Technical Paper

xDSL Local Loop Access Technology

Delivering Broadband over Copper Wires

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By Robyn Aber

Today's environment is ripe for the emergence of digital subscriber line (xDSL) technologies. The use of more multimedia information on the Internet and World Wide Web by business and residential users is a major growth factor. Another is the availability of affordable networking equipment that enables larger numbers of users to access corporate information from remote sites.

The opening of the telecommunications industry in the United States and throughout the world is sparking the entry into new service delivery by incumbent local exchange carriers (ILECs), interexchange carriers (IECs), Internet service providers (ISPs), competitive local exchange carriers (CLECs), and satellite and cable companies. Mixed media networking, the need for affordable broadband transmission rates, and a competitive telecom service environment all contribute to making xDSL the right technology at the right time. xDSL services promise to dramatically increase the speed of copper wire–based transmission systems without requiring expensive upgrades to the local loop infrastructure. New xDSL services are being readied to join the bandwidth race.

This paper describes the different xDSL technologies in development today and compares them to other current and emerging WAN service technologies. It also reports on current and future worldwide xDSL deployments and gives some market introduction projections. Finally, the paper describes 3Com's strategic direction with respect to the emerging xDSL technology market.

What Are Digital Subscriber Line (xDSL) Services?

xDSL services are dedicated, point-to-point, public network access technologies that allow multiple forms of data, voice, and video to be carried over twisted-pair copper wire on the local loop ("last mile") between a network service provider's (NSP's) central office and the customer site, or on local loops created either intra-building or intra-campus. xDSL is expected to have a significant impact in the next three years by supporting high-speed Internet/intranet access, online services, video-on-demand, TV signal delivery, interactive entertainment, and voice transmission to enterprise, small office, home office, and, ultimately, consumer markets. The major advantage of high-speed xDSL services is that they can all be supported on ordinary copper telephone lines already installed in most commercial and residential buildings.

Development History

xDSL was designed initially to provide video-on-demand and interactive TV applications over twisted-pair wires. Interest in copper-based digital subscriber line services was spurred when fiber-based broadband loops proved to be too costly for widespread deployment. Another boost came with the passage of the Telecommunications Reform Act of 1996, which allows local phone companies, long-distance carriers, cable companies, radio/television broadcasters, Internet/online service providers, and telecommunications equipment manufacturers in the United States to compete in one another's markets. The race to provide broadband bandwidth was on.

In xDSL, telecommunications companies see an opportunity to leverage customer demand for faster data access that has resulted from the explosive growth of the Internet and the advent of IP telephony. xDSL has the potential to deliver high-speed data access and much more. xDSL technology is in the early stages of commercial availability. The key players have agreed on standards and continue to work out interoperability, provisioning, and operations issues.

Different Types of xDSL and How They Work

The "x" in xDSL stands for the various kinds of digital subscriber line technologies, including ADSL, R-ADSL, HDSL, SDSL, and VDSL. To fully grasp the significance of these technologies and the applications for which each is best suited, it is important to understand how they differ. Key points to keep in

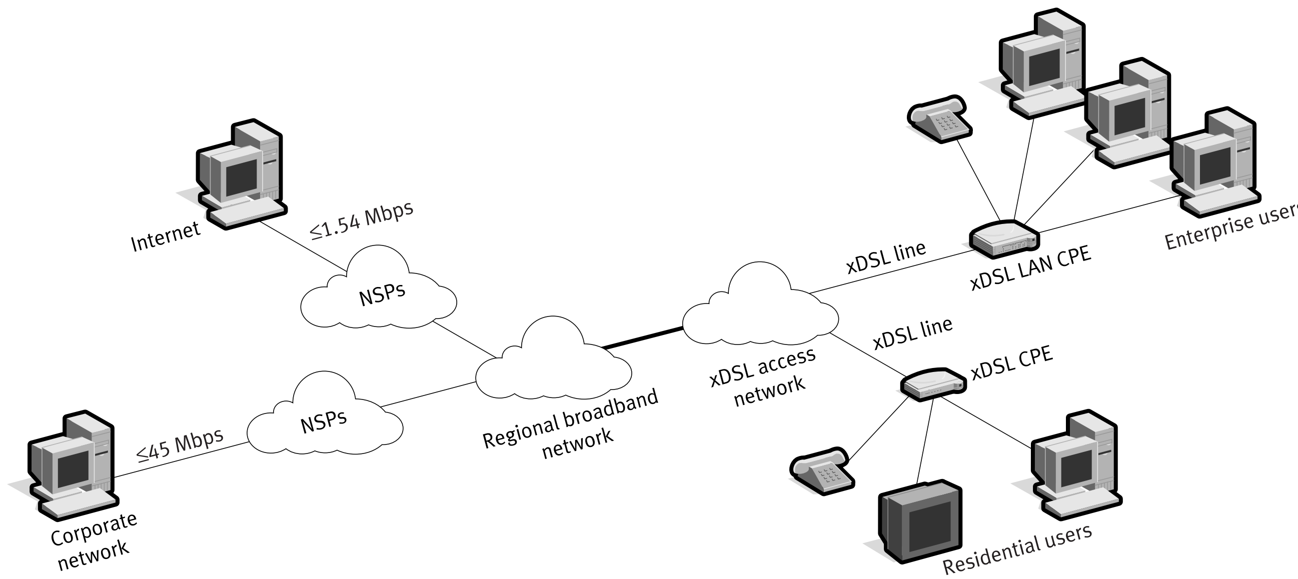

Figure 1. *xDSL in the End-to-End Network*

mind are the trade-offs between signal distance and speed, and the differences in symmetry of upstream and downstream traffic. Figure 1 shows that xDSL is used only in the local loop in an end-to-end remote access architecture.

Table 1 on page 4 compares the different types of xDSL technologies along with competing technologies, including 56 Kbps analog dial-up, cable modems, and Integrated Services Digital Network (ISDN).

Asymmetric Digital Subscriber Line (ADSL)

ADSL technology is asymmetric. It allows more bandwidth downstream—from an NSP's central office to the customer site—than upstream from the subscriber to the central office. This asymmetry, combined with "always on" access (which eliminates call setup), makes ADSL ideal for Internet/intranet surfing, video-on-demand, and remote local area network (LAN) access. Users of these applications typically download much more information than they send. Downstream, ADSL supports speeds between 1.5 and 8 Mbps; upstream, the rate is between 640 Kbps and 1.54 Mbps. ADSL can provide 1.54 Mbps transmission rates at distances of up to 18,000 feet over one wire pair. Optimal speeds of 6 to 8 Mbps can be achieved at distances of 10,000 to 12,000 feet using standard 24-gauge wire.

Rate-Adaptive Digital Subscriber Line (R-ADSL)

R-ADSL operates within the same transmission rates as ADSL, but adjusts dynamically to varying lengths and qualities of twisted-pair local access lines. With R-ADSL, it is possible to connect over different lines at varying speeds. Connection speed can be selected when the line synchs up, during a connection, or as the result of a signal from the central office.

ADSL Lite

ADSL Lite is a lower-speed version of ADSL that will eliminate the need for the telco to install and maintain a premises-based POTS splitter. Elimination of the POTS splitter is intended to simplify DSL installation and reduce the costs of DSL for NSPs. ADSL Lite is also supposed to work over longer distances than full-rate ADSL, making it more widely available to mass market consumers. It will support both data and voice and provide an evolution path to full-rate ADSL.

The effort to introduce ADSL Lite has been spearheaded by the Universal ADSL Working Group, an industry group that worked to develop a worldwide G.Lite standard within the International Telecommunications Union (ITU) Study Group 15. An ITU standard (G.992.2) was approved in October, 1998. Additional standards work can be expected in ANSI TIE1.4, the ATM Forum, and the

How ADSL Modems Work

To create multiple channels, ADSL modems divide the available bandwidth of a telephone line using one of two methods: frequency division multiplexing (FDM) or echo cancellation.

FDM assigns one band for upstream data and another band for downstream data. The downstream path is then divided by time division multiplexing (TDM) into one or more high-speed channels and one or more low-speed channels. The upstream path is also multiplexed into corresponding low-speed channels.

Echo cancellation assigns the upstream band to overlap the downstream band and separates the two by means of local echo cancellation, the same technique used by V.32 and V.34 modems. Echo cancellation uses bandwidth more efficiently, but increases complexity and cost. For both FDM and echo cancellation, a filter called a POTS splitter front-ends an ADSL modem to split off 4 kHz for voice service (referred to as plain old telephone service, or POTS). This means that both POTS and ADSL can be transmitted on the same wire, eliminating the need to have a separate POTS line for voice communication.

Table 1. *Technology and Application Comparison*

Technology	Speed	Distance Limitation (24-gauge wire)	Applications
56 Kbps analog modems	56 Kbps downstream	None 28.8 or 33.6 Kbps upstream	E-mail, remote LAN access, Internet/intranet access
ISDN	Up to 128 Kbps (uncompressed) Full duplex	18,000 feet (additional equipment can extend the distance)	Video conferencing, disaster recovery, leased line backup, transaction processing, call center services, Internet/intranet access
Cable modem	10–30 Mbps downstream 128 Kbps–10 Mbps upstream (shared, not dedicated, bandwidth)	30 miles over coaxial (additional equipment can extend the distance to 200 miles)	Internet access
ADSL Lite	Up to 1 Mbps downstream Up to 512 Kbps upstream	18,000 feet	Internet/intranet access, Web browsing, IP telephony, video telephony
ADSL/R-ADSL	1.5–8 Mbps downstream Up to 1.544 Mbps upstream	18,000 feet (12,000 feet for fastest speeds)	Internet/intranet access, video-on-demand, remote LAN access, VPNs, VoIP
IDSL	Up to 144 Kbps full duplex	18,000 feet (additional equipment can extend the distance)	Internet/intranet access, Web browsing, IP telephony, video telephony
HDSL	1.544 Mbps full duplex (T1) 2.048 Mbps full duplex (E1) (uses 2–3 wire pairs)	12,000–15,000 feet	Local, repeatered T1/E1 trunk replacement, PBX interconnection, Frame Relay traffic aggregator, LAN interconnect
SDSL	1.544 Mbps full duplex (T1) 2.048 Mbps full duplex (E1) (uses 1 wire pair)	10,000 feet	Local, repeatered T1/E1 trunk replacement, collaborative computing, LAN interconnect
VDSL	13–52 Mbps downstream 1.5–2.3 Mbps upstream (up to 34 Mbps if symmetric)	1,000–4,500 feet (depending on speed)	Multimedia Internet access, high-definition television program delivery

Source: 3Com, March 1998.

ADSL Forum to address issues such as compatibility with home wiring and network interfaces. 3Com is an active participant in these standards bodies working on the development of ADSL Lite.

ISDN Digital Subscriber Line (IDSL)

IDSL provides full duplex throughput at speeds up to 144 Kbps. Unlike ADSL, IDSL is restricted to carrying data only. While IDSL uses the same 2B1Q modulation code as ISDN to deliver service without special line conditioning, it differs from ISDN in a number of ways. Unlike ISDN, IDSL is a non-switched service, so it does not cause switch congestion at the service provider's CO. ISDN also requires call setup, while IDSL does not (DSL is an "always on" service).

High Bit-Rate Digital Subscriber Line (HDSL)

HDSL technology is symmetric, providing the same amount of bandwidth upstream as downstream. HDSL is the most mature of the xDSL technologies, and has already been implemented in telco feeder plants (lines that extend from central offices to remote nodes) and also in campus environments. Due to its speed—1.544 Mbps over two copper pairs and 2.048 Mbps over three pairs—telcos commonly deploy HDSL as an alternative to repeatered T1/E1. (T1 lines, used in North America, have a data rate of 1.544 Mbps; E1 lines, used in Europe, have a data rate of 2.048 Mbps.) Although HDSL's 12,000 to 15,000-foot operating distance is shorter than ADSL's, phone companies can install signal repeaters to cost-effectively extend its useful range. HDSL's reliance on two and three twisted-pair wires makes it ideal for connecting PBX systems, digital local loops, IEC points of presence (POPs), Internet servers, and campus-based networks. HDSL II is proposed as the next-generation HDSL within ANSI and ETSI. It will offer the same performance as HDSL, but over a single pair.

Single-Line Digital Subscriber Line (SDSL)

Like HDSL, SDSL supports symmetrical TI/E1 transmissions, but SDSL differs from HDSL in two important ways: it uses a single copper-pair wire, and it has a maximum operating range of 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 II.

Very High Bit-Rate Digital Subscriber Line (VDSL)

VDSL technology is the fastest xDSL 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 home. However, the maximum operating distance for this asymmetric technology is only 1,000 to 4,500 feet from the central office; this distance can be extended by running fiber optic cable from the CO to an optical network unit 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 could potentially enable NSPs to deliver high-definition television (HDTV), video-on-demand, and switched digital video, as well as legacy LAN extension symmetrical services. VDSL is in the requirements and standards definition stage.

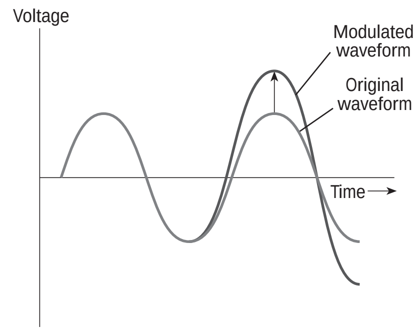

Figure 2. *An Amplitude-Shifted Sine Wave*

xDSL Delivers Broadband over Copper

The best thing about xDSL technologies is their ability to transport large amounts of information across existing copper telephone lines. This is possible because xDSL modems leverage signal processing techniques that insert and extract more digital data onto analog lines. The key is modulation, a process in which one signal modifies the property of another (see box on page 6).

In the case of digital subscriber lines, the modulating message signal from a sending modem alters the high-frequency carrier signal so that a composite wave, called a modulated wave, is formed (Figure 2). Because this high-frequency carrier signal can be modified, a large digital data payload can be carried in the modulated wave over greater distances than on ordinary copper pairs. When the transmission reaches its destination, the modulating message signal is recovered, or demodulated, by the receiving modem.

Technology and Applications Comparison

There has been a lot of speculation in the industry about which remote access technologies will succeed and which will fail. As new local access technologies are rolled out, they do not displace others; actually, the reverse is true. Technologies like analog dial-up, dedicated leased lines, Frame Relay, and ISDN all coexist successfully in the market based on differences in service availability and on their ability to generate incremental revenue by serving different applications.

DSL Modulation Schemes

There are many ways to alter the high-frequency carrier signal that results in a modulated wave. For ADSL, the most talked-about xDSL technology, there are two competing modulation schemes: carrierless amplitude phase (CAP) modulation and discrete multi-tone (DMT) modulation. CAP and DMT use the same fundamental modulation technique—quadrature amplitude modulation (QAM)—but differ in the way they apply it.

QAM, a bandwidth conservation process routinely used in modems, enables two digital carrier signals to occupy the same transmission bandwidth. With QAM, two independent message signals are used to modulate two carrier signals that have identical frequencies, but differ in amplitude and phase. QAM receivers are able to discern whether to use lower or higher numbers of amplitude and phase states to overcome noise and interference on the wire pair.

Carrierless Amplitude Phase (CAP) Modulation

Generating a modulated wave that carries amplitude and phase state changes is not easy. To overcome this challenge, the CAP version of QAM stores parts of a modulated message signal in memory and then reassembles the parts in the modulated wave. The carrier signal is suppressed before transmission because it contains no information and is reassembled at the receiving modem (hence the word "carrierless" in CAP). At start-up, CAP also tests the quality of the access line and implements the most efficient version of QAM to ensure satisfactory performance for individual signal transmissions. CAP is normally FDM based.

CAP, a single carrier system, has several advantages: it is available today at 1.544 Mbps (T1) speeds, and it is low on the cost curve due to its simplicity. It has the disadvantage that it is not a bona fide American National Standards Institute (ANSI) or European Telecom Standards Institute (ETSI) standard.

Discrete Multi-Tone (DMT) Modulation

DMT offers a multicarrier alternative to QAM. Because high-frequency signals on copper lines suffer more loss in the presence of noise, DMT discretely divides the available frequencies into 256 subchannels, or tones. As with CAP, a test occurs at startup to determine the carrying capacity of each subchannel. Incoming data is then broken down into a variety of bits and distributed to a specific combination of subchannels based on their ability to carry the transmission. To rise above noise, more data resides in the lower frequencies and less in the upper ones.

DMT's main advantage is the fact that it is the ANSI, ETSI, and ITU standard. But DMT also has drawbacks: it will initially be more costly than CAP, and it is very complex. A variant of DMT, discrete wavelet multi-tone (DWMT), goes a step further in complexity and performance by creating even more isolation between subchannels. When fully developed, DWMT could become the ADSL protocol of choice for long-distance transmission in environments with high interference. Other versions of DMT, including Synchronized DMT and "Zipper" are being proposed for use with VDSL.

The fact that so many WAN services continue to coexist often leads to confusion and complexity for enterprise network managers and planners. The range of services will certainly continue into the next century. Factors that will determine the success of one technology versus another include availability, pricing, ease of installation and use, and relevance to users' applications. Some of the key issues surrounding xDSL and competing technologies are summarized in this section.

56 Kbps Analog Modems

56 Kbps analog modems (ITU V.90 standard) provide a range of midband (28.8 to 56 Kbps) access to the Internet, intranets, and remote LANs.

In order to realize 56 Kbps throughput, there must be a 56 Kbps modem using compatible modulation techniques at each end of the connection. Therefore, NSPs and ISPs must have V.90 modems at their points of presence. A single 56 Kbps modem at the user's site will deliver the next highest speed with which it can synch up. Even when 56 Kbps modems are installed at both the carrier and user sites, these modems achieve top speeds only if the connection has just a single analog/digital conversion, and actual throughput is determined by line quality.

Another important fact to keep in mind is that this technology is asymmetric. The 56 Kbps rate is only achieved downstream on a digital line from the network to the user. The upstream connection is analog and operates in the 28.8 to 33.3 Kbps range.

ISDN

ISDN is also considered a digital subscriber line service. ISDN and xDSL technologies share some common technical characteristics: use of the existing telephone company copper cabling infrastructure; digital quality-of-service capabilities such as low noise, less interference, and clearer voice transmission; and the security of digital communications, which is inherently more difficult to tap than traditional analog systems.

However, ISDN differs from xDSL technologies in that it is a switched service in which both ends must support ISDN, whereas xDSL is a point-to-point access service. ISDN also requires external power for operation. To ensure continuous operation, customers need either a backup power system or a redundant POTS line. In contrast, xDSL carries its own power on the line. Voice and data transmission is split (multiplexed) on the wire: voice is carried under 4 kHz; data is carried above 4 kHz. If a power failure occurs, xDSL data transmission is lost, but lifeline POTS still operates.

Another key difference is that ISDN is widely available now and has momentum in the marketplace. Telcos, competitive access providers, and ISPs are investing the resources and building out the infrastructure to develop it further. As ISDN modems and terminal adapters become easier for users to configure, customer premises equipment (CPE) prices continue to drop, and tariffs are reduced, ISDN is gaining broader appeal among telecommuters and small office and retail users who require Internet and intranet access, remote LAN access, credit authorization, or database connectivity.

Cable Modems

Designed to provide broadband Internet access, cable modems are primarily targeted at consumers for residential use. Cable modems offer the potential of broadband (up to 30 Mbps) information delivery downstream to users and midband (128 Kbps) to broadband (up to 10 Mbps) connections back upstream to the cable headend. Unlike xDSL and ISDN, cable modems are a shared—not dedicated—access technology. The total available bandwidth is shared among users in a neighborhood as if they were on a LAN. Given that design, not everyone on the network will get the top speeds of 10 to 30 Mbps that are quoted for downstream throughput. Actual rates will vary according to the number of users on the system at any given time and the type of modem that is being used. Security is also an issue on these shared access systems.

The multimedia cable network system (MCNS) standard for the delivery of data over cable has been defined and is being adopted by major multiple system operators (MSOs) and cable modem manufacturers. Its adoption adds more stability to cable as a data transmission technology. However, the widespread introduction of cable modems is still contingent upon the development and implementation of complex, two-way transmission systems and operations systems for management and billing. Today's systems are primarily telco return, in which phone lines are used to provide upstream transmission.

Another hurdle that cable modems must overcome is negative perceptions about the quality of service delivered by cable systems. Some users are approaching the use of cable modems for data transfer with caution. For cable modem access providers to be successful, they must be able to compete not only on price, but also on reliability of service.

xDSL

For all intents and purposes, xDSL modems can be considered "next-generation" modems, initially targeted for business users. xDSL technologies are being positioned for a wide range of data dialtone, video dialtone, voice, and PBX interconnect applications. For the near term, however, the trend continues to be toward data applications, with voice-over-IP emerging as a new application.

While xDSL technologies hold a lot of promise, there are a number of critical issues to be resolved before they can achieve widespread commercial deployment. Standards are now agreed upon. During 1996–1997, standards bodies split along the partisan lines of DMT versus CAP modulation schemes (see box on page 6). In January 1998, ANSI re-ratified DMT as the standard of choice, and the ITU adopted it in February 1998.

Other ongoing issues for xDSL technologies include interoperability, spectral compatibility (e.g., interference between different services carried in the same cable binder), near-end crosstalk associated with reverse ADSL provisioning, and loop qualification. A nontechnical but critical factor will be how successfully NSPs move from xDSL technology and market trials to commercial rollout.

Sometime in the next three to five years, xDSL technology could potentially be used to deliver Asynchronous Transfer Mode (ATM) to the home over the existing copper infrastructure or via a hybrid fiber/copper network. Efforts to define the standards for doing this are now under way in ANSI, ETSI, the ADSL Forum, the ATM Forum, and the Full Service Access Network (FSAN) Council. While joint development efforts are proceeding, considerably more cooperative work is needed before these organizations can agree upon a set of standards that will enable the delivery of low-cost, end-to-end ATM to the desktop over xDSL.

ADSL Development and Deployment Progress

Of all the emerging xDSL technologies, ADSL is receiving the most attention because there is a standard (DMT) for it, and its capabilities provide NSPs with a competitive offering to cable modems. But there is increasing interest in symmetrical xDSL offerings such as HDSL and SDSL.

As a local access service, ADSL's implementation has no critical drawbacks. It can be deployed as an overlay network where there is subscriber demand, eliminating the need for NSPs to risk building out their infrastructure unnecessarily in the hope that the technology will catch on.

ADSL development and deployment is focused primarily in North America, followed by northern Europe and the Pacific Rim. In North America, US West, GTE, Ameritech, SBC, BellSouth, and Edmonton Tel (Canada) are the service providers leading the current wave of ADSL/xDSL deployment. Covad, Northpoint, and a handful of other CLECs are entering high-density metropolitan areas—typically offering a portfolio of xDSL offerings at different classes of service and price points, and competing with incumbent local exchange carriers. Chicago-based InterAccess was the first ISP to offer ADSL. Telia (Sweden), Telenor (Norway), British Telecom (UK), and Telfonica (Spain) are leading xDSL proponents in Europe. In the Pacific Rim, Telstra (Australia), Hong Kong Telecom, and Singtel (Singapore) are deploying xDSL for data and video applications.

ADSL modems have been tested successfully by more than 40 telephone companies, and close to 50,000 lines have been installed in various technology trials and commercial deployments. Increasingly, alternative service providers such as enterprises, multi-tenant building owners, hospitality businesses (hotels and resorts), and office park developers are offering or considering offering ADSL to their users as private network operators.

Getting Started with ADSL

ADSL is not yet generally available. It is an emerging technology that is predominantly in the early commercial deployment stage. NSPs still must put in place the overlay networks to handle commercial service offerings, and network equipment vendors must build production-level DMT systems. Users can expect to see ADSL products and services introduced throughout 1998, followed by more widespread deployment in 1999 and 2000.

ADSL Suppliers

xDSL suppliers generally fall into three categories:

- Component manufacturers
- Systems providers
- Service providers

Component manufacturers provide the chips, modems, and POTS splitters used at both ends of a line to receive, send, and process digital data. Systems providers offer end-to-end solutions that include modems, splitters, and multiplexers as well as operations, administration, management, and technical support capabilities. Service providers offer xDSL access services and may or may not bundle products from component manufacturers or systems providers to offer their subscribers turnkey solutions.

Prospective users of ADSL need to determine whether their local service provider offers a turnkey solution, or whether they must work directly with equipment manufacturers, value-added resellers, or systems integrators. It is possible that ADSL modems will be available at retail outlets during 1999 in a number of markets where service is deployed.

Network Design: What's Needed

Figure 3 illustrates the various components of an ADSL network. It includes both NSP components (central office) and user components (including branch offices, small offices, and home offices).

Potential users of ADSL will need the following:

- An ADSL modem (compatible with the one at the NSP's point of presence)
- A POTS splitter to separate voice and data transmissions (unless using ADSL Lite)

Since the ADSL modem essentially front-ends a LAN (or is capable of doing so), branch office or small business users will need a router or hub; home users will need a computer interface.

Providers of ADSL services will need modems and POTS splitters in their digital subscriber line access multiplexer (DSLAM) to terminate and aggregate incoming ADSL lines and redirect voice traffic to the public switched telephone network (PSTN) and data to a high-speed digital line (DS3, OC-3, or OC-12). The DSLAM is the major intelligence component in the ADSL system. It consists of central site modems and a service access multiplexer (SAM) that interfaces to the NSP's ATM or Frame Relay backbone. The ADSL service provisioning model includes two types of DSLAM: the central office DSLAM is built for high density and concentration, while the remote DSLAM sits in the remote DLC system. Service providers will also need billing systems, testing and diagnostic functionality, and network management capabilities.

Significant development work is still needed by NSPs and equipment manufacturers

Upgrading Digital Loop Carriers (DLCs)

The DLC system is the carrier's local loop infrastructure that connects end users located more than 18,000 feet, or 3.5 miles, from the central office. DLC systems consist of physical pedestals containing line cards that concentrate residential traffic onto digital circuits. To provide end users with ADSL capability, NSPs will simply retrofit the line cards in the DLC systems. This is a very cost-effective solution for NSPs, because they are not required to update their infrastructure to provide ADSL services. It is estimated that 30 percent of U. S. telephone customers are on DLC systems. These systems tend to be concentrated in the suburbs, where more affluent people reside; the initial residential target audience for ADSL service will be this suburban population.

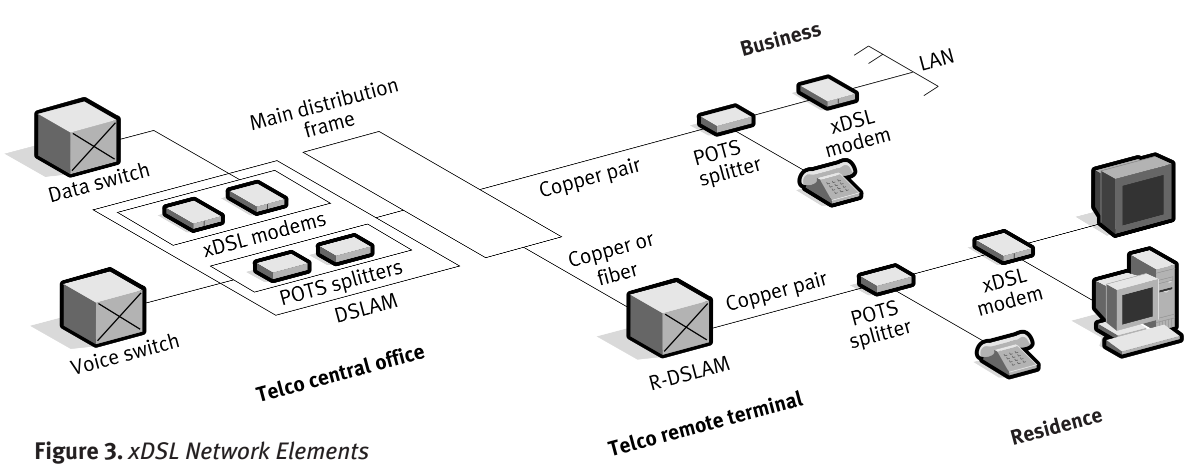

Figure 3. *xDSL Network Elements*

alike to develop more affordable, scalable, interoperable, and easily provisioned ADSL systems. But this is an exciting emerging technology that will initially provide high-bandwidth local access for enterprise networks and teleworkers.

Conclusion

xDSL technology—with its ability to support voice, content-rich data, and video applications over the installed base of twisted-pair copper wires—is inherently suited to meet user demands for broadband, multimedia communications. The most promising of the xDSL technologies for integrated Internet access, intranet access, remote LAN access, video-on-demand, and lifeline POTS applications in the near term is ADSL or R-ADSL (a rate-adaptive version of ADSL). During the past year, ADSL has concluded trials by more than 40 network service providers throughout the world, primarily in North America and northern Europe.

Service introduction began in 1997, but ADSL service is still being rolled out in many areas. In the meantime, xDSL technologies and standards will continue to evolve, as will user demand for these emerging services relative to other local access service alternatives.

3Com has been shipping its end-to-end, standards-based xDSL solutions since June 1997. With 3Com as a partner, telecom and enterprise NSPs can provision xDSL in a way that leverages their existing infrastructure and service delivery model, adding xDSL equipment as demand grows.

Glossary of Related Terms

ADSL. Asymmetric digital subscriber line. An xDSL technology in which modems attached to twisted-pair copper wires transmit from 1.5 to 8 Mbps downstream (to the subscriber) and from 16 to 640 Kbps upstream, depending on the line distance.

amplitude. The maximum value of varying wave forms.

ANSI. American National Standards Institute. The principal standards development body in the United States. It consists of voluntary members that represent the U.S. in the International Standards Organization (ISO). Membership includes manufacturers, common carriers, and other national standards organizations, such as the Institute of Electrical and Electronics Engineers (IEEE).

ATM. Asynchronous Transfer Mode. A switching technology that allows voice, data, image, and video traffic to be combined into evenly sized cells for high-speed transmission over one access circuit. Each 53 byte cell contains 48 bytes of payload and 5 bytes of control information.

AWG. American Wire Gauge. A wire diameter specification; the lower the AWG number, the larger the wire diameter.

backbone network. The major transmission path for network interconnection.

broadband. A communication channel with a bandwidth in excess of 1.54 Mbps.

CAP. Carrierless amplitude phase modulation. A version of quadrature amplitude modulation (QAM) that stores parts of a modulated message signal in memory and then reassembles the parts in the modulated wave. The carrier signal is suppressed before transmission because it contains no information and is reassembled at the receiving modem (hence the word “carrierless” in CAP).

CLEC. Competitive local exchange carrier. An alternative access provider that competes with incumbent local carriers.

CO. Central office. A facility that contains the lowest node in the hierarchy of switches that comprise the public telephone network.

core network. A combination of switching offices and transmission plant that connects switching offices together. In the U.S. local exchange, core networks are linked by several competing interexchange networks. In the rest of the world, core networks extend to national boundaries.

CPE. Customer premises equipment.

dial up. A type of communications that is established by a switched circuit connection using the public telephone network.

DLC. Digital loop carrier. The carrier's local loop infrastructure that connects end users located more than 18,000 feet or 3.5 miles away from the central office. DLC systems consist of physical pedestals containing line cards that concentrate residential links onto digital circuits.

DMT. Discrete multi-tone modulation. A wave modulation scheme that discretely divides the available frequencies into 256 subchannels or tones to avoid high-frequency signal loss caused by noise on copper lines.

DSL. Digital subscriber line. A local loop access technology that calls for modems on either end of copper twisted-pair wire to deliver data, voice, and video information over a dedicated digital network.

DSLAM. Digital subscriber line access multiplexer. Multiplexing equipment that contains a high concentration of central office splitters, xDSL modems, and other electronics to connect traffic to the wide area network (WAN).

DWMT. Discrete wavelet multi-tone. A variant of DMT modulation, DWMT goes a step further in complexity and performance by creating even more isolation between subchannels.

E1. The European basic multiplex rate that carries 30 voice channels in a 256-bit frame transmitted at 2.048 Mbps.

echo cancellation. A technique used by ADSL, V.32, and V.34 modems that isolates and filters unwanted signal energy from echoes caused by the main transmitted signal.

ETSI. European Telecom Standards Institute. A consortium of manufacturers, service carriers, and others responsible for setting technical standards in the European telecommunications industry.

FDM. Frequency division multiplexing. A technique that divides the available bandwidth of a channel into a number of separate channels.

frequency. The rate of signal oscillation in hertz (Hz).

FSAN. Full Service Access Network Council. A consortium of European service providers (PTTs) responsible for defining access network requirements.

HDSL. High bit-rate digital subscriber line. An xDSL technology in which modems on either end of two or more twisted-pair lines deliver symmetric T1 or E1 speeds. Currently, T1 requires two lines and E1 requires three.

HDTV. High-definition television. A system of transmitting television signals at 24 Mbps, which increases the horizontal lines of resolution from 480 to 560 lines per display.

IDSL. ISDN digital subscriber line. An xDSL technology that provides full duplex throughput at speeds up to 144 Kbps based on the 2B1Q ISDN modulation code.

IEC. Interexchange carrier. A long-distance service provider.

IEEE. Institute of Electrical and Electronics Engineers.

ILEC. Incumbent local exchange carrier.

ISDN. Integrated Services Digital Network. A digital subscriber line network with circuit and packet switching capabilities for voice and data communications at data rates of up to 1.544 or 2.048 Mbps.

ISO. International Standards Organization.

ISP. Internet service provider.

ITU. International Telecommunications Union. An international standards body, formerly called the CCITT.

Kbps. Kilobits per second.

LAN. Local area network. A type of broadcast network, covering a limited area, in which computers and other devices are attached to a common transmission medium.

local loop. The line from a subscriber to the telephone company central office.

Mbps. Megabits per second.

MCNS. Multimedia cable network system. A standard for the delivery of data over cable.

midband. A communication channel with a bandwidth range of 56 Kbps to 1 Mbps.

modem. Contraction for modulator/demodulator. A modem converts the serial digital data from a transmitting device into a form suitable for transmission over the analog telephone channel.

modulation. The process in which the characteristics of one wave or signal are varied in accordance with another wave or signal. Modulation can alter frequency, phase, or amplitude characteristics.

MSO. Multiple system operator. Cable service providers owning two or more cable systems.

multiplex. Combining signals of multiple channels into one channel. This process provides multiple users with access to a single conductor or medium by transmitting in multiple distinct frequency bands (frequency division multiplexing, or FDM) or by assigning the same channel to different users at different times (time division multiplexing, or TDM).

multiplexer. Equipment that divides a data channel into two or more independent, fixed data channels of lower speed.

narrowband. A communications channel with a bandwidth of less than 56 Kbps.

NSP. Network service provider.

phase modulation. A technique that changes the characteristics of a generated sine wave or signal so that it will carry information.

POP. Point of presence. Physical access point to an IEC network.

POTS. Plain old telephone service.

POTS splitter. A passive filter that separates voice traffic from data traffic.

PSTN. Public switched telephone network. A telephone system through which users can be connected by dialing specific telephone numbers.

QAM. Quadrature amplitude modulation. A bandwidth conservation process routinely used in modems, QAM enables two digital carrier signals to occupy the same transmission bandwidth.

R-ADSL. Rate-adaptive digital subscriber line. An emerging variation of CAP; it divides the transmission spectrum into discrete subchannels and adjusts each signal transmission according to line quality.

SAM. Service access multiplexer. A component of the DSLAM.

SDMT. Synchronized DMT. A multicarrier modulation scheme that adds time division duplexing on top of DMT systems and permits transmit and receive in discrete time slots. Proposed for use with VDSL.

SDSL. Single-line digital subscriber line. SDSL is essentially HDSL over a single twisted pair.

SMDS. Switched Multimegabit Data Service. A connectionless, high-speed, packet-switched WAN technology offered by telephone companies.

SNMP. Simple Network Management Protocol.

T1. A 1.544 Mbps line; the same as DS1.

TDM. Time division multiplexing. A digital transmission method that combines signals from multiple sources on a common path. This common path is divided into a number of time slots and each signal or channel is assigned its own intermittent time slot, allowing the path to be shared by multiple channels.

telco. American jargon for telephone company.

twisted-pair. Telephone system cabling that consists of copper wires loosely twisted around each other to help cancel out any induced noise in balanced circuits.

UAWG. Universal ADSL Working Group. An industry group that supports the development of a worldwide G.Lite standard within the ITU Study Group 15.

VDSL. Very high bit-rate digital subscriber line. A technology in which modems enable access and communications over twisted-pair lines at a data rate from 1.54 Mbps to 52 Mbps. VDSL has a maximum operating range from 1,000 feet to 4,500 feet on 24-gauge wire.

WAN. Wide area network. A geographically dispersed network.

xDSL. The “x” represents the various forms of digital subscriber line (DSL) technologies: ADSL, R-ADSL, HDSL, SDSL, or VDSL.

Zipper. A DMT-based modulation scheme using frequency division multiplexing. It requires synchronization of systems within the same bundle. Proposed for use with VDSL.

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500624-003 3/99