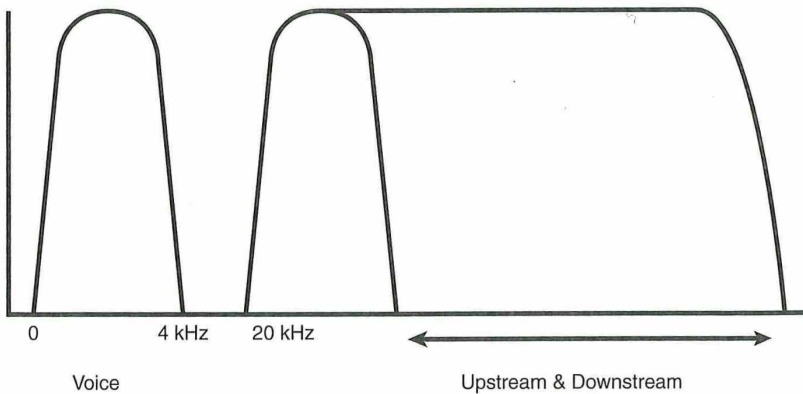
Carrierless Amplitude Phase (CAP) Modulation

CAP is closely aligned to quadrature amplitude modulation (QAM). QAM as a technique is widely understood in the industry and well deployed in older modems. Both CAP and QAM are single-carrier signal techniques. The data rate is divided in two and modulated onto two different orthogonal carriers before being combined and transmitted. The main difference between CAP and QAM is in the way they are implemented. QAM generates two signals with a sine/cosine mixer and combines them onto the analog domain.

CAP was one of the original proposals for use with ADSL technology. Unfortunately, this was a proprietary solution offered by a single vendor, which turned heads away from acceptance. Figure 29-7 shows CAP's use of the frequency spectrum of the line. Most industry vendors agree that CAP has some benefits over DMT, but also that DMT has more benefits over CAP. The point is that two differing technologies were initially rolled out for ADSL (and the other family members), which contradict each other in their implementation.

CAP uses the entire loop bandwidth (excluding the 4-kHz baseband analog voice channel) to send the bits all at once. The DMT technique has no subchannels. The lack of subchannels removes the concern and problems with individual channel transmission. Most of the RBOCs started using CAP but have since moved on to DMT.

Figure 29-7
The spectral use of
CAP



Comments on Deployment

ADSL service is catching on. However, the ILECs and CLECs are dragging their feet. As of late 1998, only about 150,000 ADSL modem pairs were installed in the United States. In contrast, over 800,000 cable modems were installed in residences and businesses across the country. The local owners of the copper loop have to take a more aggressive approach to delivering high-speed services or consumers will go somewhere else. As the market continues to mature and standards continue to develop, the local providers must preserve their infrastructure.

Whereas consumers are reluctant to proceed with ADSL, the HDSL and SDSL services are still very attractive alternatives, offering 1.544- to 2.048-Mbps symmetrical speeds or some variation, as already discussed.

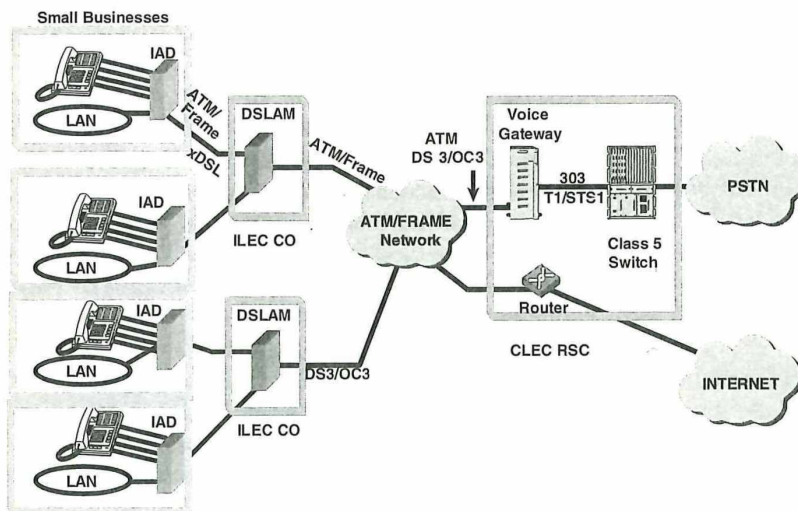
In the future, when high-speed media are installed to the door or to the curb, the logical stepping stone will become the VDSL service, perhaps sometime in 2002 to 2003. Although trials are already under way, too much time passes until the results are compiled and analyzed. Therefore, the reality of VDSL for the masses is still a long way off.

Voice over DSL

In general, a Voice over DSL (VoDSL) system functions as an overlay solution to a DSL broadband access network, enabling a CLEC to extend multiline local telephone service off of a centralized voice switch. For example, Jetstream's VoDSL solution allows up to 16 telephone lines and high-speed continuous data service to be provided over a single DSL connection, as shown in Figure 29-8. A VoDSL solution typically consists of three components.

- First, a carrier-class voice gateway resides in the regional switching center (RSC) and serves as a bridge between the circuit-based voice switch and the packet-based DSL access network.
- Second, an Integrated Access Device (IAD) resides at each subscriber premises and connects to a DSL circuit. It also serves as a circuit/packet gateway and provides the subscriber with standard telephone service via up to 16 analog POTS ports and Internet service via an Ethernet connection.
- The third component is the management system.

Figure 29-8
Integrating Voice
over DSL onto ATM
or frame relay



With VoDSL solutions, DSL broadband access networks now have the coverage, capacity, and cost attributes to enable CLECs to deliver local telephone services as well as data services to the small and mid-size business markets. It has already been established that DSL access networks have the right bandwidth to serve the data needs of small and mid-size businesses. With VoDSL access solutions, this is true for serving the local telephone service needs of those subscribers as well.

Some VoDSL solutions are capable of delivering 16 telephone lines over a DSL circuit along with standard data traffic. Because 95 percent of small businesses use 12 or fewer telephone lines, a single DSL circuit provides sufficient bandwidth to serve the voice needs of the vast majority of the market. In addition, if more than 16 lines are required, most VoDSL solutions enable a provider to scale service by provisioning additional DSL connections. In addition to providing the right capacity for providing local telephone service, DSL broadband access networks are very efficient in the way they deliver service. TDM-based transport services, such as a T1 line, require the bandwidth of the line to be channelized and portions dedicated to certain services, such as a telephone line. Even if a call is not active on that line, the bandwidth allocated to that line cannot be used for other purposes. DSL access networks are packet-based, enabling VoDSL solutions to

use the bandwidth of a DSL connection dynamically. VoDSL solutions only consume bandwidth on a DSL connection when a call is active on a line. If a call is not active, then that bandwidth is available for other services, such as Internet access. This dynamic bandwidth usage enables providers to maximize the potential of each DSL connection, delivering to subscribers the greatest number of telephone lines and highest possible data speeds.

Because telephony traffic is more sensitive to latency than data traffic, VoDSL solutions guarantee the quality of telephone service by giving telephony packets priority over data packets onto a DSL connection. In other words, telephony traffic always receives the bandwidth it requires and data traffic uses the remaining bandwidth. Fortunately, telephony traffic tends to be very bursty over the course of a typical business day, so the average amount of bandwidth consumed is minimal. For example, over a single 768-Kbps symmetric DSL connection, a CLEC could provide eight telephone lines (serving a PBX/KTS with 32 extensions) and still deliver data service with an average speed of 550 Kbps.

VoATM over DSL

Voice over ATM (VoATM) unites ATM and DSL technologies to deliver on the promise of fully integrated voice and data services. VoATM meets all requirements in terms of quality of service (QoS), flexibility, and reliability because the underlying technology is ATM, a highly effective network architecture developed specifically to carry simultaneous voice and data traffic.

ATM Suitability for Voice Traffic

Sometimes mistakenly associated with VoIP, VoATM is a completely separate technology that predates VoIP. In contrast to IP and frame relay, ATM uses small, fixed-length data packets of 53 bytes each that fill more quickly, are sent immediately, and are much less susceptible to network delays. (Delays experienced by voice in a frame relay or IP packet network can typically be ten times higher than for ATM and increase on slower links.) ATM's packet characteristics make it by far the best-suited packet technology for guaranteeing the same QoS found in toll-quality voice connections.

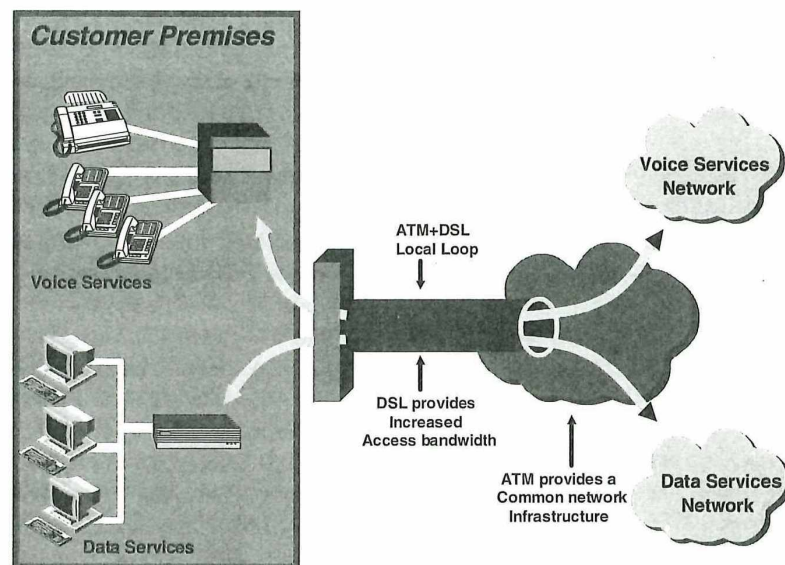
The ATM Adaptation Layer (AAL), the part of ATM responsible for converting voice and data into ATM cells, enables various traffic types to have data converted to and from the ATM cell and translates high-layer services

(such as TCP/IP) into the size and format of the ATM protocol layer. A number of AAL definitions exist to accommodate the various types of network traffic. Those AAL types most commonly used for voice traffic are AAL1, AAL2, and AAL5.

VoATM with AAL1 is the traditional approach for constant bit rate (CBR), time-dependent traffic such as voice and video and provides circuit emulation for trunking applications. ATM with AAL1 is still suitable for voice traffic, but is not the ideal solution for voice services in the local loop because its design for fixed bandwidth allocation means network resources are consumed even when no voice traffic is present. Some equipment manufacturers use AAL5 to provide VoATM and support for variable bit rate (VBR) applications. They also use AAL5 because it is a better choice over AAL1 in terms of bandwidth used. However, the means for carrying voice traffic over AAL5 is not yet fully standardized or widely deployed, and implementations are usually proprietary.

ATM with AAL2 is the newest approach to VoATM. Figure 29-9 shows how AAL2 provides a number of important improvements over AAL1 and AAL5, including support for CBR and VBR applications, dynamic bandwidth allocation, and support for multiple voice calls over a single ATM permanent virtual circuit (PVC). An additional and significant advantage of

Figure 29-9
Voice over ATM with
AAL2



AAL2 is that cells carry content information. This feature provides traffic prioritization for packets (cells) and is the key to dynamic bandwidth allocation and efficient network use.

VoATM and DSL

Because DSL links are ready-made for voice and data and ATM excels at carrying varied traffic, using VoATM over DSL over the local loop to the customer is a natural extension of these services. To enable the combination, equipment that supports VoATM is needed at each end of the local loop: a next-generation integrated access device (NG-IAD) at the customer premises and a voice gateway at the CO. The integrated access device concept is shown in Figure 29-10. The integrated devices can use many applications, as shown in Figure 29-11.

The real benefit is that the telephone line that once carried a single phone call for voice, data, or fax traffic can now be expanded to carry data and voice simultaneously on the same pair of wires. Because we use the data protocols (IP), we can multiplex several (16) conversations and Internet access on the higher bandwidth, and still have the lower end (0–4 kHz) available as a full-time fax line. The use of the bandwidth that was once arbitrarily curtailed is now a reality.

Figure 29-10
Integrated access devices

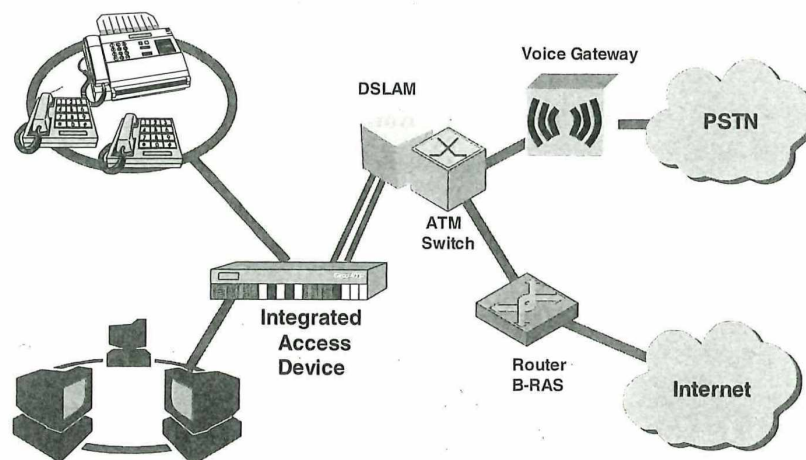
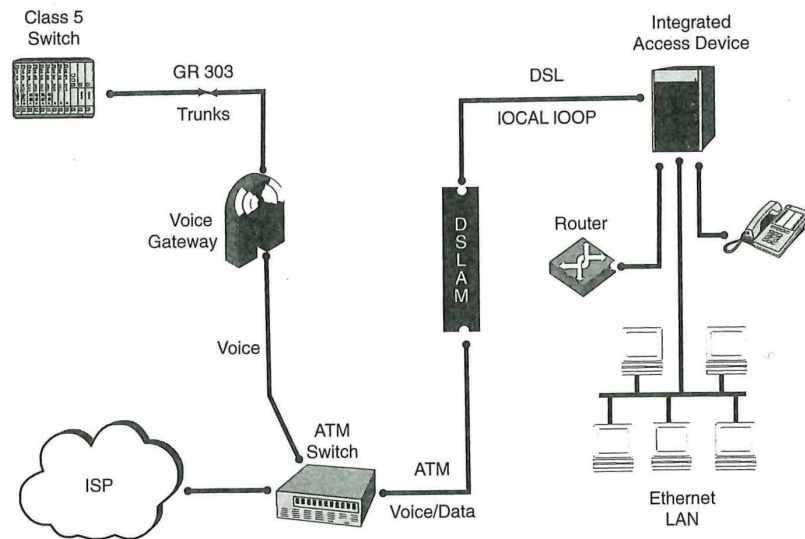


Figure 29-11
Multiple applications
of the IAD



Questions

1. What does DSL stand for?
 - a. Direct subscriber link
 - b. Digital subscriber loop
 - c. Digital speed lines
 - d. Digital subscriber line
2. How many flavors of DSL are available?
 - a. 5
 - b. 6
 - c. 7
 - d. 8
3. The x in xDSL stands for the speed of the DSL line. T/F
4. ADSL can support download speeds up to:
 - a. 6 Mbps
 - b. 8 Mbps

- c. 52 Mbps
- d. 26 Mbps
- 5. RADSL is usually installed with an upload speed of _____.
 - a. 1.544 Mbps
 - b. 1.0 Mbps
 - c. 768 Kbps
 - d. 160 Kbps
- 6. What distance can ADSL run on a 26 AWG cable?
 - a. 8–12 kft
 - b. 10–12 kft
 - c. 15–24 kft
 - d. 15–18 kft
- 7. The newest family member of the DSL family is _____.
 - a. SDLS
 - b. SHDSL
 - c. CDSL
 - d. VDSL
- 8. The speed of a G.lite service is limited to 1 megabit. T/F
- 9. VDSL will bring us download speed of up to 100 Mbps Ethernet. T/F
- 10. The ANSI specification uses bandwidth from:
 - a. 18–350 kHz
 - b. 18–550 kHz
 - c. 4–550 kHz
 - d. 18–1 MHz
- 11. The three types of modulation used today are _____.
 - a. CAP, MDT, and QAM
 - b. CAP, MDT, and TCM
 - c. CAP, DMT, and TCAM
 - d. CAP, DMT, and QAM

12. Three forms of the xDSL family are psuedo-replacements for T1; they are (select the three):
 - a. RADSL
 - b. ADSL
 - c. SDSL
 - d. HDSL
 - e. HDSL2
 - f. CDSL
 - g. Lite
 - h. TCAM
13. The use of repeaters is required to run xDSL on the copper cable pairs. T/F
14. The main types of xDSL use two pairs of wires. T/F
15. The VDSL service will be symmetrical at 52 Mbps, which is the same as ATM. T/F