The DSL SOURCEBOOK

The Comprehensive Resource On Digital Subscriber Line Technology

Completely Revised from Cover to Cover
Featuring Dozens of New and Updated Network Diagrams
Plus an Introduction to Service Level Management for DSL Providers

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FOREWORD

WELCOME...

To the fast-paced, exciting (and sometimes confusing) world of DSL (Digital Subscriber Line) technology. While many broadband access methods are gunning for ownership of the local loop, you are about to learn that DSL technology has a distinct advantage that makes it one of the most viable options for the delivery of high-speed data services.

Unlike competing technologies, DSL eliminates the need for extensive and expensive infrastructure upgrades — improvements that are hard to measure in terms of time or money. Where original telephone company strategies centered on the time-consuming and costly task of fiber installation, demand for multimegabit services has forced them to evaluate approaches that leverage the existing infrastructure and provide a quicker time to market. That is one of DSL technology's chief advantages — the ability to transform the nearly 700 million phone lines installed worldwide into multimegabit data pipes capable of speeding digital voice and data to homes and businesses.

That ability has ignited the market, as telephone companies, PTTs (Post, Telephone and Telegraph administrations), Interexchange Carriers (IXCs) and Competitive Local Exchange Carriers (CLECs) alike move to evaluate and implement this exciting new technology. Today, nearly every major service provider worldwide is using or trying one form of DSL or another. The over-hyped information age is truly upon us as the aging copper plant continues its transformation into high-speed broadband networks. New, advanced applications surface almost daily, and expectations remain high that a host of new services – and tools to guarantee performance of those new services – will be launched thanks to DSL.

DSL's enormous promise has worked the telecommunications industry into a frenzy, seemingly overnight. As a cursory survey of the market shows, the amount of information and misinformation on this topic is astounding. Wading through the alphabet soup of acronyms and sorting through DSL fact and fiction is certainly time consuming. But DSL's big bandwidth payoff is truly worth that time. That is where *The DSL Sourcebook – The Comprehensive Resource on Digital Subscriber Line Technology* comes in. This Third Edition focuses on the state of the DSL evolution and examines emerging market requirements such as automated flow-through provisioning and end-to-end services delivery and management. These are bound to be the next great frontiers in DSL.

Service providers and service users who become familiar with the growing family of DSL technologies can avoid pitfalls by effectively matching the appropriate DSL transport to the application at hand. This Sourcebook will help to level out the steep DSL learning curve and reduce the time it takes to select and implement the best technology for your given application.

While there are many hurdles in implementing any new technology, this book will help to speed you on to utilizing the hottest transport to hit the local loop in years.

Paradyne, a leader in the DSL equipment market, and TeleChoice, a leader in consulting services, are proud to bring you this concise and informative Sourcebook.

Patrick Hurley
Broadband Consultant
TeleChoice, Inc.

PREFACE

ABOUT THE SOURCEBOOK

The copper wire telephone infrastructure is everywhere. If you want to understand how you can turn existing copper into high-speed network access links, this book is for you. We wrote *The DSL Sourcebook – The Comprehensive Resource on Digital Subscriber Line Technology* to assist you in making informed choices about this exciting new market. DSL technology is quickly gaining recognition and acceptance as a viable way to meet the ever-increasing demand for more bandwidth. As the Internet continues to evolve into a global on-line interface supporting multiple media types (data, audio and video), the bandwidth demand will continue to soar.

DSL-based services are **not** just about **speed**, nor about the explosive growth of the Internet. DSL-based services are about **application**s and **opportunities**. DSL technology offers a win-win scenario for both those who provision high-speed, value-added services and for the users of those services, who realize dramatic cost and performance benefits.

Business-critical applications require reliable performance, differentiated service guarantees, a highly scalable network management system to support hundreds of thousands of users and, of course, security. As you will see throughout this Third Edition of The DSL Sourcebook, DSL can meet the deployment challenges on all fronts. Our focus on the state of the DSL evolution will offer valuable insights into emerging market trends and the shift in design requirements to support today's total business-class applications. The evolution from yesterday's delivery of "best effort" Internet access to today's requirements for Wide Area Network (WAN) services in support of advanced business applications requires new levels of service quality and service management capabilities.

A wide range of residential and business-class services and applications are enhanced by DSL technology, which will be supported by the next-generation DSLAMs (DSL Access Multiplexers) to offer a full suite of Quality of Service (QoS) capabilities. These services and applications include:

- *Traditional T1/E1 Service Provisioning*
- *Connectivity in Private/Campus Network (Multiple Dwelling/Multiple Tenant) Environments*
- *IP Internet/Intranet Access Services*
- *IP Virtual Private Networks (VPNs)*
- *Frame Relay Services over DSL (FRoDSL)*
- *Asynchronous Transfer Mode (ATM) Services*
- *Derived Voice Services over DSL (VoDSL)*
- *Video Services*

Intended audiences for The DSL Sourcebook include:

- *Network Service Providers (NSPs) including:*
  - *Incumbent Local Exchange Carriers (ILECs)*
  - *Public Telephone Operators (PTOs)*
  - *Competitive Local Exchange Carriers (CLECs)*
  - *Independent Telephone Companies (ITCOs)*
  - *Internet Service Providers (ISPs)*
  - *Other Network Access Providers (NAPs)*

- *Owners of Private/Campus Networks*
- *Corporate Network Managers*
- *Commercial Service Users*
- *Resellers/Distributors of Wide Area Network Solutions*
- *Analyst and Press Community*

At Paradyne, we're in the unique position of having a rich history in digital network access, internetworking, network management, and service level management (SLM). Paradyne was an active pioneer in the development of DSL transceiver technology. This book is a compilation of information on DSL and our perspective of its applicability in today's marketplace. We have drawn heavily on our experience in field and market trials, worldwide deployments of over 10,500 DSLAMs representing over three million ports of capacity (through 2Q00), the DSL Forum technical and marketing committees, and numerous industry panel discussions in which we were invited speakers. We welcome any comments or questions you may have and hope you find The DSL Sourcebook a valuable reference tool for all your DSL initiatives.

OBJECTIVES

The objectives of The DSL Sourcebook are to:

- *Introduce basic DSL technology concepts from a historical perspective*
- *Describe how DSL technology works in the existing local loops*
- *Discuss emerging services and applications that have necessitated greater bandwidth within the network and local loop*
- *Detail considerations and network models for DSL-based service deployment*
- *Promote DSL-based service deployment*

ORGANIZATION

The DSL Sourcebook contains three main sections describing essentially the **WHAT, HOW** and **WHY** of DSL-based service deployment.

Chapters 1-4 provide the framework for the entire Sourcebook and cover the DSL basics, offer an understanding of the existing copper wire infrastructure, including the concept of private/campus networks, and offer a reference design that identifies the components required for DSL deployment.

Chapters 5-7 delve into DSL-based services and applications. They include detailed network topologies and models covering multiple approaches to DSL deployment and discuss such issues as protocols, security, and authentication.

Chapter 8 provides answers to some common questions about DSL-based services and will serve as a useful planning reference.

QUICK-SCAN TOOLS

Throughout the Sourcebook, you will find two quick-scan tools to help you navigate easily through the information.

- *Highly technical sections are offset in rules, targeting the reader who already has a relatively high understanding of DSL.*
- *Chapter Summaries are provided at the end of most chapters.*

Chapter 1

INTRODUCTION

A CASE FOR DSL

Digital subscriber line technology is a copper-loop transmission technology that solves the bottleneck problem often associated with the last mile between network service providers and the users of those network services.

DSL technology achieves broadband speeds over the most universal network medium in the world: ordinary phone wire.

While DSL technology offers dramatic speed improvements (up to 8+ Mbps) compared to other network access methods, the real strength of DSL-based services lies in the opportunities driven by:

- *Multimedia applications required by today's network users*
- *Performance and reliability*
- *Economics*

As shown below in a sample comparison diagram, DSL-based services provide performance advantages for network service users compared to other network access methods. In addition, DSL-based services extend these operational improvements for both public and private (campus) network operators. The concepts below will be covered in greater detail in Chapter 7, Network Models. However, for the purpose of this comparison, the Service User (endpoint location) gains access to an NSP network through a Network Access Provider network.

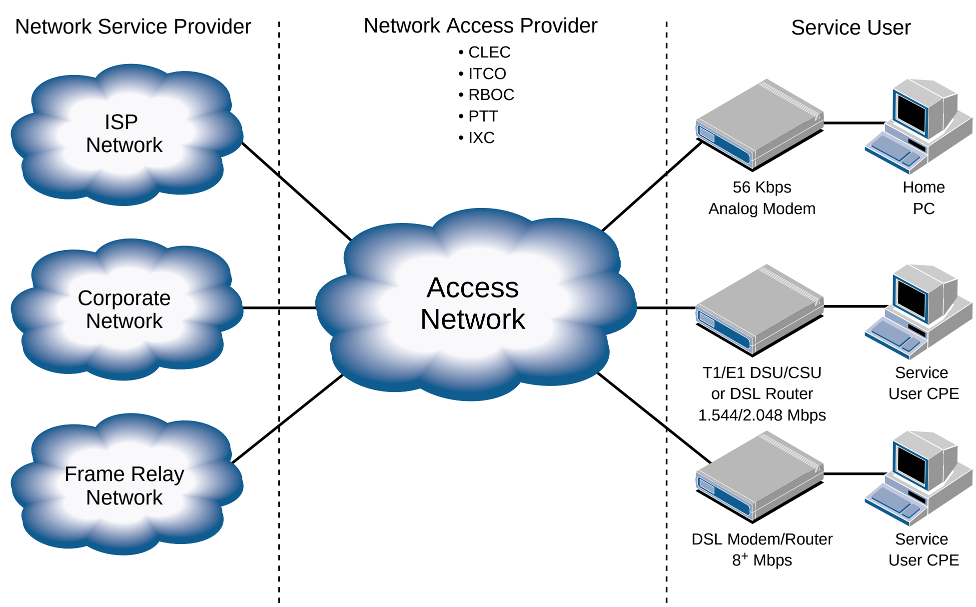


FIGURE 1-1 Speed and Performance Comparison

Imagine having the ability to:

- *Offer enhanced new services that would be valued by your customers*
- *Flexibly offer multiple services with differing tiers of bandwidth, performance guarantees, and pricing*
- *Reliably and easily deliver and manage business-critical applications*
- *Utilize new services to perform your work at speeds you once only dreamed possible*

One of the most compelling benefits of DSL technology is that it allows the NSP and the service user to take full advantage of existing infrastructures, Layer two and Layer three protocols (such as frame relay, ATM and IP), and the reliable network services they have already come to trust. In an evolving market such as DSL, support for multiple service types on a single platform offers an important investment protection. The evolving DSL market includes both packet and cell-based services such as ATM, frame relay, and IP as well as bit synchronous channelized services. Next-generation DSLAM architectures that support multiple services, technologies and transports ensure that the infrastructure investment already in place remains protected.

DSL can easily support advanced business-class services like derived Voice over DSL (VoDSL) and new variations of proven and well understood technologies such as Frame Relay over DSL (FRoDSL), with the newest generations of DSL equipment offering end-to-end service level management (SLM). To keep things simple, in our discussion of business-class DSL applications, we will group everything under one new acronym: SLM-DSL.

One could argue that without service level management, there is no real business-class DSL, because business customers require differentiated services and are willing to pay a premium for performance guarantees on their mission-critical applications.

For example:

VoDSL provides multi-line (typically 4-12 phone lines) voice capability over a DSL connection using low-latency ATM virtual circuits. Voice traffic is routed to a VoDSL gateway and then onto the PSTN (Public Switched Telephone Network). This approach offers DSL customers the cost and convenience advantages of using a single service provider for both data and voice needs, without the need to have additional phone lines provisioned. A single copper pair can meet both the voice and data needs of many small- or medium -size businesses. How? DSL networks are packet-based, allowing VoDSL solutions to use the bandwidth of a DSL connection dynamically. This means that voice calls only need to consume bandwidth when a call is active, and due to the low bandwidth utilization of voice services relative to data services, several voice calls can traverse a DSL connection simultaneously (see Figure 1-2).

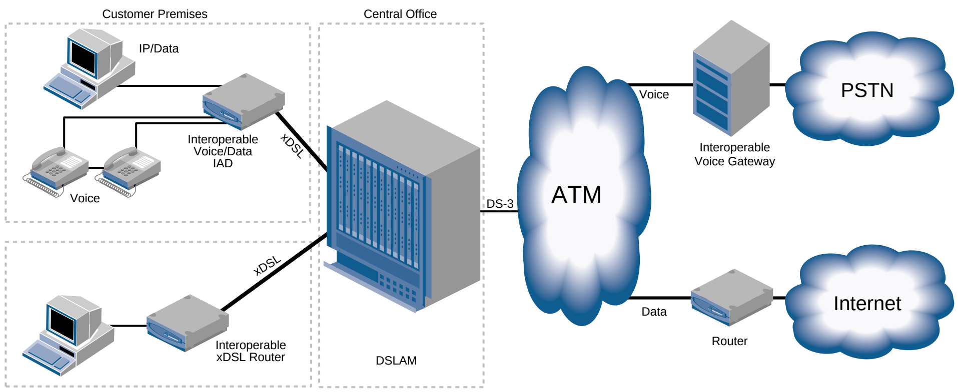


FIGURE 1-2
VoDSL Application

The business customer can't lose. The savings realized more than offset the premium they'll pay for the derived voice channels and the Real-Time Variable Bit Rate (rt-VBR) QoS classification they'll want to ensure toll-quality performance.

FRoDSL, when combined with an end-to-end service level management system, fulfills both critical elements of the value proposition:

1.Economical access to the frame relay network
2.Equivalent or better service performance guarantees

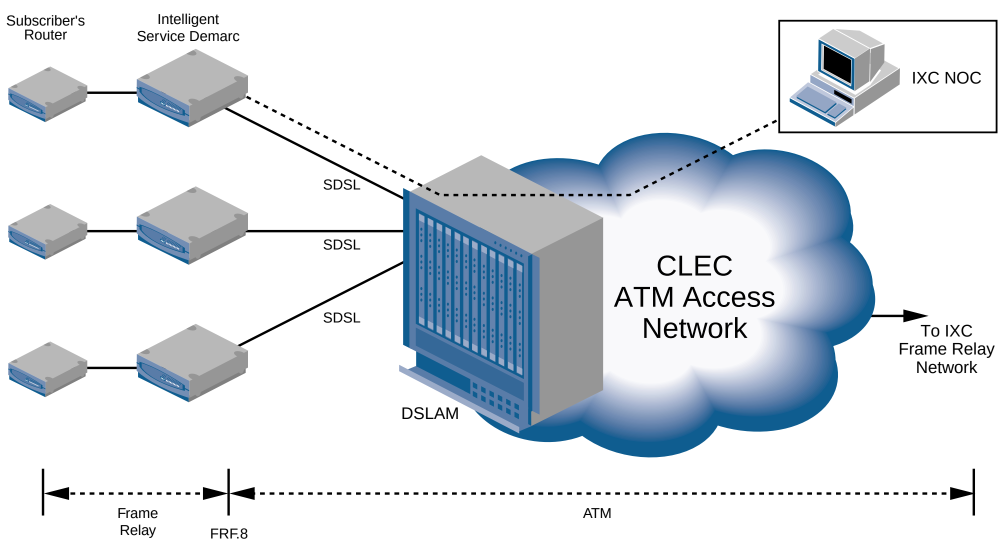


FIGURE 1-3
SLM-DSL (FRoDSL) Wholesale Application

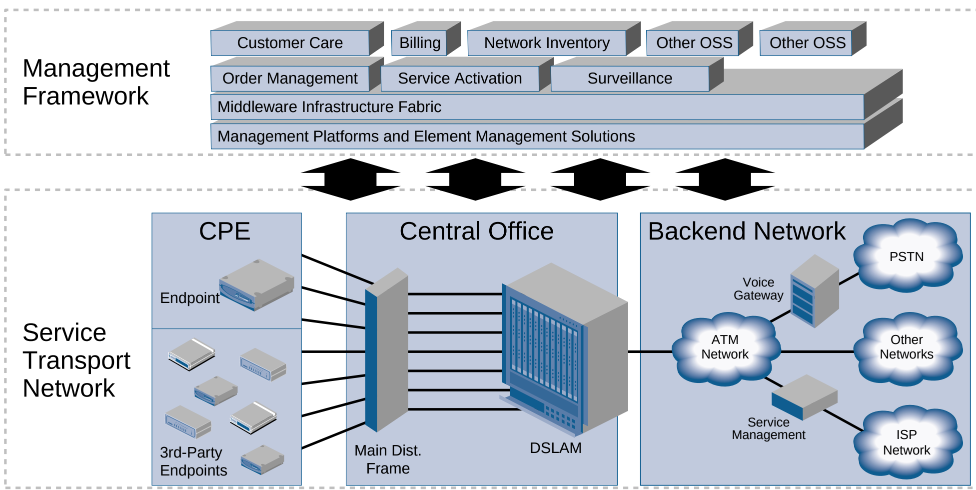
In short, FRoDSL allows business customers to do what they've already been doing for quite some time – only at a lower cost. FRoDSL will significantly lower the cost of provisioning frame relay services to a customer by reducing the cost of the local access portion of the network. Typically, frame relay customers utilizing private line access to the network spend up to 38 percent of their total costs just on this access. Using a lower-cost DSL access, along with an end-to-end service level management system that can ensure the same quality of service as private lines, can bring considerable cost savings to the provisioning of frame relay, particularly for the frame relay service providers who have been forced to lease the access component from Local Exchange Carriers (LECs).

With the rapid changes in the overall networking environment, one winning strategy for DSL-based service deployment is to build in the flexibility needed to support a range of applications. Chapter 8, Sourcebook in Review, includes a comprehensive checklist of considerations for DSL deployment planning. Some examples of key criteria for a flexible DSL-based system include:

- *Ability of the solution to support multiple service types on a single platform*
- *Scalability to support from a few users to hundreds of thousands of users*
- *Ability of the solution to provide reliable end-to-end network management in support of mission-critical applications*
- *Ease of provisioning and integration with higher-layer Operating Support System (OSS) applications*
- *Digital loop carrier (DLC) support*

The figure below shows the end-to-end services delivery and management framework. Best-in-class solutions need to consider interoperability at the Service Transport Level not only for third-party CPE, but for voice gateways, subscriber management systems and so forth. In addition, these elements must be easily integrated into the Management Framework – the higher-layer OSS applications.

FIGURE 1-4
End-to-End Services Delivery and Management Framework



After several years of commercial deployment of both symmetric and asymmetric high-speed applications, NSPs have recognized that DSL technology is not really the "next generation" of digital network access, but rather the "now generation" of digital network access.

Chapter 2

THE EXISTING COPPER WIRE INFRASTRUCTURE

TELEPHONE COMPANY NETWORKS

As noted in the introduction, DSL products bring entirely new service capabilities to the existing copper wire local access network. In order to understand the opportunities and challenges relating to the deployment of DSL-based services, it is useful to review the existing infrastructure of the telephone network.

The telephone networks currently in place within ILECs and PTOs represent a huge capital investment that has taken place over the last 120 years. This structure was primarily designed for voice services. Over time, telephone networks have undergone numerous modernization and infrastructure upgrades to take advantage of advancements in transmission and switching technologies. In particular, high-capacity, fiber optic transmission facilities currently exist in nearly every telephone company backbone network worldwide. The use of fiber optics improved the quality of the services, increased the capacity of traffic that can be supported over the backbone network, and reduced operational expenses for network operators.

As a result, high-capacity service capabilities exist between telephone company offices. However, the situation is very different when you look at the local loop access network, the last leg, which connects end service users to the telephone company backbone networks. Any discussion of the local loop and high-speed data services must start with an examination of the topology of the existing voice services physical network.

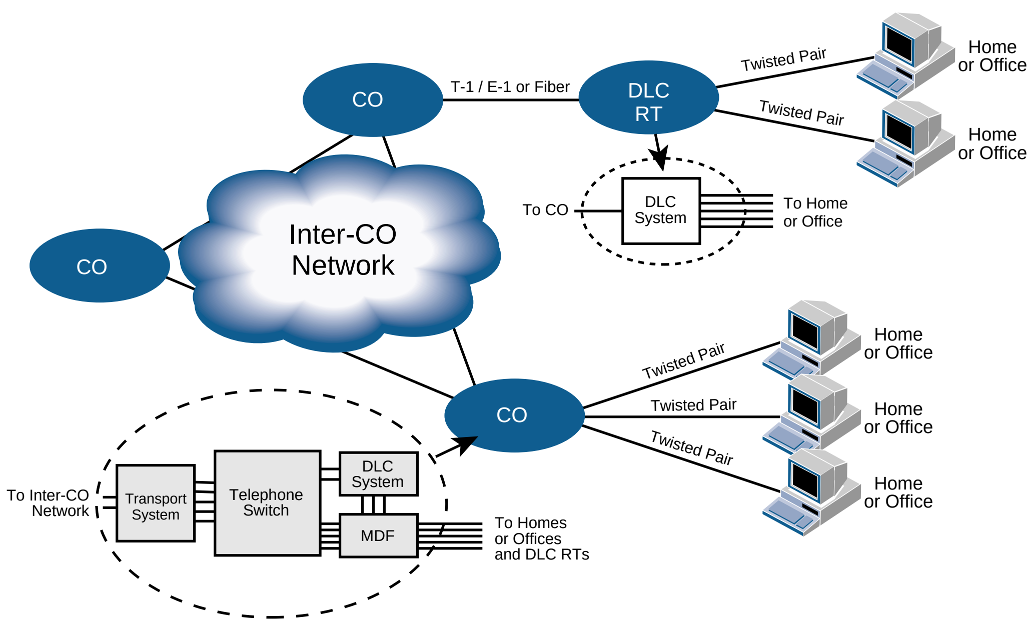


FIGURE 2-1
Typical Voice Network

CO = Central Office
RT = Remote Terminal
DLC = Digital Loop Carrier
MDF = Main Distribution Frame

Figure 2-1 represents a typical ILEC/PTO telephone network. Several central offices (COs) are depicted as being outfitted with telephone switches and transmission equipment, as well as digital loop carrier remote terminals (RTs).

From the home or office, twisted-pair copper wire local loops interconnect to the telephone switch through a main distribution frame (MDF). The MDF is the central point at which all local loops terminate in the CO.

Central offices are interconnected through an inter-CO network. This network consists of Digital Access and Cross-connect Systems (DACS) and T/E-carrier transmission equipment. Inter-CO networks have been upgraded to the latest in fiber optic ring technology (SONET or SDH).

THE ACCESS NETWORK

DSL is really an access technology, and the associated DSL equipment is deployed in the local access network. Therefore, it is very important to have a clear understanding of the local access network. Let's take a closer look.

The access network consists of the local loops and associated equipment that connects the service user location to the central office. This network typically consists of cable bundles carrying thousands of twisted-wire pairs to feeder distribution interfaces (FDIs). FDIs are points where dedicated cable is extended out to the individual service users.

Some service users are located a long way from the central office and require a very long local loop. One problem with very long loops is that the electrical signals dissipate energy as they traverse the loop, making the signals weak. In a very simplistic way, it is like a radio signal. As you go farther away from the transmitter, the weaker the signal gets, resulting in lower signal-to-noise levels.

Telephone companies found two primary ways to deal with long loops:

1. *Use loading coils to modify the electrical characteristics of the local loop, allowing better quality voice-frequency transmission over extended distances (typically greater than 18,000 feet). In this extended-distance scenario, loading coils are placed every 6,000 feet on the line.*

We will learn later that loading coils are not compatible with the higher frequency attributes of DSL transmissions and they must be removed before DSL-based services can be provisioned. The use of loading coils varies by telephone company and typically ranges from virtually none to as high as 20 percent of the local loops within a given telephone company's access network.

2. *Set up remote terminals where the signals could be terminated at an intermediate point, aggregated and backhauled to the central office, which houses the switching equipment and high-capacity transmission equipment or, in other cases, to a serving wire center (SWC) that does not have switching equipment but does have the transmission equipment that connects to other central offices. The backhaul to the CO or SWC via T1/E1 circuits may be based on copper or fiber-based technologies.*

While initial telephone networks terminated the copper wire loops directly in the CO, the combination of maintenance challenges associated with long loops and issues associated with provisioning an increasing number of loops created the need for architectural changes in the local access network. Unfortunately, the same fiber optics that could be justified from a CO connecting thousands of service users to other COs are not yet cost justified for individual users. Therefore, a compromise solution was to terminate loops at intermediate points using DLCs that are closer to the service users. These intermediate points are referred to as remote terminals.

One advantage of terminating the loops at the DLC remote terminal is that it reduces the effective length of the copper line, thus improving the reliability of the service. An additional benefit is that Plain Old Telephone Services (POTS) can be multiplexed into a higher-speed T1 (primarily a North American and Japanese standard supporting up to 24 digitized voice channels at 64 Kbps each) or E1 (an international standard used primarily by the rest of the world supporting up to 30 digitized voice channels) format for transmission to a central office over a single fiber optic or four-wire circuit. As we will see later, while the RT architecture solves many problems for POTS, it introduces complexities relative to the provisioning of DSL-based services.

DSL transmissions can only be supported over contiguous copper wire loops. Therefore, for a DSL-based service connected to an RT, the DSL portion must terminate at the RT, where the DSL transport is then converted to a format compatible with the DLC. The use of DLCs varies by telephone company and typically ranges from almost none to as high as 30 percent of the local loops within a given telephone company's access network.

Current projections estimate that nearly 700 million copper wire access lines connect homes and business customers to the Public Switched Telephone Network (PSTN) worldwide. More than 95 percent of the local access loops consist of a single-pair (two-wire circuit) twisted wire supporting POTS.

By definition, POTS is designed to carry a voice conversation, which for adequate fidelity requires the lines to handle frequencies from 0 Hz (hertz) up to about 3,400 Hz (1 Hz = 1 cycle per second). This narrowband service has historically supported only voice calls or analog modem transmissions at speeds commonly ranging from 9.6 to 33.6 kilobits per seconds (Kbps), and more recently approaching the 56 Kbps range.

On a global scale, a very small percentage of the PSTN connections are provisioned with Basic Rate Interface (BRI) Integrated Services Digital Network (ISDN) services. With Basic Rate ISDN, customers have the option of either two B-channels (Bearer channels) for one voice and one data, two voice, or two data (64 Kbps each); or 128 Kbps by combining both B-channels for data service. Basic Rate ISDN also provides a 16 Kbps D-channel (Data channel) that supports signaling for the B-channel and is capable of carrying packet data.

Basic Rate ISDN is a baseband service that is implemented using the lower 80,000 Hz of the frequency spectrum. As with newer DSL-based services, ISDN's use of frequencies above 3,400 Hz prevents its use over loops with loading coils, and special ISDN-compatible interface cards must be installed in the DLCs to pass ISDN service through to an ISDN-compatible switch.

DEDICATED T1/E1 ACCESS USING THE LOCAL LOOP NETWORK

A common surprise for many users is the realization that the same physical copper wire lines that are used to provision POTS and ISDN can be engineered and conditioned to provision T1/E1 services today as they have been for decades.

In some markets, the condition of the copper wire loops cannot be reliably engineered to support T1/E1 services. In these cases, T1/E1 services are provisioned using fiber optic cables.

Telephone companies have historically charged substantially higher recurring monthly service charges for a T1 or E1 access service, commonly ranging from $600 per month to $2,000 per month, compared to a more traditional $15 to $50 per month for an analog phone line. The perception is that special T1 or E1 circuits have to be deployed to support the high-speed services. In reality, the same copper wires are used, but special engineering design rules have to be followed.

Dedicated T1 or E1 access is higher priced in part due to the time and expense for the initial circuit engineering required to turn up the service and the cost to maintain the service. One reason for the strict engineering design guidelines and ongoing maintenance expense is that traditional T1 and E1 transmission equipment uses very simple modulation techniques, such as Alternate Mark Inversion (AMI) for T1 and High Density Bipolar 3 (HDB3) for E1, which were based on electronic circuitry developed over three decades ago.

Traditional T1 and E1 modulation techniques can only be supported over relatively short distances. As a result, the implementation of T1/E1 over longer loops requires that the loop be broken down into multiple concatenated stages with electronic repeaters at intermediate points to detect and regenerate the signal for transmission down to the next stage. The resulting special circuit engineering includes placing repeater equipment within 2,000 to 3,000 feet of the endpoints and not more than 3,000 to 6,000 feet between repeaters, depending on wire gauge.

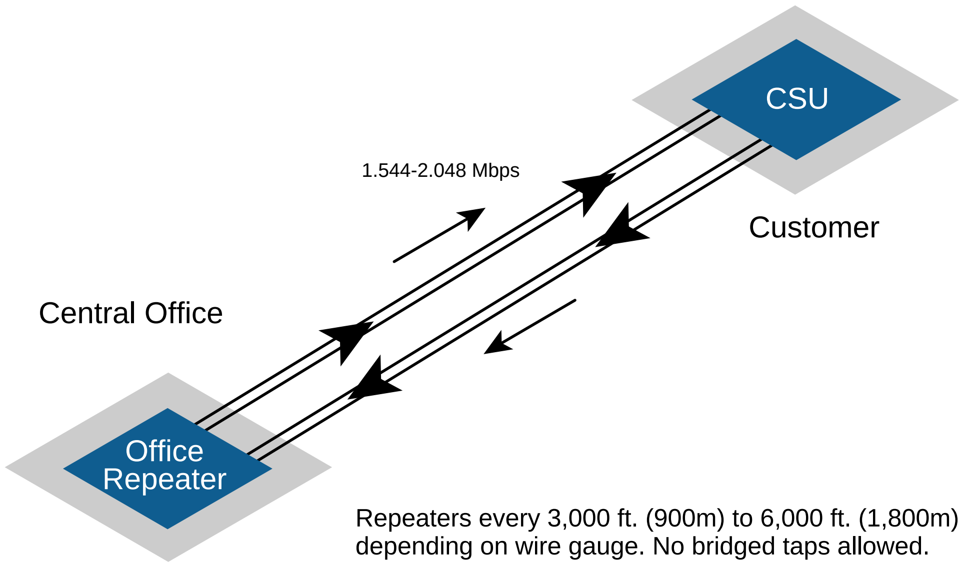


FIGURE 2-2
Traditional Repeatered T1/E1 Service Provisioning

By understanding how traditional T1 transmissions are implemented, we can more fully appreciate what DSL products do differently and why they are more effective. Let's take a closer look.

T1 is a digital service that receives digital information in the form of "1's" or "0's" from the adjoining system elements. As a function of the T1 AMI coding scheme, each bit of digital information is transmitted over the copper wire loop using an analog waveform that is modulated to represent a corresponding 1 or 0. That is, AMI coding schemes support 1 bit per baud, where a baud is one cycle of a sinusoidal waveform and the waveform is modulated to represent either a 1 or 0. The number of cycles per second is referred to as the frequency in hertz. Therefore, the transmission of the 1,536,000 bits of information payload, plus the associated framing and overhead information (which equals a total of 1,544,000 bits per second) requires use of the frequency spectrum from 0 to 1,544,000 Hz. A by-product of using these high frequencies is the distance limitation of less than 6,000 feet of 22-gauge wire between repeaters. As we will see in the next section, one solution to the distance limitation is to send more information with each baud or frequency cycle. Increasing the bits per baud results in the use of fewer frequencies and avoids some of the high-frequency attenuation, which in turn provides longer loop reach.

Traditional T1 and E1 transmission equipment cannot operate on loops that have bridged taps. As a result, all bridged taps have to be removed before traditional T1/E1 transmission equipment can be provisioned. While this may sound like a trivial exercise, the lack of proper documentation and opening and closing cable splices often makes the process of locating and removing bridged taps a time-consuming and therefore costly challenge.

A bridged tap is any portion of a loop that is not in the direct talking path between the CO and the service user's terminating equipment. A bridged tap may be an unused cable pair connected at an intermediate point or an extension of the circuit beyond the service user's location.

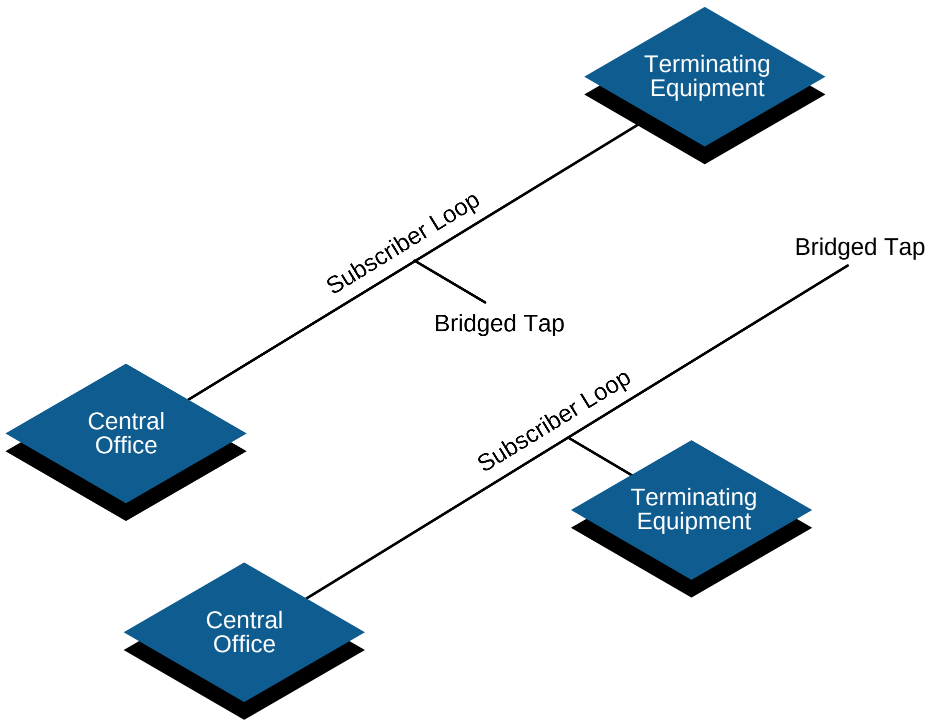


FIGURE 2-3 Examples of Bridged Taps

PRIVATE/CAMPUS NETWORKS

The sheer scale of 700 million local access lines has driven an industry focus on the telephone company access network. However, there is a significant market based on private copper wire networks that are, in some cases, isolated to a self-contained campus environment. Private/campus networks can often be visualized as a carrier-like architecture, where a single building or location on the campus acts as the hub (similar to a CO) and the remaining locations connect to this site using embedded copper wire on the campus. DSL technologies can dramatically improve operations within this environment, and this market segment is proving to be a potential early adopter of DSL-based solutions. Refer to Chapter 6, Emerging Services and Applications, for more information.

Chapter 2 Summary

- *Telephone network structure was primarily designed for voice-grade services.*
- *The use of fiber optics to increase the Quality of Service and traffic capacity while reducing operational expense has resulted in high-capacity service capabilities between COs, but not necessarily within the local access network that connects service users to the CO.*
- *DSL technology is a local access network technology.*
- *Use of remote terminals reduces effective length of the telephone line and improves service reliability.*
- *Historically, distance limitations in the local loop have required the use of repeaters and the removal of unused bridged taps to support high-speed data. DSL technology overcomes these limitations.*
- *Beyond the boundary of the local access network, the private/campus network environment is well suited for deployment of DSL-based services.*

Chapter 3

DSL BASICS

A wide array of DSL technologies and products have entered the market, bringing with them both opportunity and confusion. This chapter provides an overview of the technology that makes it possible to transmit information over copper wire loops and the evolution of the various DSL technologies. With this understanding, you can be better prepared to assess DSL technology and the associated products.

BASIC DSL CONCEPTS

The PSTN and supporting local access networks were designed with guidelines that limited transmissions to a 3,400 Hz analog voice channel. For example, telephones, dial modems, fax modems, and private line modems limited their transmissions over the local access phone lines to the frequency spectrum that exists between 0 Hz and 3,400 Hz. The highest achievable information rate using that 3,400 Hz frequency spectrum is less than 56 Kbps.

So how does DSL technology achieve information rates in the millions of bits per second over those same copper loops?

The answer is simple – eliminate the 3,400 Hz boundary. DSL, much like traditional T1 or E1, uses a much broader range of frequencies than the voice channel. Such an implementation requires transmission of information over a wide range of frequencies from one end of the copper wire loop to another complementary device, which receives the wide frequency signal at the far end of the copper loop.

Now, recognizing that we can choose to eliminate the 3,400 Hz frequency boundary and dramatically increase the information rates supported on copper wires, you may be asking, "Why don't we just ignore POTS transmission guidelines and use the higher frequencies?" The answer can get far more complex than we want to cover in this Sourcebook, so we will consider the three dominant issues associated with this question:

1. *Attenuation - The dissipation of the power of a transmitted signal as it travels over the copper wire line. In-home wiring also contributes to attenuation.*
2. *Bridged taps - These are unterminated extensions of the loop that cause additional loop loss with loss peaks surrounding the frequency of the quarter wavelength of the extension length.*
3. *Crosstalk - The interference between two wires in the same bundle, caused by the electrical energy carried by each.*

ATTENUATION AND RESULTING DISTANCE LIMITATIONS

One might compare the transmission of an electric signal to driving a car. The faster you go, the more energy you burn over a given distance and the sooner you have to refuel. With electrical signals transmitted over a copper wire line, the use of higher frequencies to support higher-speed services also results in shorter loop reach. This is because high-frequency signals transmitted over metallic loops attenuate energy faster than the lower-frequency signals.

One way to minimize attenuation is to use lower-resistance wire. Thick wires have less resistance than thin wires, which in turn means less signal attenuation and, thus, the signal can travel a longer distance. Of course, thicker-gauge wire means more copper, which translates into higher per-foot plant costs. Therefore, telephone companies have designed their cable plant using the thinnest gauge wire that could support the required services.

In the U.S., wire thickness is represented by the denominator composed of the fraction of an inch in wire size, assuming a numerator of 1. Therefore, a wire that is 1/24 inch in diameter is referred to as 24 AWG (American Wire Gauge). Wire gauges of 24, and more often 26, are present in most North American cable plants. The design rules used by nearly all telephone companies provided for a change in wire gauge with a thinner gauge used near the entrance of a central office to minimize physical space requirements and changing to thicker gauges over long loops to maximize loop reach.

In most markets outside of North America, wire gauges are referred to by their diameter in millimeters. For example, 0.4 mm, which is comparable to 26 gauge, and 0.5 mm, which is comparable to 24 gauge, are the most common; although in many developing countries, heavy gauges of 0.6 mm to 0.9 mm can be found in newly urbanized areas. This variation in wire gauge adds to the challenge of determining a particular DSL system's performance over a particular loop.

ADVANCED MODULATION TECHNIQUES MINIMIZE ATTENUATION

In the early 1980's, equipment vendors were working aggressively to develop Basic Rate ISDN, which would provide up to two 64 Kbps B-channels, plus a 16 Kbps D-channel used for signaling and packet data. The information payload, plus other overhead associated with implementation, resulted in 160 Kbps in total transmitted information. A key requirement of ISDN was that it had to reach customers over the existing non-loaded copper wire loops, equating to 18,000 feet. However, an AMI implementation of Basic Rate ISDN would require use of the lower 160,000 Hz, which resulted in too much signal attenuation and would fall short of the required 18,000 feet loop reach on 26-gauge wire.

By 1988, advancements in signal processing and line coding doubled the effectiveness of legacy AMI code by sending two bits of information with each cycle of an analog waveform or baud. The line code was called 2 Binary, 1 Quaternary (2B1Q). A 2B1Q implementation of Basic Rate ISDN uses frequencies ranging from 0 to approximately 80,000 Hz, which has less attenuation and results in the desired 18,000-foot loop reach.

HDSL Enters the Scene

In the early 1990's, some vendors encouraged the use of 2B1Q at higher speeds as an alternate way to provision T1 and E1 services, without repeaters. The technique consisted of splitting the 1,544,000-bit-per-second service into two pairs (four wires), which each ran at 784,000 bits per second. By splitting the service across two lines and increasing the bits per baud, the per-line speed and resulting need for frequency spectrum could be reduced to allow longer loop reach. This technique was referred to as High-bit-rate Digital Subscriber Line, or HDSL. The result was that an HDSL-based DS-1 service could be implemented over Carrier Serving Area (CSA) specified loops of up to 12,000 feet long (assuming 24 gauge; or 9,000 feet with 26-gauge wire), with no repeaters.

The early 2B1Q-based E1 HDSL initiatives split the 2.048 Mbps service across three wire pairs (a total of six wires) in an effort to achieve the targeted loop reach. As the technology matured and performance improved, E1 HDSL implementations migrated to a two-pair (four-wire) implementation, each operating at 1.168 Mbps, which was similar to the T1 implementations.

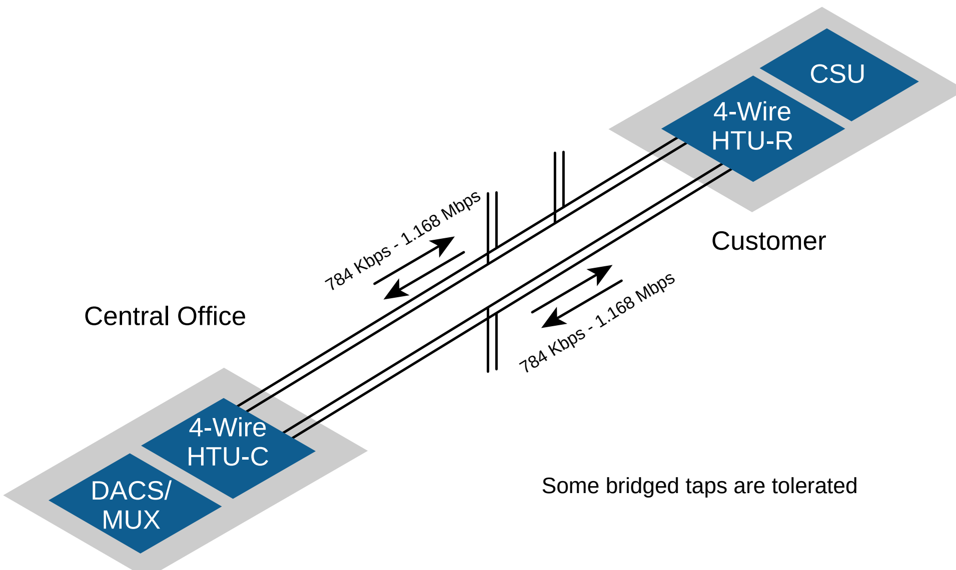


FIGURE 3-1
Repeaterless T1/E1 Replacement Model. HTU-C is the HDSL Termination Unit/Central Office and HTU-R is the HDSL Termination Unit - Remote

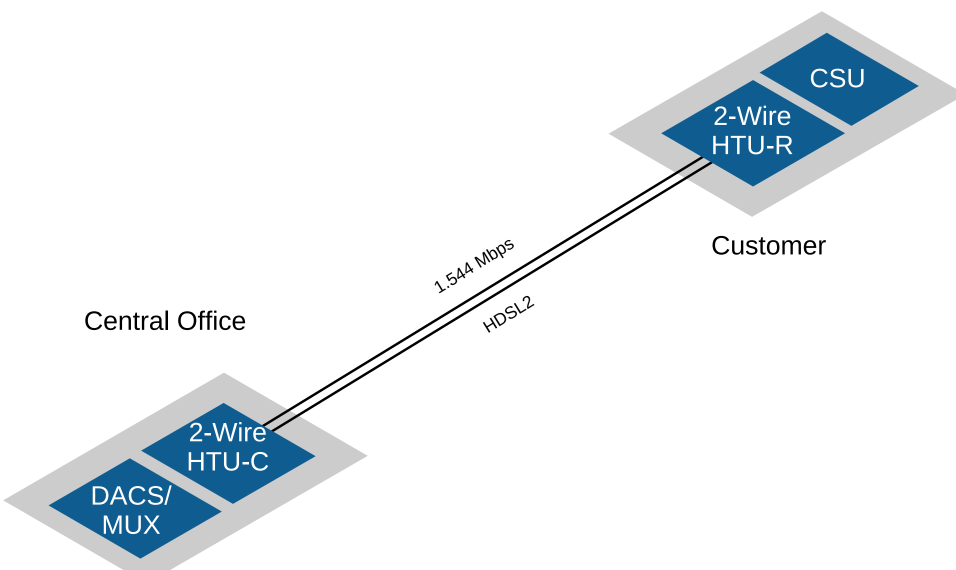
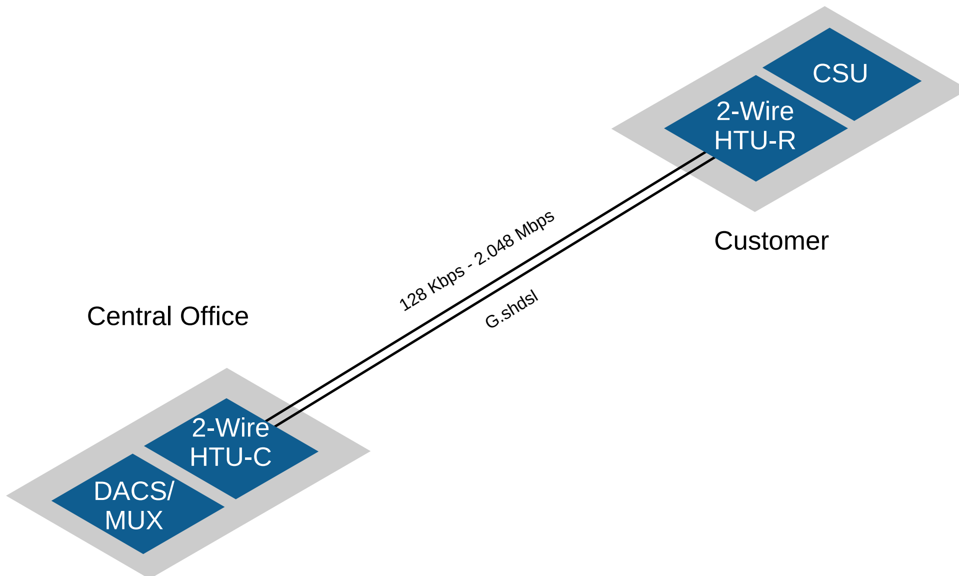


FIGURE 3-2
T1 Replacement Model Using HDSL2

FIGURE 3-3
T1/E1 Replacement Model using G.shdsl



In parallel with the 2B1Q initiative, Paradyne (at the time a subsidiary of AT&T) began development of a similar HDSL transceiver using a line code called Carrierless Amplitude and Phase (CAP) modulation. Like 2B1Q, CAP was an advanced line-coding technique allowing multiple bits of information to be represented by a single frequency cycle or baud. However, CAP could be designed to transmit multiple bits ranging from two to nine bits per baud. This enabled CAP-based transceivers to transmit the same amount of information using a lower range of the frequency spectrum than 2B1Q, equating to less signal attenuation and greater loop reach. As a result of 2B1Q's proven market acceptance with ISDN and CAP's performance benefits, both line codes were endorsed with technical reports by both the American National Standards Institute (ANSI) and European Telecommunications Standardization Institute (ETSI) standards committees for HDSL.

There are some instances where vendors have developed HDSL products using line codes other than 2B1Q or CAP. However, these examples are isolated, and alternative line codes are not recognized by the standards organizations.

FIGURE 3-4
Comparison of HDSL and T1 AMI Frequency Spectra

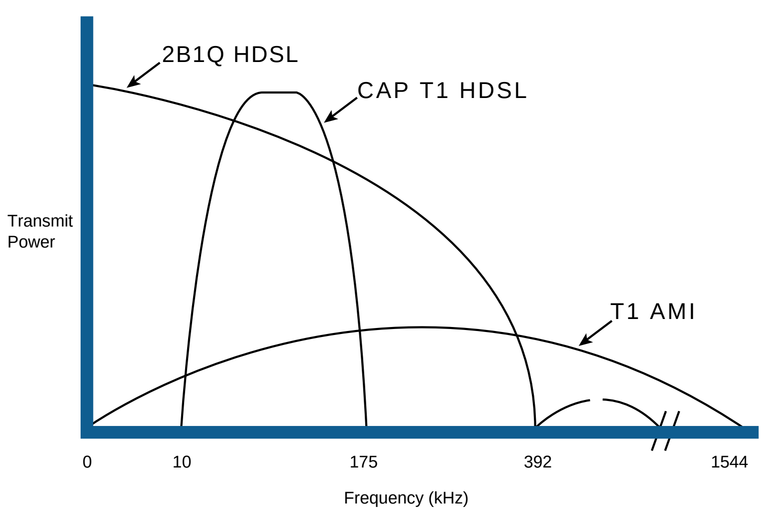


Figure 3-4 illustrates the range of frequencies used by a conventional T1 AMI encoded transmission versus that used by a T1 HDSL transmission technology. While the diagram is not to scale, the data illustrates that T1 AMI uses nearly four times the spectrum of 2B1Q and nearly nine times that of CAP.

The higher-frequency signals associated with the AMI implementation get weak sooner than the HDSL transmissions. As a result, the CAP and similarly 2B1Q HDSL systems have substantially longer loop reach than AMI or HDB3-based T1 or E1 systems, respectively.

Figure 3-5 provides a theoretical comparison of the supported line speed versus loop reach for AMI, Coded CAP and the Shannon Capacity. The comparisons assume certain industry-defined test conditions and, under these conditions, the Shannon Capacity plots represent the theoretical maximum loop reach for a given line speed.

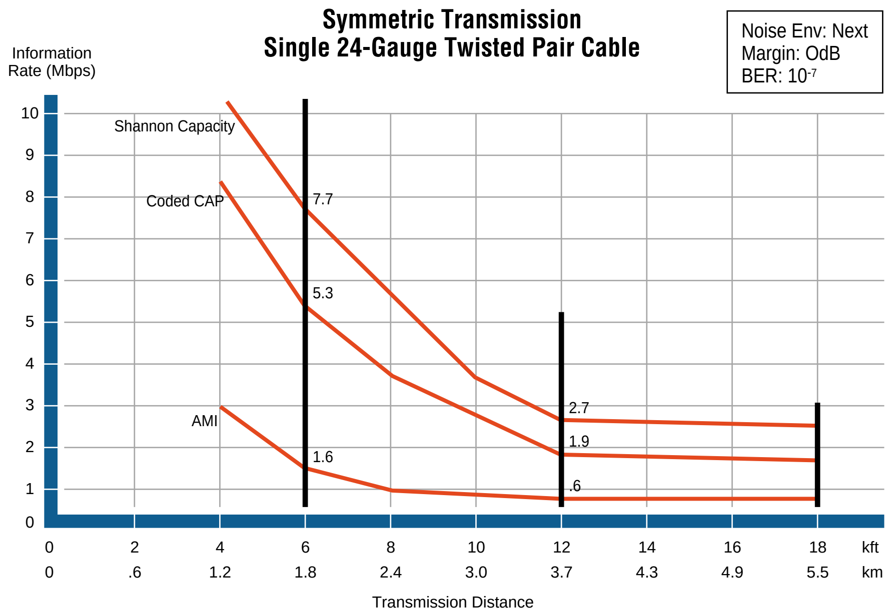


FIGURE 3-5
Line Speed and Loop Reach Comparison

BRIDGED TAPS

Bridged taps are unterminated extensions of the loop that cause additional loop loss with loss peaks surrounding the frequency of the quarter wavelength of the extension length. Since wavelength and frequency have an inverse relationship, short bridged taps have the greatest impact on wideband services, while long bridged taps have a greater impact on narrowband services. Most loops contain at least one bridged tap, and the effect of multiple taps is cumulative. Premises wiring contains additional bridged taps. The additional loss created is greatest on short bridged taps; consequently, technologies that operate at lower frequencies are less impacted.

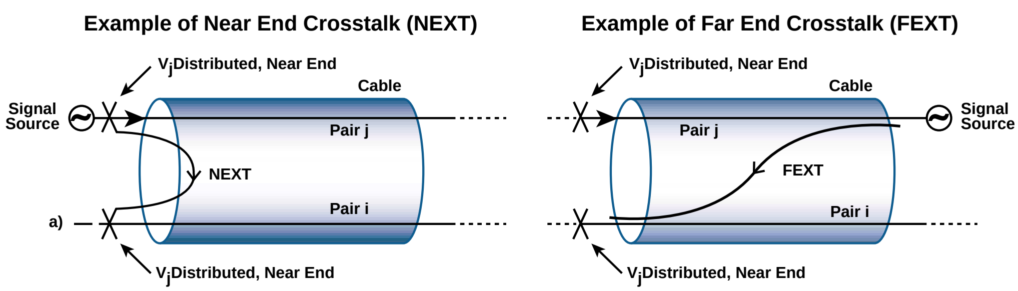
THE EFFECTS OF CROSSTALK

The electrical energy transmitted across the copper wire line as a modulated signal also radiates energy onto adjacent copper wire loops that are located in the same cable bundle. This cross coupling of electromagnetic energy is called crosstalk.

In the telephone network, multiple insulated copper pairs are bundled together into a cable called a cable binder. Adjacent systems within a cable binder that transmit or receive information in the same range of frequencies can create significant crosstalk interference. This is because crosstalk-induced signals combine with the signals that were originally intended for transmission over the copper wire loop. The result is a waveform shaped differently than the one originally transmitted.

Crosstalk can be categorized in one of two forms. Near end crosstalk, commonly referred to as NEXT, is the most significant because the high-energy signal from an adjacent system can induce relatively significant crosstalk into the primary signal. The other form is far end crosstalk, or FEXT, which is typically less of an issue because the far end interfering signal is attenuated as it traverses the loop.

FIGURE 3-6
NEXT/FEXT
Conceptual Model



Crosstalk is a dominant factor in the performance of many systems. As a result, DSL system performance is often stated relative to the presence of other systems which may introduce crosstalk. For example, the loop reach of a DSL system may be stated as being in the presence of 49 ISDN disturbers or 24 HDSL disturbers. As you can imagine, it is rather unlikely that you will deploy a DSL service in a 50-pair cable that happens to have 49 (two-wire) ISDN circuits or 24 (four-wire) HDSL circuits concurrently running in the same bundle. Therefore, these performance parameters typically represent a conservative performance outlook.

Transmitting and receiving information using the same frequency spectrum creates interference within the single loop system itself. This interference differs from crosstalk because the offending transmit waveform is known to the receiver and can effectively be subtracted from the attenuated receive signals. Eliminating the effects of the transmitter is referred to as echo cancellation.

Minimizing Crosstalk

If the effects of the attenuation and crosstalk are not too significant, the DSL systems can accurately reconstruct the signal back into a digital format. However, when the effect of these phenomena becomes too significant, the signals are misinterpreted at the far end and bit errors occur.

Some DSL systems use different frequency spectra for the transmit and receive signals. This frequency-separated implementation is referred to as Frequency Division Multiplexing (FDM). The advantage of FDM-based systems over echo-canceled systems is that NEXT is eliminated. This is because the system is not receiving in the same range of frequencies in which the adjacent system is transmitting. FEXT is present, and the FEXT signal is substantially attenuated and less of an interferer because the origin of the FEXT signal is at the distant end of the loop. Therefore, FDM-based systems often provide better performance than echo-canceled systems, in terms of crosstalk from similar adjacent systems.

One interesting phenomenon that should be considered is that echo-canceled systems of a like type introduce what is called self NEXT. Self NEXT introduces significant interference to other like-type echo-canceled systems in the same cable binder. As a result, the deployment of multiple like-type echo-canceled systems will degrade the performance of all other like-type systems within the cable binder. For example, a single CAP or 2B1Q-based T1 HDSL system may achieve the targeted 12 kft (kilofeet) loop reach. However, as additional CAP or 2B1Q-based systems are added to the cable bundle, the loop reach of the first system and the subsequent systems may be reduced to 9 kft or less. This same phenomenon is true of nearly all echo-canceled systems such as 2B1Q in general, echo-canceled CAP HDSL and SDSL, and echo-canceled DMT ADSL systems, which are discussed in subsequent sections. Therefore, when selecting a DSL technology, service providers should examine the system performance in the presence of self NEXT, which is certain to exist as more services are deployed.

The engineering compromise of FDM systems is that the separated upstream and downstream signals occupy a greater range of frequencies than echo-canceled systems which overlap the transmit and receive signals resulting in less reach. In some cases, attenuation becomes the most significant factor in performance. In other cases, crosstalk is the most significant factor in performance. Therefore, the optimal implementation varies as a function of the environment. In deployments where crosstalking systems are expected to be limited and NEXT is moderate to low, an echo-canceled system may perform better. In other cases where deployments of crosstalking systems are expected to be significant and NEXT is likely to be more dominant, an FDM system may perform better.

About the only sure way to manage the issues of crosstalk is to first research the services that are deployed within a given cable bundle and avoid those services that will provide substantial crosstalk. One example of this is the traditional T1 or E1 services. The spectral placement of T1 AMI and similarly the E1 HDB3-based services provides extensive crosstalk to almost all DSL-based services. As a result, most service providers follow design rules that do not allow the use of T1 or E1 services in the same cable bundles with DSL-based services. You should expect reductions in loop reach in scenarios where T1 or E1 is provisioned in the same cable bundle as DSL-based services.

FCC and Spectrum Management

In an effort to spur competition after the implementation of the Telecom Reform Act of 1996, the FCC held a roundtable on Spectrum Management in October 1998 to obtain industry input into the development of rules that would allow different carriers to share the same cables with competing products. As an outcome of the roundtable, ANSI Committee T1E1.4 was asked to develop a standard on Spectrum Management. T1E1.4 was selected because of its technical expertise in developing loop access technology standards. Progress has been slow, primarily due to the difficulty in reaching a workable balance between CLEC and ILEC deployment concerns. However, approval is expected in the February 2001 time frame, with expectations that the FCC will adopt key aspects of the standard in a future order. The industry will use this standard as a basis for technology deployment and loop reach rules.

Spectrum Management Standard

The objectives of the standard are to enable innovation and competition among service providers and also among vendors that provide products while protecting existing services. This is accomplished by use of transmit power, frequency and loop reach restrictions. Nine spectrum management classes were developed covering frequency spectrums of various widths and associated loop reach restrictions. Wider spectrums permit higher data rates, but also have greater restrictions on loop reach.

SDSL Offers HDSL Speeds on a Single Pair

Transceiver systems can now achieve an entire T1 or E1 line speed on a single loop at distances approaching, and in some scenarios exceeding, the conventional two-loop HDSL systems. This single-pair implementation of T1 or E1 HDSL is referred to as Symmetric Digital Subscriber Line (SDSL). Due to the lack of a formal naming convention in the industry, the term SDSL has become more generic over time and is also used to refer to symmetric service at a variety of rates over a single loop.

In principle, the tradeoff between four-wire HDSL and two-wire SDSL systems is loop reach. By splitting the information across two loops, HDSL systems can operate in lower frequencies than SDSL, resulting in a slight loop reach advantage for HDSL. However, in most markets, T1 SDSL's single-pair loop reach of approximately 11,000 feet (3.4 km) compared to T1 HDSL's dual-pair 12,000 feet (3.6 km), assuming 24 AWG, is close enough to be negligible. In these markets, SDSL's ability to support a full T1 or E1 service using one-wire pair rather than two is a distinct advantage.

New Generations of Symmetric Services

Refinement and development of new line codes for symmetric DSL services has continued even as HDSL and SDSL have been deployed rapidly and in mass. Particularly, there are two emerging standards for symmetric DSL which, as this Sourcebook is being written, are beginning to enter the market:

G.shdsl — a new standards-based replacement for SDSL. This multi-rate replacement for proprietary SDSL offers symmetric bandwidths of between 192 Kbps to 2.3 Mbps, with a 30 percent longer loop reach than SDSL and improved spectral compatibility with other DSL variants within the network. G.shdsl is expected to be applicable worldwide.

HDSL2 — a single-pair, ANSI standard-based replacement for HDSL. HDSL2 offers the same 1.544 Mbps bandwidth as traditional four-wire HDSL solutions, with the advantage of requiring only a single copper pair, plus the additional advantage of being a standards-based solution with multi-vendor interoperability. HDSL2 is expected to be applicable in North America only, which is why some vendors are opting to build to the emerging universal G.shdsl specification.

ASYMMETRY ALLOWS US TO TAKE ADVANTAGE OF THE ENVIRONMENT

Maximizing loop reach with various line codes resulted in extensive study of the characteristics of the loop plant itself. This study revealed that we could transmit a signal a greater distance from the CO to a remote home or office than could be achieved in the opposite direction. This was due to the effects of crosstalk, which are more dominant on the telephone company side of the copper wire loops than on the remote subscriber side. This phenomenon is due to the fact that more copper wires – each of which introduces a crosstalk component – are combined in large bundles as they get closer to entering the CO. Conversely, as we traverse the loop from the central office out to the end service user, the loops tend to branch off for connection, resulting in fewer copper wire loops. Therefore, less aggregated crosstalk is introduced by the transmitters at the far end wire bundles.

Another way to take advantage of the characteristics of the telephone plant is by ensuring (in FDM systems) that the lower frequencies are used to transmit toward the CO. Since lower frequencies are attenuated less than high frequencies, this arrangement ensures that the received signal is as high as possible when it reaches the noisy CO environment (where crosstalk is worse).

In summary, you can more reliably transmit a higher-speed signal from the CO to the remote location than can be transmitted from the remote location to the CO. Devices that were designed to support this concept of a higher-speed service from the CO to the service user and a lower-speed service from the service user to the CO are called Asymmetric Digital Subscriber Line, or ADSL, devices.

Reversing the direction of an ADSL system to provide the higher-speed channel into the network, with the lower-speed channel to the service user, results in substantially reduced loop reach. In addition, if this configuration is implemented in the cable binder with ADSL services configured in the opposite direction, the opposing systems will provide substantial self NEXT, and one or both systems may become inoperable. If such a configuration is allowed by the ILEC, the opposing services must be provisioned over different cable binders.

A Bit of History about ADSL Line Codes

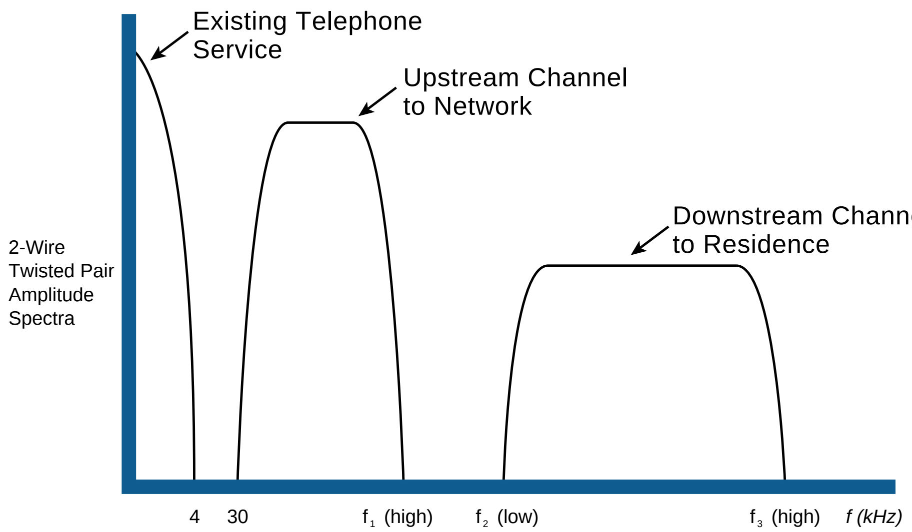
About the same time the industry recognized the asymmetric attributes of the local loops, telephone companies developed a strong interest in providing entertainment video services. This interest was prompted by the desire to increase revenues through new services and by recognizing that cable TV operators outside the U.S. were beginning to offer telephony services over their coaxial cable plant.

By late 1992, three line codes were emerging as the most likely technologies to support high-speed video dial tone services. These were:

1. *QAM, or Quadrature Amplitude and Phase Modulation, a line coding technique used in modems for over 20 years*
2. *CAP, which was introduced earlier for HDSL and is actually a variant of QAM*
3. *DMT, or Discrete MultiTone, a line coding technique that was patented (but not implemented) by AT&T Bell Labs over 20 years ago*

Unlike 2B1Q, which is a baseband technology that transmits at frequencies that include 0 Hz or DC, the above-mentioned line codes are typically passband and can be designed to operate over any specified range of frequencies. ADSL was originally envisioned as a residential service that would need to independently coexist with the already provisioned POTS. Therefore, the passband attributes were considered a prerequisite to frequency

FIGURE 3-7
Typical ADSL Frequency Spectrum



separation or FDM between POTS, an upstream channel from the service user to the network, and a downstream channel from the network to the service user. In addition to the above FDM implementation, some DSL technologies, including certain implementations of DMT, were designed to provide echo cancellation of the upstream and downstream channels to minimize the use of higher frequencies and optimize loop reach. However, some observers believe that the performance of these echo-canceled systems tends to degrade as an increasing number of similar services are deployed within the same cable bundle, offsetting any substantial gains associated with avoiding higher frequencies.

ADSL Standards

In 1992 and early 1993, the ANSI T1E1.4 Working Group moved toward selection of a single line code for an ADSL Video Dial Tone standard. The Working Group focused on a variety of video service options ranging from a single pre-recorded, pre-compressed MPEG-1 (Motion Picture Experts Group) video to a system that could support up to four concurrent MPEG-1 videos, or a single MPEG-2 real-time encoded video running at an aggregate of 6 Mbps. The focus then shifted toward achieving the maximum loop reach at specified data rates optimized for video. The nature of bit synchronous video required an absolute fixed data rate to avoid any degradation of picture quality.

Although representatives from each line code camp stated that theoretical performance between the technologies was effectively equal, DMT was the first line code to demonstrate actual support for 6 Mbps service and was selected as the official ADSL standard for Video Dial Tone services.

While DMT was selected as the official standard, CAP-based systems were used worldwide to implement many ADSL and Video Dial Tone trials and commercial deployments, effectively establishing CAP as a competing de facto ADSL standard. During this time, the threat of the cable TV industry offering telephony services in the U.S. largely subsided. Internationally, Video Dial Tone applications garnered and continue to hold interest. In many markets, they were difficult to cost justify relative to the wide-scale availability of cable TV and satellite TV. As a result, the Video Dial Tone initiatives have largely disappeared in North America.

The final standard for ADSL – approved by the International Telecommunications Union (ITU) (G.dmt or G.992) and ANSI (T1.413 Issue 2) – was, as previously mentioned, a DMT-based system and is the basis of most new ADSL deployments today. Some providers, however, have continued to deploy CAP-based systems in their networks.

THE APPLICATION SWITCH FROM VIDEO TO DATA

Through the course of these lengthy Video Dial Tone trials, the industry came to recognize that many data applications were actually asymmetric in nature. The best example of this is Internet access. Typically, Internet users send a small stream of data to a distant server requesting the download of a particular data, graphic, audio or video file. In response, the server begins sending the file at the data rate that can be supported across the network to the distant workstation. This transaction is extremely asymmetric in nature. During this same time, the Internet evolved into a whole new phenomenon with unheard of growth rates of new Internet service subscribers. The biggest complaint across all users was that it took too long to download files at dial modem or even ISDN data rates. Hence, a new service need and a new technology were soon married, and ADSL was re-focused to support Internet access.

Video has not disappeared entirely as an application for DSL; however, IP-based video delivery – utilizing systems such as RealMedia or Windows Media – has become increasingly popular and sophisticated. Using compression schemes such as the industry-standard MPEG-2 or newer schemes that allow even greater compression of video, IP-based video delivery continues to be a viable application for DSL.

Optimization for Data Services

When the application was bit synchronous video, the DSL line had to run at a specified line speed. However, data can run at a wide range of speeds. The only effect is that slower speeds take more time to transport large files. Therefore, with data applications, we have the option of reducing the line speed to allow the service to be provisioned over longer lines. Both CAP and DMT transceivers were modified to optimize service on a per-loop basis, and this implementation was called Rate Adaptive Digital Subscriber Line, or RADSL.

RADSL technology supports the option of allowing the transceiver to start up by automatically increasing the line speed to the highest attainable data rates that can be reliably achieved over a given loop. While this feature was designed primarily to simplify service installation, it also gives service providers the option of a graceful service degradation in the event of degrading loop conditions. Today, there are other DSL technologies that also support rate adaptation, and service providers interested in this functionality should examine the degree to which it is supported within the different technologies.

RADSL Standards

As you can see, the industry and technologies have evolved dramatically since the ADSL Video Dial Tone standards decision in March 1993. In recognition of this, ANSI's T1E1 Working Group has established a RADSL standard known as ANSI TR59. The FCC has specifically cited RADSL as a technology that is spectrally compatible with both voice and other DSL technologies within the local loop.

True Interoperation

While many vendors meet the same line coding standard at the physical layer, many vendors are not aligned on the networking model at the logical layer, as we will discuss in Chapter 7, Network Models. Essentially, systems manufactured by different vendors do not automatically interoperate across the DSL link today.

In reality, line codes are only important across the local loop. To interoperate, the equipment at the wire center and the endpoint must at least utilize the same line code. Today, the different line codes are less of a problem as the industry continues to take advantage of the standards for interoperability.

CONTINUING DEVELOPMENTS IN DSL

The onslaught of new vendors is sure to bring continued variations in DSL technology. Even as mass deployments of ADSL and SDSL reach the market, new variants are being developed and marketed to fulfill the needs of certain segments of the DSL market.

IDSL Provides DSL Over ISDN

In some cases, DSL concepts have been applied to existing technologies. For example, ISDN-DSL, or IDSL, first emerged as a new spin of the 1980's technology. IDSL is simply ISDN CPE (customer premises equipment) talking to ISDN-compatible line cards that reside on the other end of the copper wire loop and terminate the ISDN signal independent of the telephone switch. In this scenario, as with all DSL variations, the data service is directed to a WAN data service, rather than a switched network.

While IDSL builds on a proven technology, it is functionally a subset of ISDN in that it forgoes any ability to support telephone service and switched connectivity in general. One key benefit of IDSL is to the service provider seeking to move long-duration ISDN data connections to the Internet or remote LAN access servers off of the switched network.

Another key benefit is that, because IDSL uses ISDN signaling methods, it is able to transmit over copper pairs that are served by digital loop carriers. These devices, which are remote terminals designed to extend the reach of POTS and ISDN services beyond the usual reach of central office terminated copper lines, are often connected to the central office by fiber optic private lines and, as such, cannot carry other DSL signals such as ADSL and SDSL.

Multirate Symmetric DSL

Beyond the 144 Kbps bandwidth provided by IDSL, there are newer technologies that have emerged that can be best classified as residential and small office/home office (SOHO) opportunities. These technologies offer operational ranges between 128 Kbps and 2.048 Mbps.

For symmetric applications, Multirate SDSL (M/SDSL) has emerged as a valuable technology in meeting carrier requirements to deliver Time Division Multiplex (TDM) services on a near ubiquitous basis. Building on the single-pair SDSL technology, M/SDSL supports changing operating line rates of the transceiver and, thus, the operating distance of the transceiver. The CAP version supports eight distinct rates allowing 64 Kbps/128 Kbps service to reach 29 kft (8.9 km) on 24-gauge (.5mm) cable and 15 kft (4.5 km) at a full 2 Mbps rate. With an auto-rate ability (similar to RADSL), symmetric applications can now be universally deployed.

G.lite for the Consumer Market

In January 1998, the Universal ADSL Working Group (UAWG) was announced. Comprised of leading organizations within the telecommunications, networking and personal computer industries, the group was formed to develop a lower-speed, lower-cost variant of ADSL that could be consumer installed and rapidly deployed by service providers. The result of this group's work is a new, standards-based subset of ADSL known as G.lite. G.lite was approved as a standard by the ITU (G.992.2) in June 1999 and can offer speeds of up to 1.5 Mbps downstream and up to 512 Kbps upstream. Significantly, G.lite was designed to provide this service over existing phone lines without the POTS splitter usually required by full-rate ADSL solutions. Part of the G.lite standard is a technique known as "fast retrain," which limits the upstream power of the G.lite signal when a telephone handset is in use, in order to minimize interference, and then restores the power when the phone is back on hook.

Many G.lite installations, however, have been proven to work better and be more reliable when microfilters – passive devices which block higher frequency signals – are installed on all other POTS phone lines within a customer's premises. These microfilters have also been proven effective in customer self-installed full-rate ADSL installations, which limits the appeal of G.lite, since full-rate ADSL can also offer this user-installation capability while providing a much higher data rate.

ReachDSL – Another Option for Business and Residential Customers

ReachDSL is a symmetric DSL technology that addresses subscriber demand for high-speed DSL services at extended distances. Complementing standard ADSL technology (DMT/G.lite), ReachDSL products support speeds ranging from 128 Kbps to 1 Mbps and have been designed to work over a wider range of line conditions and in-premises wiring. ReachDSL solutions are capable of sharing lines, impervious to bridged taps, and ideal for business, residential and even private network environments.

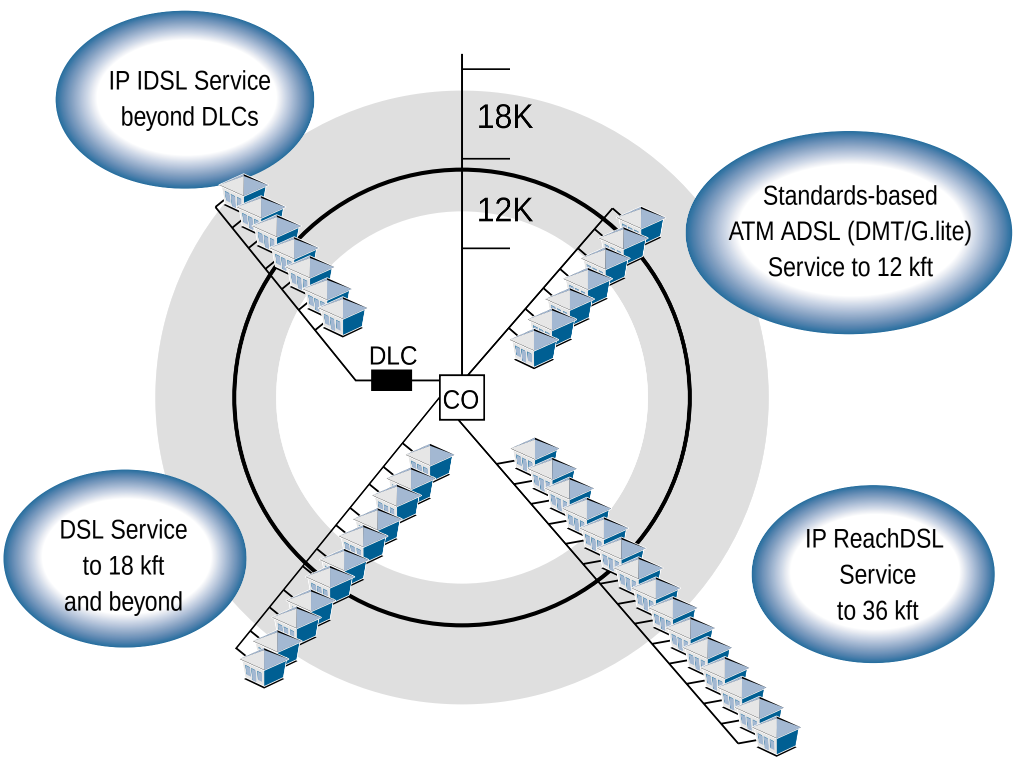


FIGURE 3-8
ReachDSL Conceptual Model

ReachDSL Benefits:

Splitterless installation – No POTS splitter is required at the customer premises, simplifying installation and allowing customer self-installation.

Greater loop reach – Complementing ADSL systems, which can typically reach distances of less than 18,000 feet from the central office, ReachDSL systems extend services well beyond 20,000 feet, with some current installations exceeding 30,000 feet.

Spectral compatibility – ReachDSL solutions offer superior spectral compatibility. One member of the ReachDSL family, MVL® (Multiple Virtual Lines), was the first DSL system recognized by the FCC with Part 68 approval, meaning that it is "friendly" to other services being offered over the telephone network and not an interferer. Other ReachDSL solutions also operate within Spectral Management Class One to offer superior reach and speed.

Lower product cost – Since ReachDSL products utilize "off the shelf" rather than customized Digital Signal Processors (DSPs).

Dynamic bandwidth allocation – Allows the service to be customized for different applications.

These advantages are extremely important to cost justify and address mass-market service deployment in the business and consumer sectors.

VDSL Delivers Video and Higher Bandwidth

The newest emerging variant of DSL is VDSL, or Very High Speed DSL. VDSL systems are still being developed so the final capabilities are not yet firmly established, but proposed standards call for downstream bandwidths of up to 52 Mbps and symmetric bandwidths of up to 26 Mbps. The tradeoff to these bandwidths is a much shorter loop reach, often as short as 1,000 feet for the highest possible bandwidths, with rate adaptation to lower speeds as the loop length increases. Given these limitations, VDSL deployments are envisioned to use a slightly different model than traditional DSL, with the DSLAM moving out of the telephone company central office and into the neighborhood, with fiber optic lines feeding local cabinets containing the DSLAM.

The high speeds offered by VDSL will bring opportunities for service providers to offer the next generation of DSL services, with video being seen as a prime application. At 52 Mbps, a VDSL line can offer a customer multiple channels of full-quality MPEG-2 video streams and even offer one or more channels of full-quality High Definition Television (HDTV). Some service providers have begun trial deployments of VDSL systems providing these services, with the VDSL endpoint appearing in the residence as a cable TV-like set-top box, with an Ethernet or other data interface for connecting to PCs for simultaneous data services.

The basic premise of DSL being a local loop technology in which compatible devices reside on either end of a single copper wire loop assures that new DSL technologies will continue to emerge over time. A strategic agenda item for the service provider is to ensure that the selection of a specific DSL technology or network model for service deployment today will not limit the options to adopt new technologies in the future.

Summary of Various DSL Technology Attributes

As you can see, there are several varieties of DSL to choose from. Selection of one technology over another is dependent on multiple factors, ranging from the types of services to be offered, the dominant topology of your existing network, and your plan for evolving to other services in the future. The following is a summary of the primary DSLs.

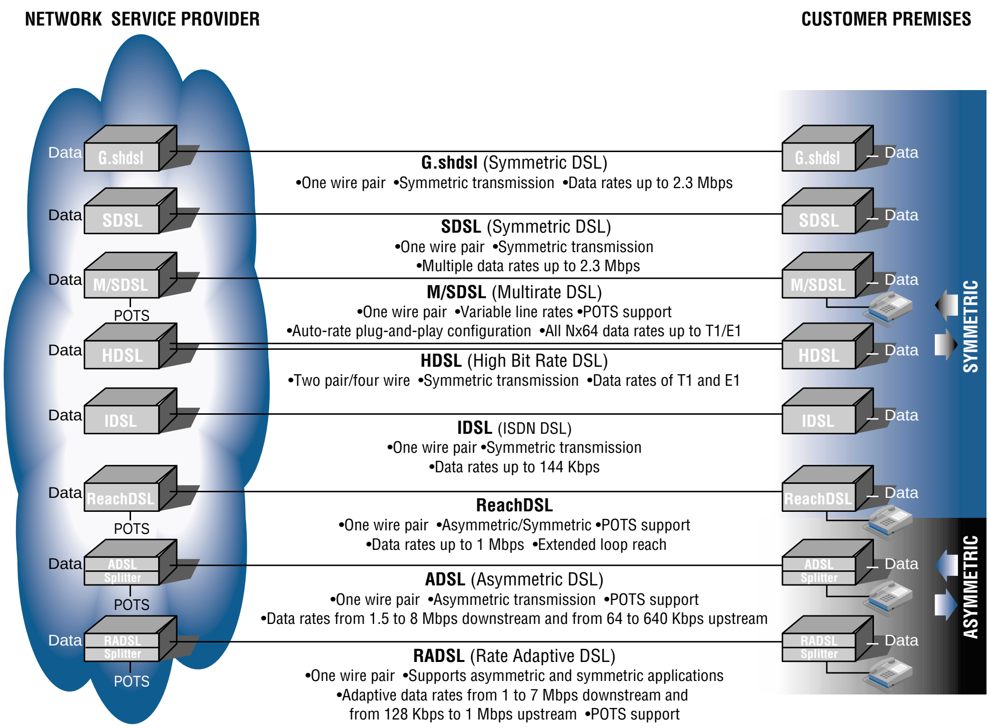


FIGURE 3-9
The Primary DSLs

Figure 3-10 provides a useful context for examining the different technologies. These achievable data rates may vary based on loop condition, impairments, crosstalk and vendor implementation.

FIGURE 3-10
DSL Transceiver Reference Chart

DSL Tranceiver Reference Table		DMT ADSL	CAP RADSL	CAP S/HDSL	2B1Q S/HDSL	2B1Q IDSL	CAP SDSL	G.shdsl	ReachDSL
Symmetric Applications (bps)	128 Kbps	X	X	X	X	X	X	X	X
	384 Kbps	X	X	X	X		X	X	X
	512 Kbps	X	X	X	X		X	X	X
	768 Kbps		X	X	X		X	X	X
	1 Mbps		X	X	X		X	X	X
	T1 1.544 Mbps			X	X		X	X	
	E1 2.048 Mbps			X	X		X	X	
Asymmetric Downstream		X	X						
Optional Analog POTS		X	X	X					X
Rate Selectable		X	X	Future	Future		X	X	X
Auto-Rate Adaption Option		X	X				X	X	X
Echo Cancelled		*		X	X	X	X	X	
FDM		*							
Typical Loop Reach (24 AWG)		18 kft (1.5 Mbps)	18 kft (1.5 Mbps)	14 kft (HDSL)	10 kft	26 kft	29 kft (128 Kbps)	14.5 kft (1.5 Mbps)	18,000 kft (512 Kbps)**
		6 kft (7 Mbps)	6 kft (7 Mbps)	12 kft (SDSL)			21 kft (768 Kbps)		
Typical Loop Reach (.5 mm)		5.5 km (1.5 Mbps)	5.5 km (1.5 Mbps)	4.3 km (HDSL)	3.0 km	8 km	8.9 km (128 Kbps)	4.4 km (1.5 Mbps)	
		1.8 km (7 Mbps)	1.8 km (7 Mbps)	3.6 km (SDSL)			6.4 km (768 Kbps)		

* Certain vendor implementations only ** No loop length limit at 128 Kbps when loop has existing telephony service

Chapter 3 Summary

- *Working beyond the POTS frequency range introduces new transmission challenges. In this chapter, we focused specifically on three: attenuation, bridged taps and crosstalk.*
- *Advanced modulation techniques to minimize attenuation were introduced, including HDSL as a replacement for T1/E1 repeatered services using 2B1Q and CAP encoding schemes.*
- *Crosstalk and efforts to minimize it were discussed, comparing echo-cancellation techniques to FDM techniques.*
- *A history of the DSLs, applications, and standards were covered, including ADSL for Video Dial Tone (bit synchronous) applications, the emergence of data applications and Rate Adaptive DSL. While bit synchronous video applications require specified line speeds, data applications allow for optimization of the transmission.*
- *Description of DSL Types:*

  Service providers and service users will need to assess their needs to determine which DSL technology best meets their needs. These considerations may include:

  - *WAN service type (IP for Internet/Intranet and LAN extension services, frame relay or Channelized T1/E1 for bit synchronous services)*
  - *Local loop service type (symmetric, asymmetric or both)*
  - *Loop reach (reachable customers from the CO)*
  - *Two- or four-wire implementations*
  - *Single DSL-based service or concurrent POTS + DSL*
- *New and emerging variants of DSL including:*
  - *HDSL2 and G.shdsl*
  - *G.dmt and G.lite*
  - *ReachDSL*
  - *IDSL*
  - *VDSL*

Chapter 4

DSL SYSTEM COMPONENTS

ADDING DATA TO THE TRADITIONAL VOICE NETWORK

In this chapter, we will lay the groundwork for the discussion of DSL-based services and network models that will be covered in Chapter 7, Network Models. To that end, we will first focus on the physical rather than the logical network structure. A reference diagram is provided, along with a description of the system components and their function within a DSL-based services network.

As discussed in Chapter 2, The Existing Copper Wire Infrastructure, the traditional ILEC/PTO network was designed to carry voice traffic and performs this function extremely well. However, in general, the existing telephone network is not particularly adept at carrying high-speed data.

In Figure 4-1, we show a traditional ILEC/PTO network configured to support low-speed data (e.g., 28.8 Kbps) as well as higher-speed data. At the customer location, a standard analog modem is utilized for the provisioning of low-speed connectivity to the local access network, whereas a Digital Service Unit (DSU) or Network Termination Unit (NTU) is utilized for higher-speed digital connections such as 56/64 Kbps or T1/E1 services.

As we move from the low-speed analog world to the higher-speed digital world, you will notice an important change has taken place in the topology at the CO. Whereas analog modem traffic can be carried through the telephone switch (providing worldwide dialing capability), high-speed data will typically bypass the switch altogether. This is largely because telephone switches are not designed to carry high-speed data.

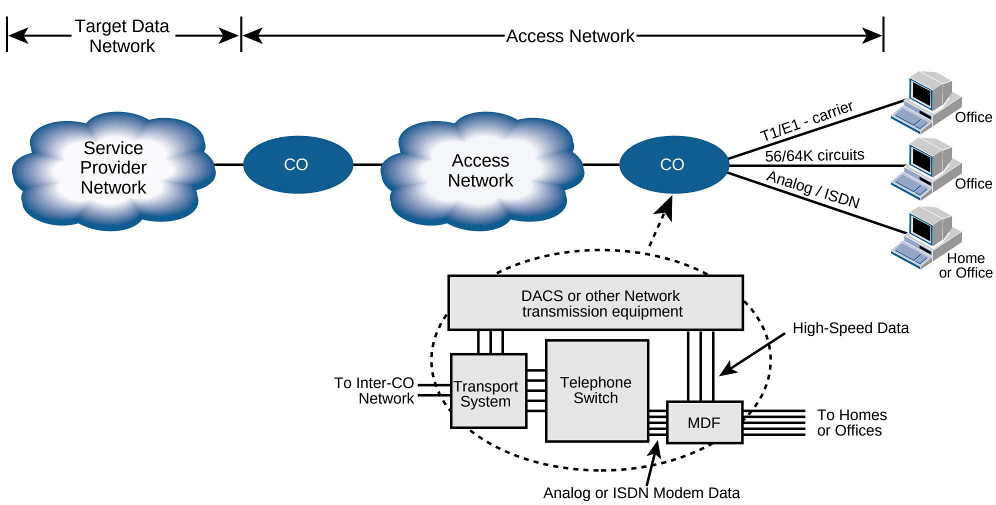


FIGURE 4-1
Adding Data to Traditional Voice Network

In Figure 4-1, we can trace the path of the high-speed data circuits across the local loop, through the DACS and transmission system, bypassing the telephone switch. Since the DACS is used as the basis of transport, Time Division Multiplex (TDM) technology is used throughout the network.

In general, it can be said that low-speed data services based on traditional modem technologies integrate well into the POTS network, since the telephone switch is integral to the solution, whereas higher-speed services must be configured as a dedicated network, bypassing the switch entirely. This concept will be extended as we explore specific configurations of DSL-based services.

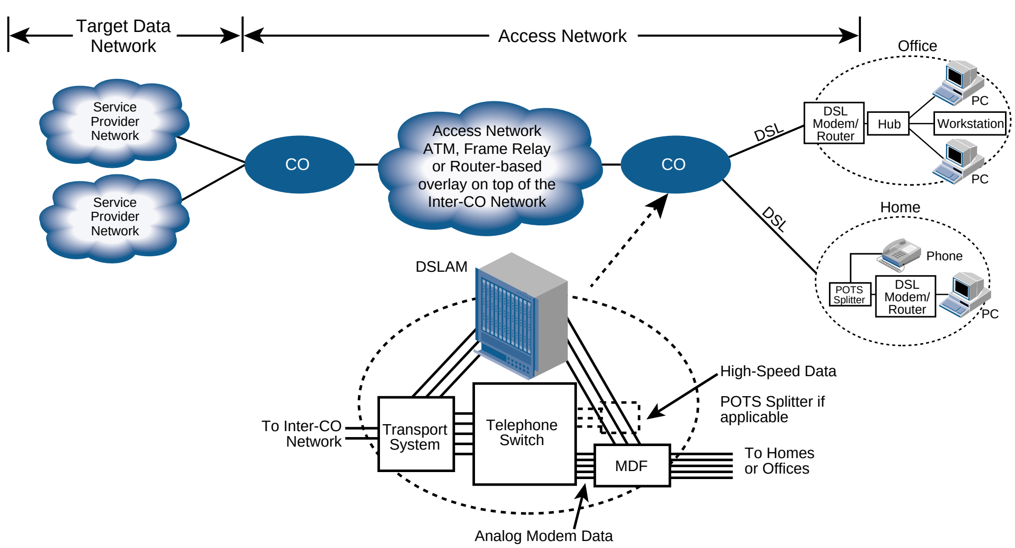
DSL technology, when deployed in the local loop, enables high-speed access service without repeaters. When DSL-based services are provisioned, data received in the CO bypasses the telephone voice switch, is concentrated, and handed off to the inter-CO DACS network. As we will show in the following section, a DSLAM can be utilized to group data channels before the handoff. Furthermore, we will show how packet and cell multiplexing technology in addition to TDM can be introduced into the DSLAM, resulting in much greater bandwidth efficiency.

DSL-BASED SERVICES AND COMPONENTS

Let's start off by presenting a DSL network reference diagram. Several types of data networking equipment are required for the deployment of high-speed DSL-based services.

Figure 4-2 shows a multiservices DSLAM located at the CO and a DSL endpoint located at the home or the remote office. Often these endpoint units are modems, routers or Integrated Access Devices (IADs) capable of supporting both voice and data. Transmission speeds of 8 Mbps and beyond are possible, depending upon a number of factors including equipment, loop length, and condition of the loop.

FIGURE 4-2
DSL-Based Services Reference Diagram



Let's describe each specific component and its function within a comprehensive DSL solution.

Transport System
This component provides the carrier backbone transmission interface for the DSLAM system. This device can provide service specific interfaces such as T1/E1, T3/E3, OC-1, OC-3, OC-12, STS-1 and STS-3.

Local Access Network
The local access network utilizes the local carrier inter-CO network as a foundation. In order to provide connectivity between multiple service providers and multiple service users, additional equipment may be required. Frame relay switches, ATM switches and/or routers can be provisioned within the access network for this purpose. More and more, ILECs and PTOs are looking to ATM equipment to fill this role, and next-generation DSLAMs include ATM switching to fulfill it.

It is sometimes instructive to consider the concept of an Access Node (AN), which is the place where switches and/or routing equipment are physically located. Depending upon the scale of the desired access network and the costs associated with transport, we can expect to find one or more ANs per local access network, thus creating an overlay structure on top of the inter-CO network. In some cases, the AN is integrated within the DSLAM, as is the case with next-generation DSLAMs that incorporate ATM switching systems.

Multiservices DSLAM
Residing within the CO environment (or in a nearby virtual collocation space), the DSLAM is the cornerstone of the DSL solution. Functionally, the DSLAM concentrates the data traffic from multiple DSL loops onto the backbone network for connection to the rest of the network. The DSLAM provides backhaul services for packet, cell and/or circuit-based applications through concentration of the DSL lines onto 10Base-T, 100Base-T, T1/E1, T3/E3 or ATM outputs.

Some DSLAMs are now being temperature "hardened" for installation in areas that are not environmentally controlled. This allows installation of DSLAMs in remote terminals or curbside cabinets instead of just in COs or virtual collocation spaces. The ability to move the DSLAM into these remote locations (along with extended loop reach technologies) can greatly increase a service provider's footprint, enabling service provisioning to customers who would otherwise be beyond the reach of DSL.

In addition to concentration functions and depending upon the specific service being provisioned, a DSLAM will provide added functions. The DSLAM may, in some cases, be required to open data packets in order to take some action. For example, in order to support dynamic IP address assignment using the Dynamic Host Control Protocol (DHCP), each packet must be viewed in order to direct packets to the proper destination (this is referred to as a DHCP-relay function). More detail is provided in Chapter 7, Network Models.

FIGURE 4-3
DSLAM Features and Benefits

FEATURE	BENEFIT
Multiservices Support for Total Business-Class DSL	Investment protection. As the DSL market grows, application diversity will grow too. Business-class DSL requires manageability, scalability and support for IP, frame relay, TDM, voice and ATM services with a full suite of QoS service performance guarantees.
DSL Line Code Support	Deployment flexibility and scalability. The DSLAM should support a variety of DSL line codes (e.g., CAP, DMT, 2B1Q) and line protocols. DSLAM's support for standard ADSL, SDSL and IDSL can be augmented with innovations such as ReachDSL.
Flexible Architecture	Investment protection. Intelligent and flexible DSLAM architectures support the ability to combine the strengths of ATM with the strengths of IP such that a wide variety of services, applications, network models and DSL transports are supported for business and consumer markets.
Scalability	Flexibility to support from a few to many service users at competitive price points. Keep in mind that scalability must be achieved within NEBS physical and power dissipation requirements.
Maintainability	NEBS compliance for ease of deployment and ongoing maintenance.
Manageability	Standards oriented for compatibility with various network management system (NMS) platforms and reliable end-to-end network management. Use of Internet technology components such as eXtensible Markup Language (XML) will become increasingly important as vendors strive to facilitate integration across the service transport network and between higher layer OSS applications. SLM-DSL can be used to support advanced applications and management access for wholesale and direct services provisioning.

DSL Modem/Router

The DSL modem/router endpoint is the customer site equipment for the service user's connection to the DSL loop. The DSL endpoint connection is typically 10Base-T, V.35, ATM or T1/E1, with new generations of consumer products also supporting such methods as USB, IEEE 1394 (Firewire), and PCI internal form factor. Additionally, CPE endpoints are being developed with additional ports designed to support specific applications, such as RJ11 ports for voice support (e.g., IADs for VoDSL services), video ports for DSL-based video services, and new networking interfaces such as Home Phoneline Networking Alliance (HomePNA) or wireless networking interfaces like 802.11 Wireless Ethernet.

DSL CPE endpoints are available in a number of different configurations depending upon the specific service being provisioned. In addition to providing basic DSL modem functionality, many endpoints contain additional functionality such as bridging, routing, TDM multiplexing or ATM multiplexing.

Bridged endpoints serve the marketplace well with their ease of installation and maintenance. Any bridged implementation device should feature a learning filter in order to keep unwanted traffic from traversing the network.

Routed endpoints offer IP flexibility at the customer site. With an IP-aware endpoint, subnets can be created and maintained, allowing efficient segmentation of the remote LAN as well as multicast and unicast downstream recognition. Multiple service domains can also be utilized by the remote LAN users at the same time. Multiple service domains become important when you have a large group of users who need to access different service providers like the corporate LAN and the Internet through different ISPs.

Protocol-transparent endpoints behave very much like a DSU/CSU. They provide an interface to the DSL link for existing routers and/or FRADs (frame relay access devices). The routers and FRADs handle all of the connected LAN's traffic management, while the DSL endpoint passes all traffic to the upstream DSL link.

Channelized TDM endpoints can operate like DSU/CSUs for traditional T1/E1 service. They also provide interfaces to routers, FRADs, multiplexers, PBXs or any other device accustomed to a traditional service.

The DSL modem/router should be designed so that it can be installed with little or no configuration necessary. Additionally, many service providers have mandated that the DSL endpoint be installed by the service user, necessitating plug-and-play characteristics.

The DSL endpoint should be highly manageable by the service provider. Features to look for include:

- *Ability to provide Layer 1 and 2 management statistics such as signal-to noise ratio*
- *Ability to provide Layer 3 MIB statistics such as packet counts*
- *Devices that are fully manageable by the service provider, without the need for on-site personnel*
- *Devices that support performance monitoring and end-to-end visibility for rapid fault detection, isolation and correction*
- *Ability to be remotely downloaded with new software as required*
- *Interoperability with third-party CPE including IAD*

POTS Splitters and Microfilters

Optional POTS splitters reside at both the CO and service user locations, allowing the copper loop to be used for simultaneous high-speed DSL data transmission and single-line telephone service when the DSL variant being used supports such services. POTS splitters usually come in two configurations: a single splitter version designed for mounting at the residence and a multiple splitter version designed for mass termination at the CO. Note that while many DSL line coding schemes support a single channel of POTS service, others do not. (See Figure 4-2: DSL-based Services Reference Diagram.)

POTS splitters can be either passive or active. The active POTS splitter requires an external power source for voice and DSL to operate over a single copper pair. The passive POTS splitter requires no power and will typically have a higher MTBF (Mean Time Between Failures) than its active counterpart. While the passive POTS splitter supports lifeline services such as 911 in the event of a DSLAM or DSL modem power loss, the active POTS splitter must have power backup in order to provide these critical services in the event of a power loss.

DSLs like G.dmt ADSL, G.lite, ReachDSL and RADSL can be installed today without a separate CPE POTS splitter. Instead, passive devices known as microfilters can be user installed between each POTS device in the customer premises (such as phones, analog modems and fax machines) and the wall jacks. The microfilter is basically a "low-pass" filter that allows voiceband services to pass, while filtering out the higher frequencies used by DSL, thus eliminating interference. The advantage of this approach is that while traditional POTS splitters were installed at the Network Interface Device (NID) by a service provider installer, microfilters can be easily plugged in by the end user, eliminating the need for a service call for installation. For DSL service that works over the POTS connection, this is the primary choice for installation.

While RADSL-based products introduced the ability to frequency split the baseband lifeline POTS from the passband digital data service, some of the newer "splitterless" technologies like ReachDSL and G.lite will similarly support the mix of digital data service with baseband POTS, while preserving all lifeline attributes. Going a step further, some splitterless technologies offer dynamic detection of on-hook and off-hook conditions – known as "fast retrain." Off hook, these products automatically frequency shift and attenuate the lower frequencies of the digital signal to eliminate audio signal interference; when the receiver is back on hook, the digital signal is dynamically shifted back to lower frequencies to provide the maximum sustainable data rate.

A WORD ABOUT NEXT-GENERATION DSLAMS

First- and second-generation DSLAM systems were basically IP data services systems that performed the task of aggregating multiple DSL connections by using PPP and ATM Permanent Virtual Circuits (PVCs) to connect users to the ISP. This approach, while adequate for simply aggregating "best effort" services, becomes unwieldy and unworkable when a service provider attempts to offer multiple services and differentiated levels of Quality of Service to a customer. Customers using a first-generation DSLAM were basically limited to a single level of QoS over their PVC connection (usually Unspecified Bit Rate, or UBR, which is best effort). Today's multiservices model is designed to provide a customer with service options beyond just high-speed Internet access, including business-class services such as FRoDSL, VPN, and VoDSL, which require a more sophisticated means of guaranteeing Quality of Service.

So how do these next-generation DSLAMs offer such services? There are many approaches, but the most common is to fully utilize the QoS mechanisms built into ATM. Next-generation DSLAMs have at their core an ATM switching fabric that goes beyond providing fixed PVCs and can provide switching to allow customers to utilize Switched Virtuall Circuits (SVCs). These SVCs can be dynamically provided by the DSLAM to utilize all of the class of service, traffic shaping, and prioritization capabilities inherent with ATM. This enables a service provider to offer, for example, over a single DSL connection, prioritized low-latency SVCs for voice traffic, separate prioritized SVCs for connection to a VPN or corporate frame relay network, and a third, lower-priority (best effort) SVC for Internet surfing.

FIGURE 4-4
ATM Quality of Service Categories

Quality of Service Classification	Application
Constant Bit Rate (CBR)	Circuit Emulation Service (CES), Traditional Voice
Real-Time Variable Bit Rate (rt-VBR)	Delay-sensitive applications such as packet voice VoDSL
Non-Real-Time Variable Bit Rate (nrt-VBR)	Frame Relay, VPNs
Available Bit Rate (ABR)	Tolerates Cell Delay Variation, Bursty Applications
Unspecified Bit Rate (UBR)	Best Effort

The service provider is thus able to engineer the network and the service offerings to provide differentiated services in order to maximize revenue. A single next-generation DSLAM is able to offer prioritized services like voice or frame relay to those willing to pay for them (like business users), while simultaneously offering best effort services for those who are not.

Integrating this ATM switching capability into the DSLAM enables the service provider to eliminate extra devices in the network, provides fewer points of failure, and facilitates management of the network.

END-TO-END NETWORK MANAGEMENT COMPONENT

Perhaps one of the most essential elements of a comprehensive DSL system is the network management system (NMS). Business-critical applications require reliable network management support, and this key attribute should be factored into any DSL-based services implementation plan.

The DSL system and its management components should be securely partitionable to allow management by the service provider and the commercial or residential service user. Given that the size of a DSL network may vary from small to extremely large, the management system must also be scalable to accommodate these differences without a loss of management functionality.

Management systems must be flexible and robust enough to support multiple services both among different users and within a single user's service portfolio. New services being offered over DSL, like true end-to-end managed frame relay, VoDSL and VPN services, require strict adherence to Quality of Service parameters and measurement and monitoring of these parameters to ensure compliance with Service Level Agreements (SLAs). SLAs are contractual agreements between the service provider and service subscriber and usually carry some sort of monetary remedy for any non-compliance. The NMS utilized in such a model must go beyond the basics and allow service providers and end users to select and provision services, monitor performance and report the performance relative to the SLA.

Among the features to look for in a DSL NMS are the following:

- *The NMS should be an open, standards-based solution, compatible with a variety of other network management systems, to allow integration into existing and new systems including higher-layer OSS applications*
- *Java APIs (application programming interfaces) and Web-based interfaces to provide easy access to the system on a variety of platforms*
- *A scalable architecture that can grow as the network grows*
- *A distributed architecture that allows authorized access to the system from anywhere*
- *Advanced diagnostic and line testing tools to allow rapid qualification and troubleshooting of faults*
- *Performance monitoring systems to allow precise, granular measurement of Quality of Service parameters for SLA monitoring*
- *Logging functionality to provide historical records of network performance and reliability*

Network Management and Beyond: Service Delivery

Network management systems are a vital component in the DSL network, as are the physical components involved in the DSL chain (the endpoint, the DSLAM and the access network); but the delivery of DSL services involves even more management steps. As DSL moves from thousands to millions of customers, the ability of any service provider to rapidly deploy service depends upon automation. Systems and processes that worked for a hundred monthly installs will often not scale to meet the mass-market demand for DSL.

An overall service delivery system will typically require integrated and coordinated efforts by multiple partners, working across multiple networks, to ensure success. For example, when an ISP sells a DSL service to a customer, there may be network management, provisioning and billing systems from the ISP, a CLEC, an ILEC and perhaps even a value-added service provider (like an ASP partner) involved in the process. Among the elements that must be coordinated to provide service delivery are the following:

- *Line testing and qualification systems to verify that a copper loop will perform properly for a given DSL service*
- *Copper management systems within the CO, which automate the connection of copper loops to the DSLAM*
- *Provisioning and ordering systems from multiple providers, including the unbundled loop provider, the DSLAM and DSL service provider, and the access network provider or ISP*
- *Gateway software to automate the flow of order and provisioning status between various network elements*
- *Inventory management systems to coordinate the inventory of network resources and physical equipment such as endpoints, POTS splitters and microfilters*

Additional elements of a service delivery system are more strategic. For example, partnerships with network endpoint manufacturers, DSLAM manufacturers and service providers should be in place to ensure interoperability between devices. Service providers and equipment vendors should ensure that network management systems and flow-through provisioning systems are interoperable. Finally, vendors of DSL network equipment, including both DSLAMs and DSL endpoints, can build auto-configuration or self-provisioning capabilities into their products, to create true plug-and-play user installations, without expensive and time-consuming service calls.

BUT THIS ISN'T THE WHOLE STORY

So far, most of our discussion has been about the physical world. That is, we have examined the types and functions of various networking components that must be configured to provision high-speed DSL-based services in an overlay configuration. We have, to a large extent, avoided discussion about the logical construction of the network.

In Chapter 7, Network Models, we will explore the subject of logical network models and associated requirements in order to deploy various network services including:

- *IP/LAN services such as Internet access or remote LAN access*
- *Frame relay services*
- *Nx64 Kbps services*
- *ATM services*

Chapter 4 Summary

In this chapter, we covered the evolution of traditional voice networks showing that low-speed data services based on traditional modem technologies integrate well into the traditional telephone network. High-speed services must be configured as a dedicated overlay network.

We introduced DSL systems into the network as a technique for the delivery of high-speed network services. Various DSL components necessary for end-to-end service deployment were discussed.

We also discussed the value of a multiservices approach to DSL and identified the components required for a comprehensive DSL network solution including:

- *Multiservices DSLAMs*
- *Remote DSL transceiver units*
- *POTS splitter and microfilter devices*
- *End-to-end network management systems*

Chapter 5

MARKET EVOLUTION AND DEPLOYMENT REALITIES

The emerging DSL market is quickly gaining recognition and acceptance as a viable way to meet the ever-increasing demand for more bandwidth. New vendors appear on the scene almost daily with announcements or plans to capitalize on the DSL opportunity, while established players continue mass-market rollouts of DSL services. This chapter will review the market dynamics and deployment realities. In Chapter 6, Emerging Services and Applications, we will cover some of the more compelling examples of DSL-based services.

MARKET DIRECTION

While many traditional telephone companies are facing competition from cable companies, wireless operators, and other new service providers, regulatory agencies worldwide have begun to allow outside access to the central office and local copper wires. We will cover some of the regulatory issues later in this chapter. The market dynamics, coupled with the insistent demand from commercial and residential service users for higher speeds, innovative services and reasonable prices, have created the cause and the effect of the spiraling need for bandwidth.

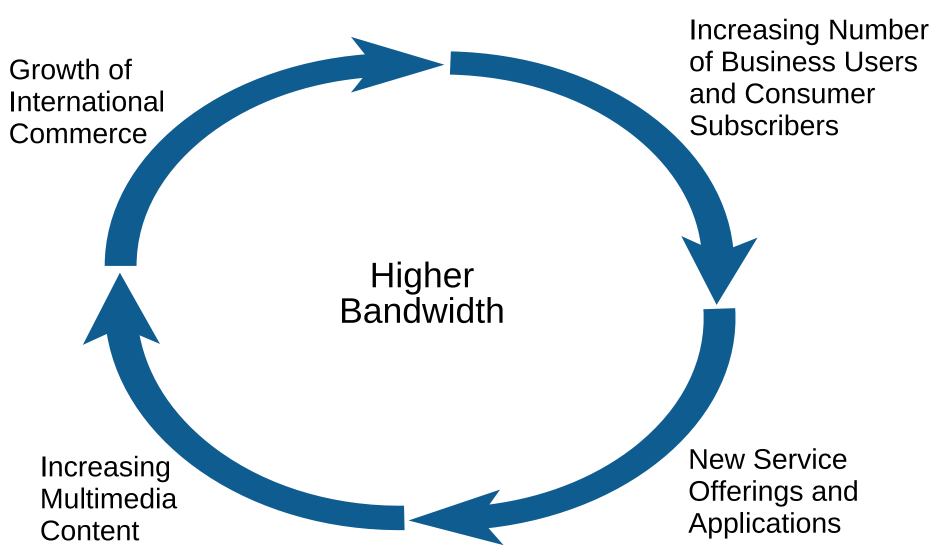
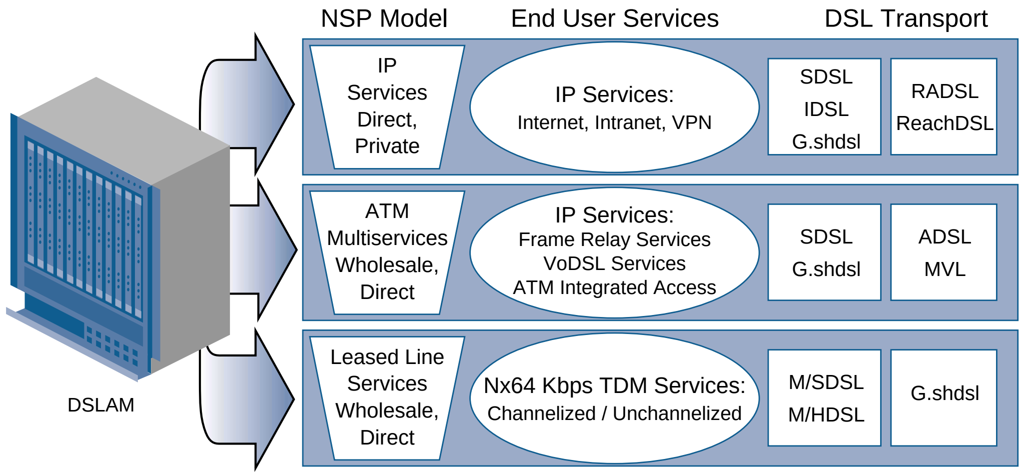


FIGURE 5-1 The Spiraling Need for Bandwidth

The result of this spiraling demand for bandwidth is a marketplace in flux. Service providers and service users alike seek economical bandwidth solutions for emerging high-speed applications. Although DSL technology enables broadband applications over virtually any existing copper loop, there are different business models and subscriber services and even different DSL transports to address these services, as shown in Figure 5-2.

FIGURE 5-2
Deployment Models, Services and Transports



For example, early on, as ISPs filed for CLEC status to provision high-speed services directly to their subscribers, they used a direct-services business model. At this early market juncture, they would often make use of optimized IP services to engage the business customer or customers within private network and multiple dwelling unit/multiple tenant unit (MDU/MTU) environments. The name of the game was customer acquisition and, as the CLEC provisioned services directly to subscribers, interoperability issues were secondary.

In late 1998 and throughout 1999, we witnessed the emergence of wholesale business models, wherein the CLEC would sell wholesale access to ISPs, who would in turn provision the services directly to the end subscriber. In this wholesale model, the CLEC does not own nor manage the end-customer relationship and "interoperability" became the rallying cry to achieve critical market mass.

Today, we are seeing these business models converge, as everyone scrambles to leverage investment infrastructures to capture higher-margin business customers with differentiated classes of service guarantees.

It should also be noted that commercial business applications supported with existing services such as dedicated T1/E1 and fractional T1, frame relay, and LAN-to-LAN connections can be delivered more affordably using DSL technology. DSL-based services efficiently position both the service provider and the corporation for a smooth transition to emerging broadband services. An early application of the DSL evolution in the local loop has been a phased process in the commercial sector, initially used selectively to convert some services or a given network to DSL-based services for high-speed Internet, Nx64, and frame relay access. Increasingly, however, DSL service providers are finding great demand for broadband services from smaller enterprises that historically have not been in a position to afford or cost-justify other traditional broadband services. The rise of e-commerce has greatly increased the demand for bandwidth and broadband-enabled services such as Virtual Private Networks (VPNs), intranets and extranets for companies that previously had rather limited needs for data services.

Figure 5-3 illustrates how the ongoing introduction of DSL-based services will most likely evolve.

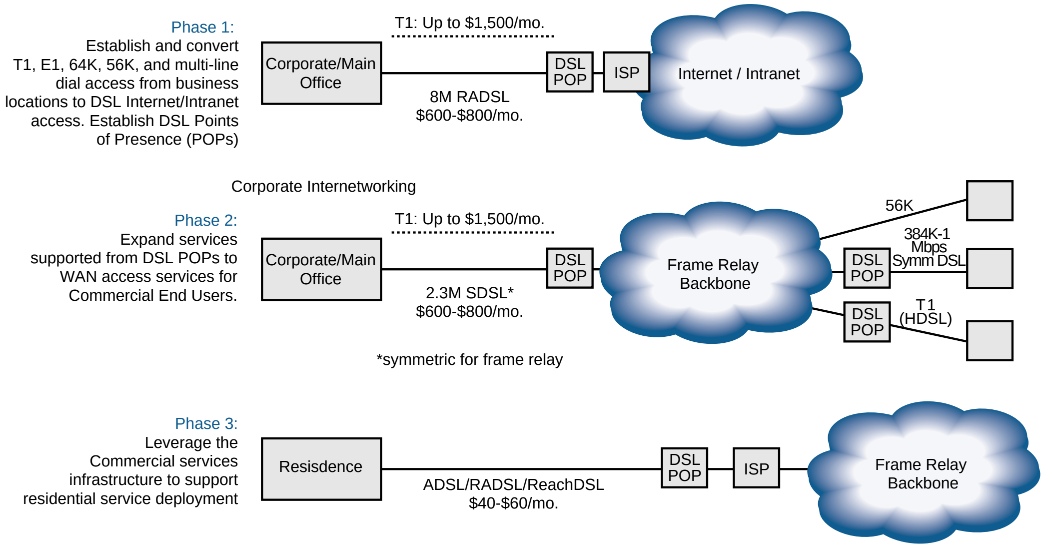


FIGURE 5-3
Phased Deployment of DSL-Based Services

As noted earlier, DSL-based services are also well suited for early adoption in the private corporate and campus environments. Deployment of DSL equipment within private networks (such as multiple tenant environments) can avoid many issues faced with placement of the DSLAM in a CO or RT. The copper infrastructure in a true campus or high-rise building environment tends to be owned by the landlord and not the ILEC, creating an interesting opportunity for the entrepreneurial service provider to deploy DSL-based services independent of the ILEC.

For example, the private/campus network environment can be a CLEC model where a T3/E3 service is provisioned to the campus edge and then multiple services are fanned out to multiple users within the private/campus network using DSL. The resulting deployment scenarios could include support for both channelized services, packet and cell-based services. We will explore the campus opportunity more in Chapter 6, Emerging Services and Applications.

DEPLOYMENT STATISTICS TO DATE

Since moving from the early trial stages to real-life deployments over the past few years, DSL has rapidly grown to be a true mass-market service, with commercial services being offered worldwide by both ILECs and PTOs and a host of competitive providers and CLECs. The fastest growth to date has been in the North American market, where all of the major incumbent providers and dozens of competitive providers have begun to offer commercial DSL services.

According to the latest deployment figures available as of this writing, there are over **one million lines in service** in the U.S. and Canada. The growth of DSL service deployment continues to be significant, with a 50 percent quarter-to-quarter growth rate recorded during the first quarter of 2000.

Within the U.S., the largest DSL market to date, there has been a significant differentiation between the CLECs and ILECs in terms of market focus and deployment numbers. CLECs have, for the most part, been focused on business customers, with 78 percent of their customers being businesses (many of them small- to medium-size businesses utilizing SDSL services). The FCC mandate for line sharing is expected to level the playing field for CLECs by enabling them to access the telephone lines that are already in place to deploy high-speed data services. The line-sharing mandate brings significant savings to the CLEC. (See the section on Line Sharing at the end of this chapter).

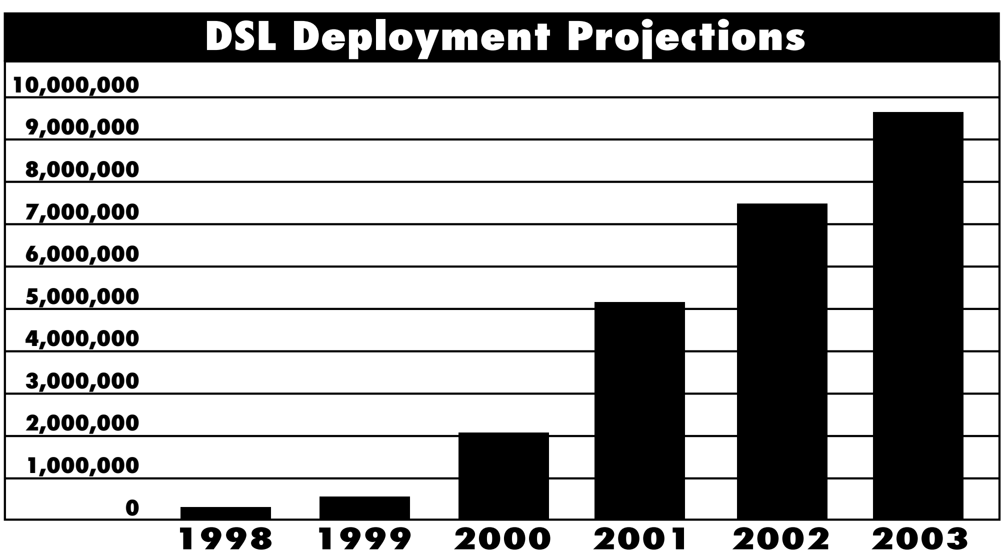
ILECs have had greater overall numbers of subscribers, with a focus on residential customers, with 84 percent of their customers being consumers instead of businesses. Overall, 69 percent of DSL customers have been residential – demonstrating the mass-market appeal of DSL for home Web surfers and telecommuters. The following figure shows the overall numbers of lines deployed in the U.S. and Canada, with a breakdown between ILECs, CLECS, and IXCs, as well as a breakdown between business and residential customers.

FIGURE 5-4
North American DSL Deployment as of Q2 2000

North America 2Q00 DSL Deployment Summary				
Service Provider	2Q00 Lines in Service	% Residential	% Business	DSL-Equipped COs
ILECs - U.S.	914,000	80%	20%	4,443
CLECs - U.S.	277,478	29%	71%	7,217
IXCs -U.S.	13,000	16%	84%	2,000
Total - U.S.	1,204,478	68%	32%	13,660
ILECs-Canada	187,000	88%	12%	660
Total -N.A.	1,391,478	70%	30%	14,320

Given the huge demand for bandwidth in general, and DSL services in particular, the DSL market in the U.S. is expected to continue to grow rapidly, with the total number of DSL subscribers expected to exceed two million by the end of 2000 and to reach nearly 10 million by 2003. Figure 5-5 below shows the expected growth rate of the U.S. DSL market.

FIGURE 5-5
DSL Market Growth



Outside of North America, there is also rapid growth in DSL deployment, although most other regions are behind the U.S. and Canada in terms of deployments to date. In the European market, DSL deployment has lagged behind the U.S., but both PTOs (like France Telecom, Deutsche Telecom and BT) and European CLECs have recently begun to move beyond the trial stage and into mass-market deployment. Most estimates conclude that the total European Union (EU) market for DSL will grow to be at least as large as the U.S. market.

In Asia, there have been aggressive deployments in several areas, including Singapore, Hong Kong , Taiwan and Korea, as well as Japan and China. In fact, Korean DSL deployment has been in a massive growth stage during the past year, with estimates of a million lines in service by the end of 2000, compared to less than 100,000 lines in place at the end of 1999. The prevalence of multi-dwelling unit housing in the Korean market has facilitated this deployment by placing many users within short range of deployed DSLAMs.

DEPLOYMENT REALITIES

Historically, common carriers provided high-bandwidth services to the edge of the network. As other services such as frame relay were offered, newer service providers built their own backbone networks and then contracted with the ILECs/PTOs for connections to the network edge (the service user connection) through the local serving central office. In either case, customers who needed these higher speeds over the local copper loop facility paid high monthly rates to the access provider, if in fact the copper could even be provisioned for these services at all.

In the above example, the ILECs/PTOs act as network access providers on behalf of network service providers. Contracted access services tend to be expensive for a number of reasons. Now, a new generation of DSL equipment promises to enable lower-cost access. In addition, new regulations in many parts of the world will allow for new entrants into the network access business.

Since DSL systems, by definition, require physical connection to the local loop, ILECs, PTOs and CLECs wanting to offer DSL-based services must locate the DSLAM within 12,000 to 18,000 feet (3.6 to 5.5 km) of the service user (although certain DSL technologies, such as M/SDSL and ReachDSL, can offer even longer loop reaches). ILECs, as custodians of the copper infrastructure, can accommodate this requirement easily. CLECs can achieve the requirement in one of six ways:

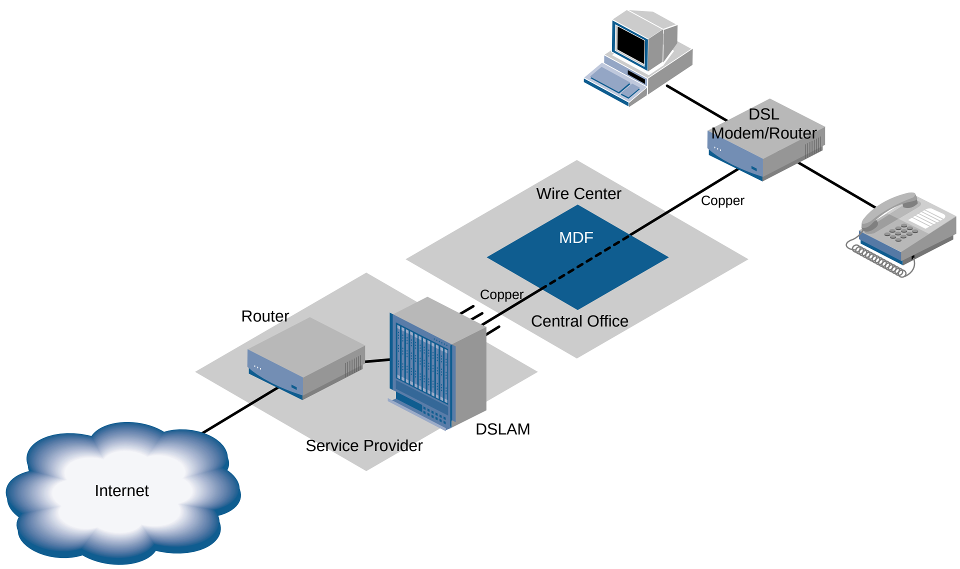
1. *Physical Collocation – Floor space in the central office and copper facilities is leased from the ILEC. CLEC equipment is physically located in the CO and maintained by CLEC personnel.*
2. *Virtual Collocation – Similar to the above, except that the CLEC provides the DSLAM equipment and subcontracts its maintenance from the ILEC.*
3. *Cageless Collocation – The CLEC uses the ILEC's equipment racks in the CO to deploy their equipment and services. This saves the CLEC from having to pay for a full 10-foot by 10-foot cage.*
4. *Adjacent Site – The DSLAM is located in facilities owned and operated by the CLEC, and an unconditioned dedicated copper circuit is ordered from the local access provider. The total length of the copper loop from the user's site through the incumbent's CO and to the CLEC's location must not exceed the DSL reach, usually 12,000 to 18,000 feet (3.6 to 5.5 km).*

5. *Campus CO Site – The DSLAM is located at the edge of the campus where services are distributed. The DSL lines are limited to distribution of services within the campus, and the DSLAM is connected to the NSP location via a traditional ILEC broadband service.*

6. *Multiple Tenant Unit (MTU) or Multiple Dwelling Unit (MDU) – Similar to the campus CO site, with a focus on single buildings with a number of potential DSL customers, like high-rise office or apartment buildings. The DSLAM is located in the central wiring closet of the MTU/MDU and is connected to the NSP by a traditional ILEC broadband service or by another DSL connection, depending upon the bandwidth requirements of the building.*

Often, a CLEC will implement the adjacent site model by renting a small room or closet very close to the CO to reduce costs and increase the coverage area. Additionally, this option is pursued by new entrants to the CLEC market, as space within the CO is limited and often unavailable. This is illustrated in the figure below.

FIGURE 5-6
Conceptual CLEC/ISP Backhaul Model



Aside from the regulatory hurdles of becoming a CLEC and the ensuing negotiations for equipment collocation, and the expenses involved, the business case must be made. It is currently estimated that in some regions approximately 200 DSL customer lines on a collocated DSLAM would be needed for the business model to achieve success. Fortunately, multiservices DSLAM capabilities (such as T1/E1, IP, frame relay, ATM) help to quickly move this scale of service to reality.

These deployment realities can also vary depending upon the target market of the DSL provider. For example, a CLEC with a business focus could typically sell premium services with performance guarantees to support applications like frame relay or virtual private networks (VPN) in addition to basic IP services and Internet access. These higher-margin services would mean the CLEC business case would typically hold together with fewer customers per DSLAM than would a consumer-focused ILEC model. Again, this is because consumer-grade services are more price sensitive and don't deliver the value of performance guarantees required by the business-class DSL user.

THE NEW REGULATORY ENVIRONMENT

Globally, the telecommunications services business has changed tremendously over the past half decade. Many countries have removed the barriers to competition for service-provider companies that want to enter local markets, fostering new opportunities for carriers and service users alike. The incumbent telephone companies also benefit by being able to branch out and offer innovative services to existing customers, requiring only an incremental investment.

In the United States, the Telecommunications Reform Act of 1996 moved deregulation closer to reality. Among other provisions, the Act lets anyone who qualifies enter the communications provider business and compete on an equal basis with the ILECs. This allows CLECs, ISPs, independent telephone companies, and even long distance carriers to lease network elements in order to provide high-speed access to their services. Literally hundreds of new companies have been formed to offer alternative access services, including DSL-based services. The ILEC, in turn, can now act as a CLEC in areas outside of its traditional serving region, offering megabit access as well as value-added services and long distance services both inside and outside of its serving region.

Just as the Telecommunications Act of 1996 has revolutionized the telecommunications industry in North America, the World Trade Organization Global Telecommunications Agreement, signed by 69 countries in February 1997, is seen as the beginning of a global revolution in the telecommunications industry.

The Agreement:

- *Gives U.S. and foreign companies the opportunity to offer a variety of new and existing services*
- *Ensures that companies can invest in foreign telecommunications firms*
- *Adopts regulations that promote competition*

The Agreement went into effect January 1, 1998, although it will take several years for some countries to implement.

Some countries were well on their way to deregulation even before signing the agreement. The European Union had as a goal to open its markets by January 1998. Although not all EU countries have reached full compliance yet, many have met or beat the deadline and are already operating in a highly competitive environment. Finland opened its IT market in the 1980's and in 1994 allowed competition in the local, long distance, and international telecommunications sectors. Neighboring Denmark opened its telecommunications market to full competition in mid-1996. By contrast, in Greece, full liberalization of public voice telephone and facilities-based services is not expected prior to 2003.

Deregulation in the more developed countries of Europe and Asia Pacific is fueled largely by new technologies and increasing competitive pressures. In developing countries, the privatization of the national Post, Telephone and Telegraph (PTT) companies, followed by increased competition, is being pushed by the need for cash to expand the network in order to meet demand for services and compete in the global community. For example, in countries like Brazil, where millions of people are on waiting lists to get basic phone service, the investments made by Telebras (the Brazilian PTT) prior to privatization were not sufficient. Since privatization, however, Telebras and its subsidiaries have received significant investments that have allowed them to spend billions of dollars on network expansion.

Line Sharing Provides Even Greater Access

Perhaps the most significant recent deregulation development within the U.S. has been the FCC's "line sharing" order, which went into effect June 6, 2000. Historically, when a CLEC provisioned a DSL service to a customer using an unbundled ILEC copper element, the CLEC was required to provision the service on a different copper pair than the one already in place for providing ILEC voice services to the customer. ILECs, on the other hand, commonly provided voice-compatible forms of DSL, such as ADSL, MVL or RADSL, over the existing line. This disparity gave the ILEC a significant competitive advantage over the CLEC, both in terms of provisioning time (since there was no need to install or qualify a new copper pair) and in terms of economics (since the CLEC had to pay a monthly line charge – typically around $20 – while the ILEC did not). The FCC, recognizing this competitive disparity, ruled that ILECs are required to provide to CLECs the same access to these existing voice lines as the ILECs themselves currently enjoy.

Specifically, the FCC ordered this access for DSL technologies that are spectrally compatible when coexisting with voiceband services. The FCC listed ADSL, RADSL and MVL as POTS-friendly technologies that will not interfere with existing voice services. Other DSL technologies, such as SDSL, are not compatible with POTS voice services and, therefore, do not fall under this ruling.

Although this ruling has already gone into effect at this writing, it will take some time for it to be ubiquitously deployed throughout all ILEC networks, as technical, regulatory and business details are worked out between CLECs and ILECs. Some of the items still being agreed upon between ILECs, CLECs and regulators include:

- *The pricing of this access to existing lines. Although some CLECs have argued that ILECs should provide this access for free, since there are no incremental costs involved, most agreements to date have involved some small monthly fee paid to the ILEC by the CLEC. It is important to note, however, that whatever cost is eventually agreed upon, it will be significantly less than the cost of a separate copper pair that CLECs have been burdened with until now – therefore lowering the CLEC's cost of offering DSL services to customers.*
- *Line qualification and testing techniques. Because "line-shared" lines carry lifeline POTS voice services, ILECs have very stringent requirements for availability and uptime. ILECs and CLECs are currently investigating several different systems and techniques that will allow qualification and testing of DSL services without interfering with voice services.*
- *Collocation and copper management. Just as testing and line qualification can interfere with voice service availability, the method of collocating equipment and managing copper loops in a line-shared environment is different than the traditional CLEC model where no voice services were offered over DSL-equipped lines. CLECs and ILECs must agree upon ways to physically interconnect existing voice lines to CLEC DSLAMs without interfering with ILEC management of voice services.*

ILECs, CLECs and equipment vendors are all working rapidly to resolve these issues, and line sharing is beginning to be deployed in many CLEC networks. This deployment should have a significant and positive effect on the deployment of DSL services, as it lowers the cost of doing business for CLECs while simultaneously improving their ability to rapidly deploy services to potential customers.

Chapter 5 Summary

This chapter covered some of the dynamics in the emerging DSL market, such as the spiraling need for more bandwidth. Also discussed were DSL-based service deployment realities, such as:

- *Phased approach to DSL-based service deployment beginning with commercial customers who will selectively convert existing network services*
- *Rapid growth of a consumer market for DSL services, following directly behind the commercial market*
- *Mass deployment of DSL services worldwide, with the North American market leading in terms of deployments to date*
- *ILEC's ability to provision DSL-based services today and options for the CLEC and ISP relative to deployment: Physical Collocation, Virtual Collocation, Cageless Collocation, Adjacent Site, or Campus/MDU/MTU installations*
- *The new regulatory environment in the U.S. and internationally*
- *FCC ruling on line sharing, which substantially increases CLEC access to unbundled copper elements for providing DSL services, while simultaneously decreasing their costs for such access*

Chapter 6

EMERGING SERVICES AND APPLICATIONS

AN ACCESS TECHNOLOGY FOR THE NEW CENTURY

As content-rich applications continue to grow and stress both public and private access network infrastructures, the local portion of the enterprise becomes a major challenge for access providers. How do we cost effectively provide corporations with the speed needed without major investments in local loop upgrades? In many cases, DSL technology is the answer.

As previously stated, DSL is not a service as much as an enabler of high-speed services. It provides an economical way to provision services versus traditional channelized T1/E1 and 56/64 Kbps circuits. The reason the DSL market is growing so rapidly is that DSL-based services do not cause us to change the services we currently use, but rather they allow us to provide them at faster speeds, with lower costs, and with equivalent or better service performance guarantees than previously thought possible.

To further illustrate this point, we will look at four traditional services and how they are used in conjunction with DSL-based offerings:

- *Channelized T1/E1 services*
- *IP services*
- *Frame relay services with full service level management capabilities*
- *Asynchronous transfer mode (ATM) services with a full suite of QoS classifications*

In addition, we will examine the application for DSL-based services within campus and private network environments. A campus, for our purposes, can be any entity that owns or controls its copper wire infrastructure. This includes high-rise office and residential buildings, universities, and corporate and government campuses.

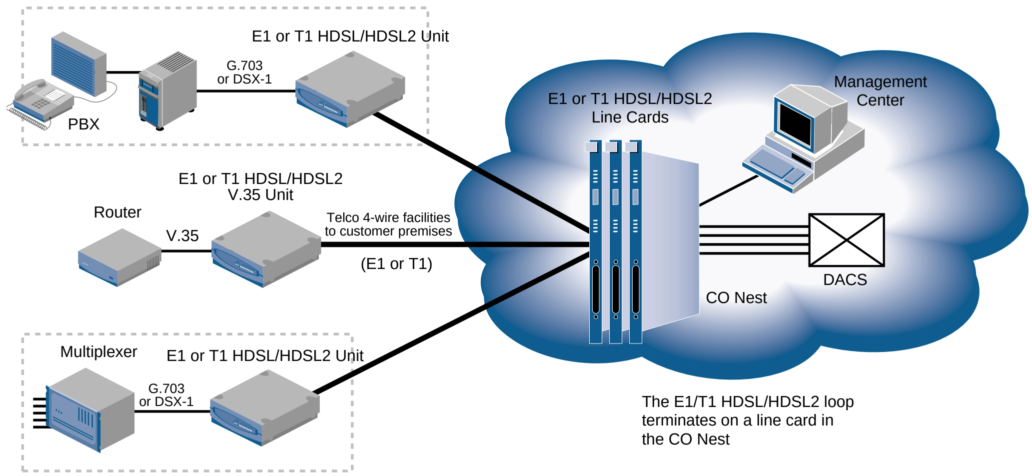
Finally, we will discuss the emerging service option of Voice over DSL. As previously discussed, certain DSL variants (such as ADSL, RADSL, and ReachDSL) can allow simultaneous use of traditional POTS services on the same line used for DSL. In addition to this, new systems are being deployed that allow VoDSL services – multiple packetized voice channels using IP (VoIP) or ATM PVCs over the DSL connection.

CHANNELIZED T1/E1 SERVICES

Traditional T1/E1 services can be costly to provision, as we learned in Chapter 2, The Existing Copper Wire Infrastructure. Service providers have been able to reduce the cost of provisioning T1/E1 services with HDSL by eliminating the need for the special engineering, repeaters, and labor associated with traditional T1/E1 deployment. HDSL is currently still the most widely used application for DSL technology. Figure 6-1 illustrates some common uses of HDSL for service provisioning.

The extension of T1/E1 service from the CO to the service user provides for transparent transport of all service offerings (IP, frame relay, Nx64, and ATM).

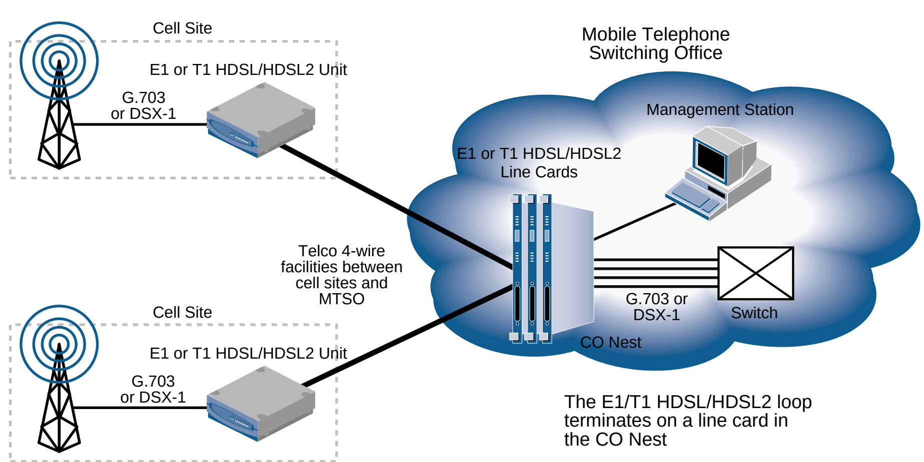
FIGURE 6-1
T1/E1 Extension to the Customer Location



In the T1/E1 replacement scenario, the CO hosts the HDSL/HDSL2 nest, which houses HDSL/HDSL2 line cards. These line cards each terminate two HDSL/HDSL2 lines, each carrying 784 Kbps for T1 or 1,168 Kbps for E1 in the CO. The two lines are then combined and converted to either a G.703 interface (E1) or a DSX-1 interface (T1) for connection to other central office equipment, such as a DACS. The customer site equipment consists of HDSL/HDSL2 standalone line units configured as either a data unit with a V.35 port or a native port (G.703/G.704 for E1 or DSX-1 for T1). The V.35 port could be connected to a router or other data equipment that is capable of using the V.35 interface. The native port products (G.703 or DSX-1) would be connected to either a digital PBX, multiplexer or other customer premises equipment that is capable of using the native E1 or T1 interface.

Another interesting application for HDSL services lies within a cellular network operator's infrastructure, which delivers T1 or E1 services from their MTSO (Mobile Telephone Switching Office) out to the various cell sites, as shown in Figure 6-2. This is particularly important for wireless carriers who must lease T1 or E1 lines from a third-party local exchange provider. The wireless carrier can save significant costs by leasing the copper and deploying services without having to lease the tariffed T1 or E1 service.

FIGURE 6-2
T1/E1 Cellular Environment



Since 1996, SDSL (single pair symmetric DSL) devices have been on the market, offering the potential to further reduce the cost of T1/E1 line provisioning. SDSL provides most of the benefit of HDSL, and it operates over two wires instead of four. This represents a substantial gain in efficiency and cost. Most SDSL services deployed to date, however, have been IP services – which we will discuss in the next section – rather than customer-transparent replacements for T1/E1 services. New standards-based replacements for HDSL – HDSL2 (U.S.) and G.shdsl (worldwide), have recently been approved and are beginning to be rolled out in service provider networks. HDSL2 and G.shdsl are single-pair technologies, offering the cost savings and copper plant conservation of SDSL by using two wires instead of four.

In summary, HDSL, HDSL2, G.shdsl or today's SDSL-based implementations of T1/E1 service provisioning provide the same quality of service as conventional AMI/HDB3-based systems. However, DSL provides a lower installation and recurring maintenance expense due to the reduced circuit engineering requirements and the elimination of repeaters in the local loop.

IP SERVICES – THE ARRIVAL OF INTERNET-BASED NETWORKING

Over the last few years, the Internet, or more correctly the World Wide Web, has had a profound impact on our ideas about information flow. Once the exclusive domain of academia, the Internet's global collection of interconnected computer networks has become the medium of choice for the dissemination of information for both individuals and corporations.

The idea of an easy and cost-effective way to provide updated information to employees, partners, and customers is extremely attractive to businesses. This new and simple way to communicate gives people the freedom to develop much richer content than ever before. But this newfound freedom comes with a price – the graphical nature of the content creates large files that have to be downloaded into the user's PC. Given the speeds of analog modems, a lot of time is spent waiting for file downloads, even though the bandwidth of the backbone network keeps increasing. Most frequently, the cause is a bottleneck in the local loop.

Recently, we have seen several new trends emerge in the Web environment that increase bandwidth requirements by at least an order of magnitude:

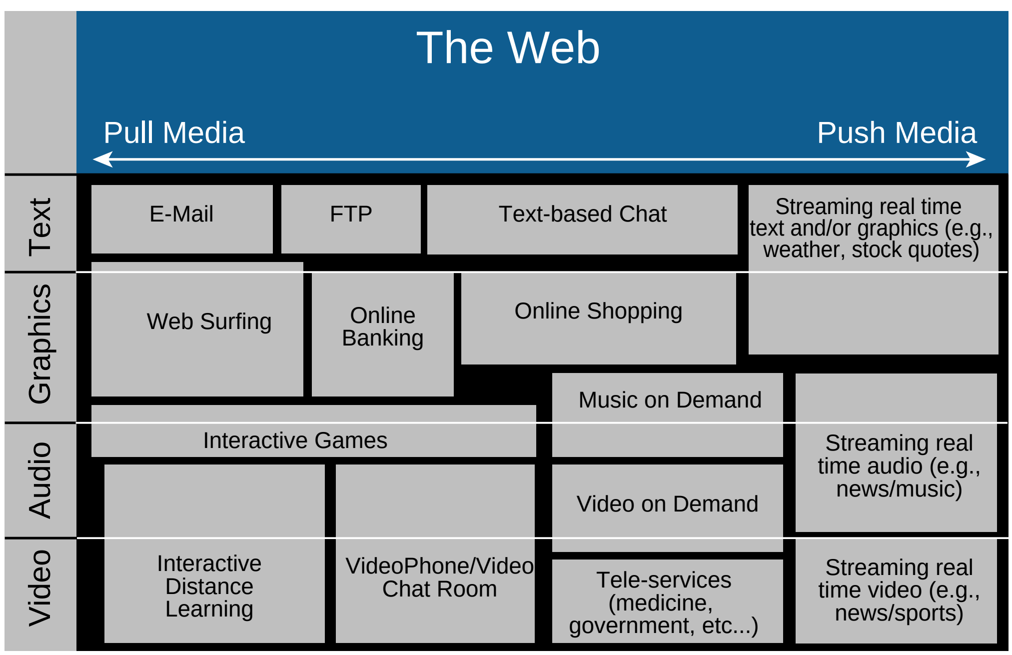
- *The addition of audio and video media to Web computing based on the TCP/IP protocol. This includes streaming media such as RealAudio and video content, as well as new digital means of distributing audio/video entertainment, such as the incredibly popular MP3 format for digital audio files.*
- *A growing trend for today's Internet service providers is to become application service providers, or ASPs. In this model, a variety of end-user applications (ranging from desktop and productivity software like word processors to sophisticated business applications such as e-commerce solutions, Electronic Resource Planning [ERP] and inventory management) are hosted and managed by a remote service provider, with end users accessing the applications themselves remotely through an IP connection.*
- *Interactive conferencing or collaboration applications, such as IP-based audio conferencing, document sharing and whiteboarding, are also*

becoming increasingly common. These applications allow remote parties – in both business and consumer environments – to communicate using the shared IP backbone of the Internet or other public IP networks.

- *Even computer gaming has moved from a standalone, PC-based application to a networked one. Many leading PC games now include networking functionality. This capacity utilizes remote servers and IP-based networking to allow users to participate in multi-user games with other users throughout the world.*
- *The rise of multi-PC households and home networking. Today's families often have multiple PCs in the home at one time – a kid's PC for games and homework, a home PC for e-mail and online banking, and perhaps a laptop from work. All of these PCs are being connected together to share files, printers, and Internet access. At the same time, standalone Internet appliances are being developed, such as WebTV devices, which also demand a share of the Internet connection. An analog modem quickly runs out of bandwidth and can't provide connections to multiple services (e.g., parents connected via VPN to the office network, kids connected to the school extranet) at one time.*
- *The integration of a push paradigm of content presentation into the existing pull paradigm that is represented by today's Web browser. The pull paradigm requires active participation from a user to access content (e.g., typing URLs, initiating searches, etc.), while the push paradigm feeds content to a passive viewer/listener (e.g., stock ticker for text, radio for audio, and TV for video).*

The Web browser is evolving into an interface supporting not only audio, video, and other multimedia applications, but also the blend of pull/push paradigms for content presentation, opening up the Web to a wide range of applications, as shown in the following figure.

FIGURE 6-3 Emerging Web-based application matrix generated by the addition of audio and video media, and integration of the pull/push paradigms of content presentation



The first thing that comes to mind when we think of IP is the Internet. The packet-based architecture of the Internet enables optimum utilization of the backbone bandwidth, translating into low usage costs. DSL-based services provide the added benefit of extending this oversubscribed, statistical usage-based network even closer to the user, resulting in savings over both the local loop and backhaul network from the DSL POP (point of presence) to the ISP POP.

Related to the Internet are applications for intranets and extranets, which are private and semi-private corporate networks. Whereas the term intranet implies a single company or organization, the term extranet sometimes implies a closed network comprised of multiple companies. Private corporate intranets are being improved to provide higher levels of QoS to the business customer for Internet services. The rapid growth of these corporate networks gives credence to the value of the Web and Web-based technologies for commerce.

Intranets and extranets have given businesses a way to cost effectively provide rich and extremely detailed information to various populations. Now, for example, instead of a broad memo describing the new medical plan, a company can put an interactive "benefits calculator" on the Intranet so that each individual can determine how he or she will be affected by the plan. Now, instead of a company sending its chassis vendor a set of requirements for a new widget, it can put a 3-D rendered image of the product concept on the extranet so the vendor can fully grasp the ideas behind the concept. Extranets are increasingly incorporating Internet technologies such as XML, which allow partnering companies to move all of their ordering, inventory management, shipping and other business processes into an integrated online environment.

The wealth of extremely rich content portends a dramatic change in business communications and information flow. There is another trend, however, which can impact this brave new world of information: an increasingly dispersed and remote workforce.

The concept of remote LAN access is not a new one, but it is one that has undergone a great deal of change. In most cases, today's remote worker must remain in constant contact with the company. In effect, the remote worker should appear as just another user on the corporate LAN. The problem is that traditional methods of remote access do not meet today's needs. The typical remote worker utilizes an analog modem or ISDN to access the network. Since both of these technologies pass through the PSTN, the terminating equipment, which also provides the security and user authentication, is located in the corporate office with the modems. These traditional access methods are either too slow to be effective for a multimedia Intranet or too expensive to be justified for a small branch office or a teleworker.

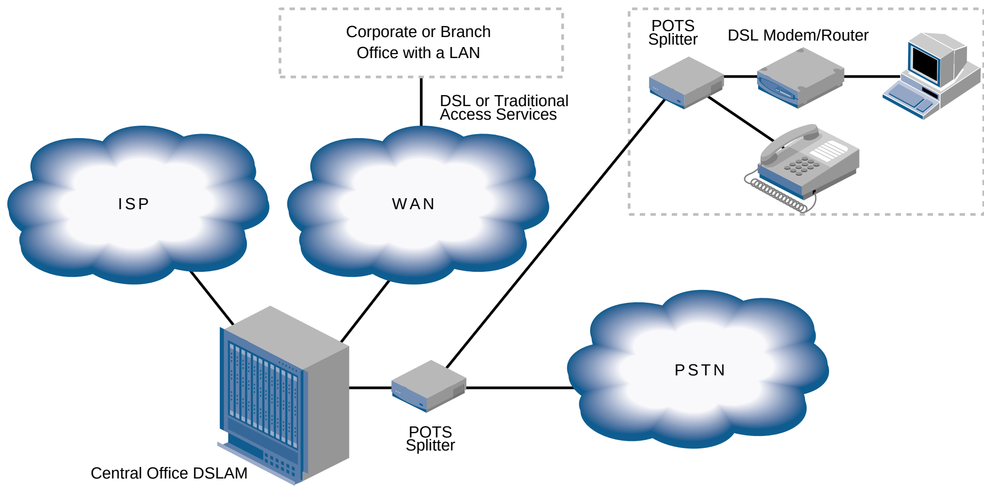
Here again, DSL can fit the bill, providing economical, high-speed access to the corporate networks. DSL's multimegabit speeds offer the LAN-like performance needed to support the multimedia information flow. Concentration at the network edge and oversubscription of the network (which assumes not all users are sending or receiving data at the same time) allow the DSL-based network service provider to offer high-speed access at a very attractive price.

Remote access applications utilizing DSL technology still require the security and authentication to be handled at the corporate office. This does not change with DSL-based services. What does change is the location of the terminating equipment, which is now in the CO rather than the corporate office. Therefore, extending DSL speeds to the remote worker is not simply a matter of replacing a modem in your existing corporate server.

Virtual private network services (discussed in more detail in Chapter 7) can offer DSL-equipped remote workers an even more cost-effective means of accessing the corporate network or intranet by utilizing a shared IP-backbone for long-haul network transport. When combined with QoS enhancements being offered by next-generation DSL solutions, VPN-equipped teleworkers can feel like they are directly connected to the office network, even when they are hundreds or thousands of miles away. VoDSL services can be combined into the equation to offer teleworkers remote access to the corporate PBX, so that they truly are plugged into the enterprise.

The figure below illustrates remote access for branch offices and telecommuters.

FIGURE 6-4
Remote Office/ Telecommuter Application



FRAME RELAY SERVICES

Frame relay is a packet service that offers significant savings over traditional leased line networks. Frame relay takes advantage of the concepts of shared bandwidth, traffic patterns, and oversubscription, allowing service providers to offer more speed for less compared to leased line network arrangements. An examination of these concepts is provided in the following analogy.

The frame relay network can be viewed as a group of interconnected high-speed highways that come together at fixed access points. These access points are the frame relay switches. Connected to these access points are on-ramps (service user access lines). Typically, a large number of these on-ramps are brought into each access point. Anyone who has driven on an interstate highway knows that most of the time we can get on the highway, travel its length at high speed with other drivers, and exit at the appropriate off-ramp. In essence, the highway is a shared resource used by everyone. The lanes of the highway are its bandwidth. The larger the number of lanes, the greater the bandwidth. The interstate highway system, like the frame relay backbone, is an efficient and cost-effective way to move traffic – most of the time.

Traffic engineering is a method used by frame relay service providers to determine how much bandwidth a particular network needs to handle the traffic load most of the time. Also considered is oversubscription of the bandwidth, which is necessary from an economic standpoint.

Frame relay uses a network of switches to concentrate traffic from a number of users onto a common backbone. These switches also provide congestion management to avoid the potential gridlock during heavy traffic hours. The frame relay network is designed to reduce overall WAN costs by acting as a shared bandwidth pool. The frame relay switches are strategically placed by the network designers in the most cost-effective locations. This means that the access point may be across the street or across the state.

Users traditionally access frame relay via dedicated leased lines from the customer location to the service provider's POP. The cost of traditional frame relay access lines (56/64 Kbps or T1/E1) is, in most cases, distance sensitive. The longer the distance, the higher the cost. Another area of growing concern is that the popularity of frame relay has caused corporations to consolidate different types of traffic over the service. This causes potential bottleneck problems over the local access loop. This is where DSL comes in.

By using DSL access instead of 56/64 Kbps DDS, full T1/E1, and perhaps most importantly fractional T1, service provisioning becomes easier, more flexible, and more cost effective. Access speeds of up to 2.3 Mbps and end-to-end network management are possible. Please refer to the figure below.

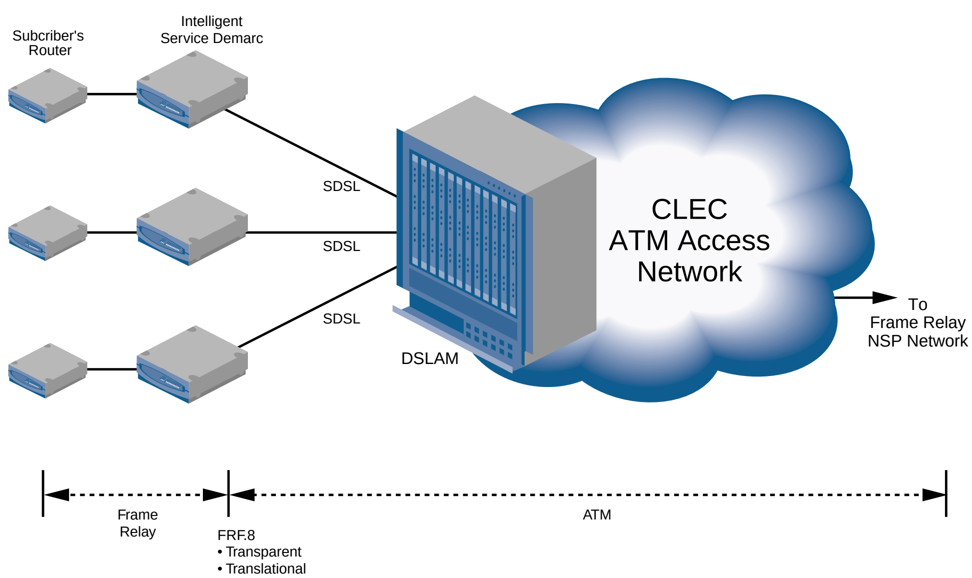


FIGURE 6-5
DSL and Frame Relay

FRoDSL offers three significant benefits for the network access provider, the frame relay service provider and the frame relay service user:

1. *DSL can reduce the local access portion of the cost of subscription, which, according to some analysts, is as high as 38 percent or more of the total overall cost. As stated in the previous section, DSL eliminates the expensive special engineering and repeaters required in traditional access technologies.*

2. *SLM-DSL implementations, as shown above in Figure 6-5, enable business-class DSL applications in that they can support full-service performance visibility and provide end-to-end SLA functionality.*

3. *DSL can effectively bring the access point to the network closer to the subscriber. The intelligent service demarc supports both modes of FRF.8 interworking: transparent (frame relay terminates at a frame relay head-end RFC 1490 encapsulation) and translational (frame relay ter minates at an ATM headend RFC 1483 encapsulation).*

As explained in Chapter 3, DSL Basics, DSL is a local loop technology. This means that DSL equipment is not only installed at the customer site but also in the CO at the other end of the copper wires. From the CO, DSL technology can support not only the customer site but also the sites of all of the other frame relay subscribers served out of that central office. This is where the real NSP benefit lies.

A DSLAM can concentrate all of the traffic from the local frame relay subscribers in the local central office. The frame relay service provider who uses DSL-based access can take this concentrated frame relay traffic and send it over a high-speed link to the frame relay switch. The result is that the frame relay service provider can move the point of traffic concentration and congestion management closer to the subscribers, capitalizing on the same economies that are used in the network backbone.

FRAME RELAY OVER DSL AND SERVICE LEVEL MANAGEMENT

The predominant frame relay application is branch-to-headquarters enterprise connection (sometimes called a hub and spoke arrangement). For these applications, control of service quality is paramount. Mission-critical applications are deployed using frame relay services requiring strict adherence to latency, throughput and availability specifications. QoS guarantees must be equivalent to or better than what the customer currently receives in order to migrate their frame relay access method from traditional leased line methods to DSL. Unlike most Internet services where delays and outages can be frustrating (but not enterprise-threatening), transactional and other types of mission-critical applications must run correctly or else dire consequences will result.

In order to guarantee customers the proper level of performance, service providers often offer frame relay services with SLAs, which provide customers with measurements of statistics like network availability, throughput and latency. If the service provider cannot meet the established goals, penalties are assessed. An end-to-end service level management system that can accurately and granularly measure these performance metrics is a key requirement for a service provider that wishes to offer such SLAs.

Traditionally, it has been difficult for service providers to offer service level management and, therefore, sophisticated SLAs on their DSL-based services. This difficulty is based on the fact that service providers must deal with several different network technologies and elements (the DSL endpoint, the DSLAM, and the access network), often with parts of these network segments "owned" by different service providers. Performing the end-to-end performance monitoring across these disparate elements has, in the past, proven nearly impossible – which has been a major disadvantage to a DSL provider wishing to compete with traditional frame relay access methods. Best effort implementations are insufficient to the business-class customer who has come to expect much more.

One solution to this problem is to use ATM throughout the DSL access and backbone network (as shown in Figure 6-5) to make use of the inherent Quality of Service characteristics of ATM within next-generation DSLAMs. SLM-DSL products use this method to provide business-class services such as frame relay access over DSL. In this case, the DSL endpoint performs the FRF.8 interworking function to convert the ATM cells from the DSLAM into frame relay for handoff to the CPE. In addition, the intelligent demarc endpoint collects the critical QoS performance metrics as specified by the Frame Relay Forum (FRF.13 – Service Level Definitions Implementation Agreement, August 1998) for verification and reporting.

In Figure 6-6, the FR NSP (in this case, an IXC), has overall end-to-end responsibility – from service demarc to service demarc. Note that in this example, a CLEC network is utilized to provide access on one side of the circuit, whereas traditional LEC-based access is utilized on the other.

Maintaining end-to-end visibility and control is extremely important for business-class DSL-based services. While the frame relay service provider is responsible for managing the end-to-end frame relay service and customer SLA, the access providers (CLECs, traditional LECs) are actively involved.

DSL service providers who can offer management connectivity for network performance visibility and control within this model can tout an advantage for frame relay service providers who must own and manage the end-customer relationship.

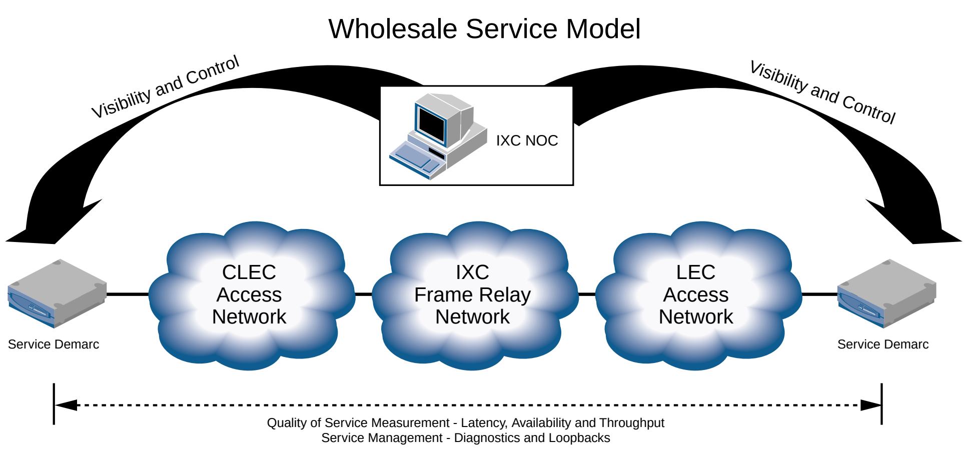


FIGURE 6-6
SLM-DSL Frame Relay Application End-to-End

Business-class DSL systems should be capable of performing non-disruptive, end-to-end loopback tests, in effect checking circuit operation all the way down to the end user's customer premises equipment, without having to dispatch technicians to check equipment (at significant cost to the provider).

Additionally, SLM-DSL solutions must allow service providers or users to:

- *Utilize real-time performance monitoring to verify and track SLA performance*
- *Set service level performance thresholds within the endpoint to allow alarms which initiate troubleshooting before SLAs are not met*
- *Offer mechanisms for service level metrics to be logged daily and offloaded to provide historical data*

The ability to provide frame relay over DSL with true end-to-end SLM can mean significant cost savings to both frame service providers and to end users. As mentioned in Chapter 1, it is estimated that frame relay customers spend, on average, 38 percent of their total service costs just on access. Moving from TDM access technology to less expensive DSL access, while maintaining the ability to offer SLAs, can offer significant opportunities for a service provider to extend cost savings to existing customers, while moving other customers up from lower-speed access methods like ISDN.

ASYNCHRONOUS TRANSFER MODE SERVICES

The concepts behind ATM are powerful and have begun to take hold in the networking community. ATM is a cell-based technology that has fixed-sized cells that have a predictable delay; switching is done in the hardware and is extremely fast. Additionally, ATM offers QoS guarantees for multiple classes of service that meet the needs for applications that are time sensitive, such as voice and video, adding up to lower latency and the ability to handle virtually any application. This makes ATM networks ideal for both high-speed access over the local loop as well as backbone transport of a wide variety of traffic types. Although there are some similarities between frame relay and ATM, differences include:

- *Variable length frames versus ATM's fixed cells*
- *More extensive signaling and networking parameters with ATM, resulting in more control over QoS and performance for a wider range of traffic types*

Because ATM access services are now emerging, branch offices of organizations can take advantage of ATM benefits end to end, across the backbone network, and all the way to the desktop PC. ATM over DSL will complement these applications.

The consolidation of IP traffic for LAN-to-LAN and remote LAN access is another combination of DSL and ATM that makes very good sense. By concentrating multiple sources of LAN traffic at the CO, economies of scale are possible. In addition, it becomes a platform for growth and allows easy migration to desktop ATM.

ATM in the backbone network, working with the appropriate DSL system components, offers a highly efficient method to package WAN facilities. This is a significant factor in terms of overall network design economics and allows service providers to fully utilize the capabilities of next-generation DSLAMs with internal ATM switching capabilities. For example, multiple DSLAMs can be aggregated to share a single WAN interface to achieve PVC conservation and these benefits:

- *Simple and efficient provisioning over the ATM backbone network*
- *Ability for the service provider to inject capital as the network grows*
- *Scalability*

In Chapter 7, Network Models, we will discuss physical layer attributes in the backbone network. In addition, consideration must be given in terms of how to grow and serve up bandwidth incrementally without large corporate infrastructure investments.

In summary, ATM has emerged as an ideal transport for local access as well as CO network backbone transport. In addition to ATM, T1/E1, IP and frame relay services are also expected to support access over the local loops. The advent of ATM over DSL allows the NSP to utilize a single infrastructure to deploy a variety of services; therefore, the popularity of ATM services will continue to grow.

PRIVATE/CAMPUS NETWORKS

One of the major misconceptions about DSL is that it is future technology destined only for the local loop. The truth is that DSL is an enabling copper wire technology that is widely available today and can be used to solve many of the problems encountered in private network environments.

A private, or campus, network environment can be defined as an organization, institution, corporation or agency that requires high-speed data communications. The campus could be a government installation, a college, a hospital, a local government, a utility company, or even the business tenants within a big city corporate high-rise building. These diverse organizations share one unifying characteristic: the ubiquitous copper cable infrastructure that makes up their voice network. It is this copper infrastructure that lets us use DSL technologies to solve many of the problems that we encounter in trying to manage campus data networks.

Before we delve into the applications where DSL would provide viable solutions, let's take a look at why DSL is a preferred alternative to traditional solutions to campus data network access problems.

As we read in Chapter 2, The Existing Copper Wire Infrastructure, DSL is a method of transmitting high-speed data for extended distances over copper wire, simultaneously (in some cases) with traditional telephone service. DSL-based services are effective at distances in excess of three miles. The three things that differentiate DSL-based services from traditional campus solutions are:

- *High speed*
- *Long reach (distance)*
- *Cost effectiveness*

In traditional models, these are mutually exclusive. Traditional high-speed solutions either require expensive infrastructure investment (i.e., fiber optic or coaxial cable) or would only operate over very limited distances. Solutions that operate over extended distances have typically run at less than desirable speeds. DSL technology offers the best solution, high speeds and long distances cost effectively – all over existing copper infrastructure.

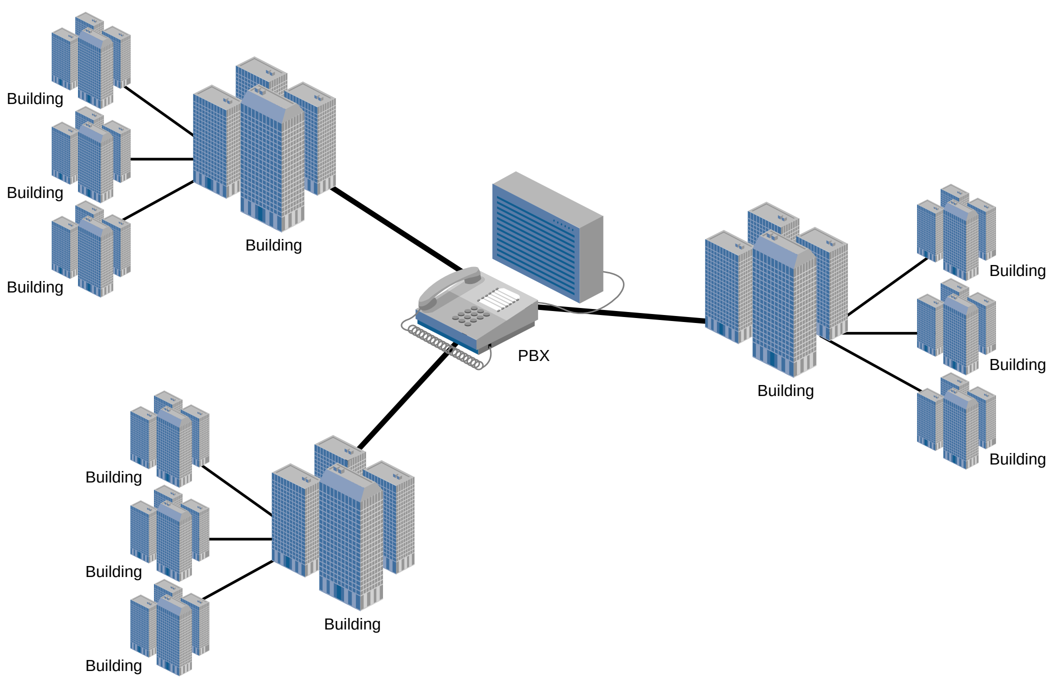
LAN Extension Opportunity

By their very nature, campus LANs tend to evolve in diverse geographic areas. Over time, the people who use these LANs need to share information with one another. The challenge we face is how to connect these disparate LANs together to allow these users to share information.

Often these LANs are separated by distances too great to simply extend the LAN segment (the limit for Category 5 UTP-based Ethernet is 90 meters). The alternatives require special media such as shielded twisted-pair or fiber optic cable or contracting with a service provider to connect the two campus locations. Installing new media across a campus can, in many cases, be prohibitively expensive, and using a service provider results in a recurring monthly charge. This is where DSL technology and the copper infrastructure come into play.

The telephone wiring infrastructure in most campuses is typically a star or distributed star topology (see figure below). As we can see from the illustration, the copper cable connects all buildings on the campus. Using DSL technology, this telephone wiring can be used for easy, inexpensive LAN-to-LAN connectivity. We simply connect the DSL device to the telephone wires at one building and connect a companion DSL device to the other end of the wires at the other building. Once done, the DSL devices are connected to their respective LANs (typically via bridge or router). The result is a simple, quick, and inexpensive way of accomplishing high-speed LAN extension over the existing copper wire infrastructure. Traffic between LANs can be symmetrical or asymmetrical; SDSL/G.shdsl, HDSL/HDSL2, RADSL and ReachDSL technologies may be the DSLs of choice.

FIGURE 6-7
Distributed Star Topology Depicting the Campus Environment



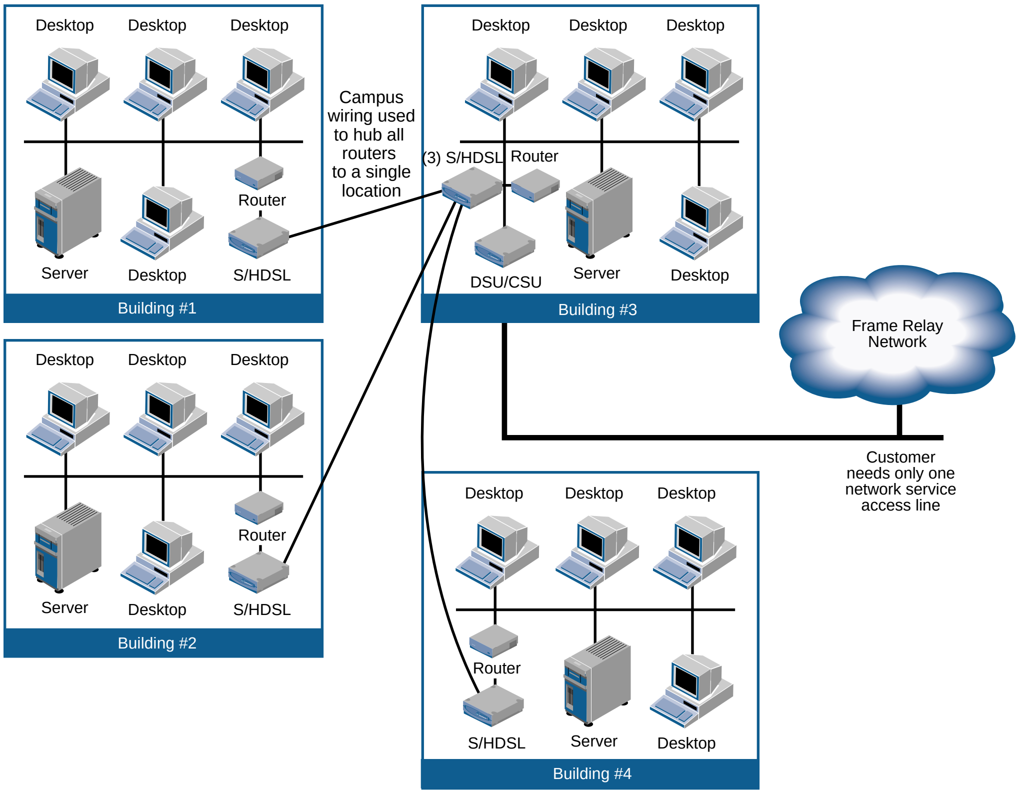


FIGURE 6-8
The Power of DSL in Private/Campus Network Environments

The above figure provides an example of the power of DSL technology in the private campus environment. Four geographically separated buildings each have LANs supporting the personnel in those buildings. These LANs must all be able to communicate with each other (mesh network) and communicate with other corporate locations throughout the country or world.

To satisfy the high-speed connection from each router, the traditional method would be to contract with a service provider for a high-speed connection to a frame service for each building, resulting in a monthly recurring charge and the requirement to route all traffic (even traffic destined for other campus locations) through the frame relay network. With DSL technology, campus wiring replaces three of the four service provider connections and eliminates the need to route campus traffic through the frame relay network.

Or consider the following scenario. A CLEC wants to provide an extension of WAN service. In this scenario, the CLEC can extend a private fiber link or provision a T3/E3 service from the telephone company to provide connection of the CLEC network to the campus edge. Once on the campus, the CLEC can use DSL to provision services to the individual user.

With DSL technology, this scenario can be repeated incrementally across the building network to concentrate all voice, data and video traffic for connection to a service provider network. There is no need to do extensive infrastructure planning, budgeting and implementation only to find out later that there are additional needs that were unplanned.

Colleges, universities and high-rise buildings also provide opportunities where DSL-based service deployment makes good sense. In fact, one of the fastest growing market segments for competitive service providers is in the MDU and MTU marketplace, where dozens of new providers are partnering with owners of high-rise office buildings, office parks, apartment buildings and condominium complexes to provide Internet access and other services to tenants. These opportunities are by no means limited to examples A and B that follow.

Example A – College DSL Opportunity

The learning environment today is often the proving ground of high technology. As a fallout of the PC revolution, computing power, which was once the domain of the college MIS department, is now available on the desktop at an affordable price. In fact, many colleges now require PC ownership for all students and have moved much of their day-to-day administration – such as course syllabi, registration and grade distribution – online. As a result, campuses are populated with distributed, high-power desktop computers. One of the challenges in this distributed environment is how to provide access to the campus data network and the Internet.

This is particularly important for the on-campus student body, where data service in the dormitory can provide benefits to both the students and to the educational institution.

Three methods can be used to get data service to the student body:

1. *Dial-up analog modem. While a viable solution, it is less than ideal. First, current dial-up speeds of up to 28.8 Kbps (sometimes 33.6 - 56 Kbps) are not sufficient to allow an acceptable level of productivity for the student trying to work from the room. Second, dial-up can cause congestion in the PBX system, interfering with voice traffic. Lastly, dial-up opens the potential for abuse by anyone who has access to the voice network. Problems with stolen student accounts and hackers causing disruption are not uncommon. Another disadvantage is that only one student in a room can access the data network at a time and, of course, phone service is unavailable during the session.*
2. *Rewire the dormitory for LAN services. This involves pulling Category 5 (CAT5) cable into each room, installing hubs at the distribution closets and either bridging or routing to the campus backbone. The advantages of this solution are that it solves many of the problems described above for dial-up. It supports the speeds necessary to provide acceptable levels of productivity for the student and does not cause the switch congestion in the PBX. LAN extension solves the multi-user and concurrent phone usage problems and is innately more secure than dial-up. However, deploying the facilities for LAN extension can be an enormously expensive proposition, particularly in older buildings.*
3. *DSL technology. If we consider DSL-based services, we find a solution that provides an economical way to deliver the LAN-like speeds students need without the enormous cost of an infrastructure upgrade or the congestion and security risks in a dial-up solution.*

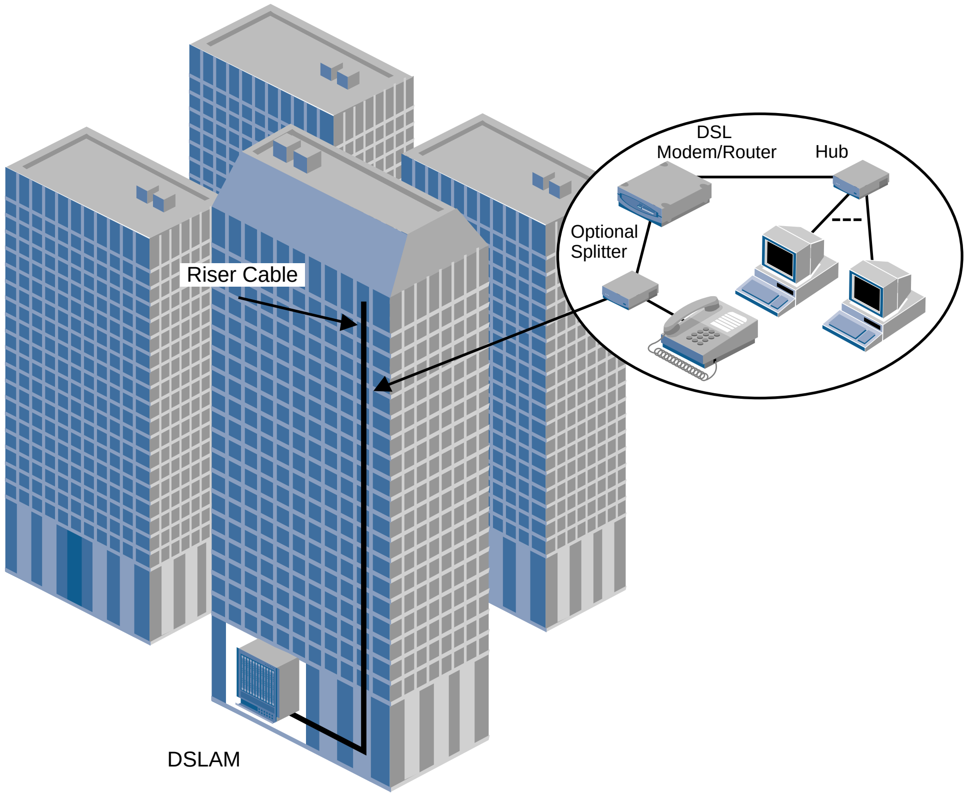


FIGURE 6-9
DSL in the Dormitory

A DSLAM installed in the basement of a dorm complex, connected to the campus backbone as shown in the above figure can serve every student in the dorm who requires high-speed service.

With DSL, it is as simple as connecting the DSL system to the building's existing telephone wiring and installing a DSL endpoint in the room. The student can simply plug in their PC to the endpoint. If there is more than one student in the room, the addition of an inexpensive hub allows all of the students in the room to have simultaneous access to the network over a single DSL line.

Because DSL uses the dorm's existing telephone wiring, it can be deployed selectively to those students who need the service without rewiring the whole riser. With optional POTS splitters or microfilters, ADSL, RADSL and ReachDSL technology can allow the telephone to be used for voice calls concurrently with the high-speed data service. DSL technology overcomes all of the disadvantages of the dial-up solution and offers the benefits of LAN extension without the costly expense of rewiring each dorm.

Example B – High-Rise Building Environment DSL Opportunity

While we have focused on DSL technology as a solution for solving problems in the geographic campus, we should also mention the big city high-rise office building as a campus environment. The high-rise office building is a microcosm of the larger campus universe. Because the tenants of a high-rise can represent many different companies, there are many different needs for data communications. And, as mentioned earlier, the MTU and MDU environments represent a large and growing opportunity for DSL-based services.

One tenant may want to extend their LANs from one floor of the building to their offices on a different floor. Another tenant may want Internet access for their company, and yet another may want a high-speed connection to their corporate frame relay network. The challenge here is how to meet the ever-changing needs of the tenants without breaking the bank with constant and costly infrastructure upgrades.

DSL technology is an ideal solution in the high-rise building environment. DSL technology uses the existing telephone wiring to enable a wide variety of services required by the tenants without the constant infrastructure changes traditional solutions would entail. DSL can support the floor-to-floor LAN extension for one tenant, high-speed Internet access for another, and corporate frame relay access for another.

Installation of such a system mirrors that of our college dormitory example. DSL endpoints are installed in each tenant's office space and connected to the hub of the tenant's LAN. A DSLAM is installed in the basement or central wiring closet of the building and uses the existing voice wiring to provide high-speed data services – concurrently with voice services in the case of ADSL, RADSL or ReachDSL technologies. The building service provider (often called B-LEC, or Building LEC) then utilizes a traditional private line or another DSL connection for the WAN connectivity back to the NSP.

This model is increasingly being used for residential buildings as well – both high-rise apartment buildings in urban markets and for campus-like groupings of dwellings like garden apartments or condominium complexes. The DSLAM is installed in the basement of the high-rise or in some central location in a condominium setting, and the existing phone lines are used to provide multiple broadband services to tenants of the complex. This provides several benefits for the building owner/management, including:

- *An increased monthly revenue stream from tenants for services like Internet access*
- *Increased marketing power with prospective tenants – many Internet-savvy consumers and teleworkers rank availability of broadband Internet access as one of their top criteria for choosing new housing*

THE NEXT WAVE: VOICE OVER DSL SERVICES

When the market for telecommunications services for small- and medium-size businesses is examined, an interesting fact emerges: these enterprises typically spend much more money – often as much as 10 times more – on voice services than they do on data services. When traditional DSL services are added to the mix, the small-to-medium enterprise will normally use one copper pair for the DSL line and then operate each individual voice line over a separate copper pair. This model has disadvantages for both the service provider (particularly the CLEC) and for the customer, due to the increased costs of provisioning additional copper pairs for voice services and also due to the fact that many service providers are experiencing "copper exhaustion" where demand for new pairs simply exceeds the supply.

VoDSL solutions can use the same single copper pair used to provide DSL services and provide multiple voice channels (typically 4-12 depending upon compression schemes and the bandwidth of the DSL connection). VoDSL systems can utilize transport technologies such as IP, ATM, frame relay or TDM, but the majority of systems deployed to date are ATM-based, using ATM PVCs or SVCs to route voice traffic through the NAP's network and eventually onto the PSTN.

Among the requirements for VoDSL systems are the following:

- *A minimum of 4 to 12 voice channels supported per DSL circuit in order to meet the needs of most small and medium businesses, as well as branch offices of larger enterprises*
- *Toll-quality voice performance with low levels of noise, echo and latency*
- *Standardized interfaces on the customer end, allowing connectivity to existing telephony equipment like phones, key systems, analog modems and fax machines*
- *Transparent carriage of existing PSTN features such as caller ID, call waiting and forwarding, etc.*
- *Dynamic allocation of bandwidth for voice calls, with prioritization of bandwidth used for voice to ensure quality of service*

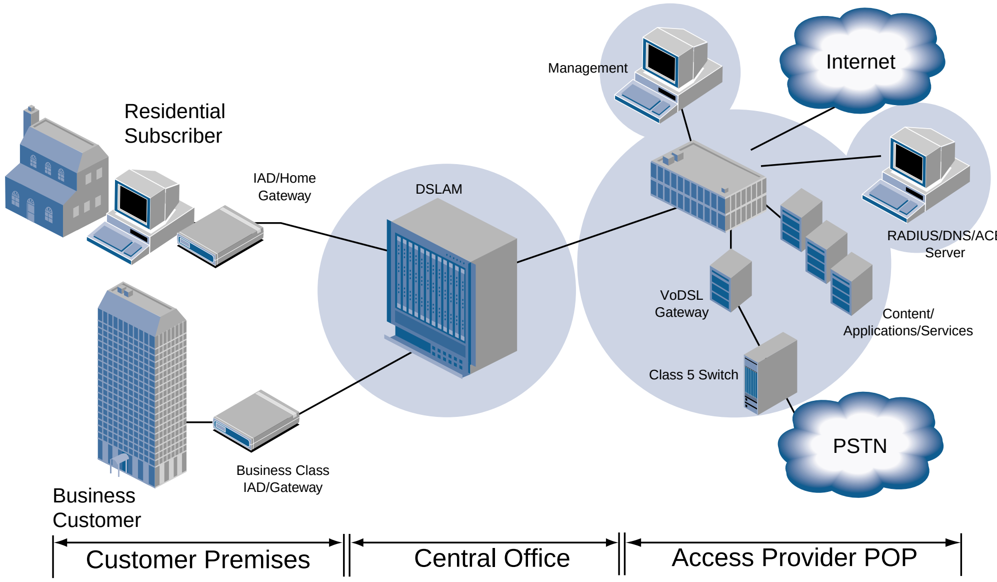
There are three main components of any VoDSL system:

1. *The VoDSL Integrated Access Device, which packetizes voice and signaling data into ATM cells (or IP packets) and transports them across the DSL link (and conversely converts incoming voice packets back into circuit-based analog voice channels). In addition to multiple voice ports for connecting to telephony equipment, the IAD also includes data ports for connecting to computers or LAN hubs and often a router.*

2. *The VoDSL-capable DSLAM, which is a multiservices DSLAM capable of directing data packets onto the Internet or other data network, while simultaneously directing voice data packets or cells to the VoDSL gateway and onto the PSTN.*

3. *The VoDSL gateway, which converts the packetized voice back to circuit-based voice traffic (and vice versa for voice traffic travelling downstream to the IAD) and then forwards these circuits to the Class 5 switches of the PSTN using the industry-standard GR.303 interface.*

FIGURE 6-10 VoDSL Network Model



The figure above shows a typical VoDSL network implementation, utilizing an ATM-based system. IP and other transport methods will utilize a similar network architecture.

The Voice over DSL market is just beginning to emerge as a commercial service as this Sourcebook is written, with a small number of DSL CLECs having commercial service offerings. Most DSL service providers (both ILECs and CLECs), however, are well into trial deployments of the technology, and the market is expected to grow rapidly. In fact, deployments are expected to grow from 40,000 lines in service in 2000 to over one million lines by 2003, and over two million by 2004. The figure below shows the projected growth of VoDSL over the next four years.

FIGURE 6-11 VoDSL Market Projections

VoDSL Market Projections

	DSL Lines with VoDSL	VoSDL Telephone Numbers in Use	Avg. Amount of Telephone Numbers per New DSL Line
YE 2000	40,000	360,000	9
YE 2001	100,000	840,0000	8
YE 2002	550,000	3,990,000	7
YE 2003	1,150,000	7,290,000	5.5
YE 2004	2,000,000	10,690,000	4

Chapter 6 Summary

As content-rich applications continue to grow and stress both public and private network infrastructures, the local portion of the required connectivity becomes a major challenge for the network service provider. In this chapter, we discussed some of the emerging services and applications well served by DSL technology.

Four traditional services were covered including:

1. *Channelized T1/E1 services and applications*
2. *IP services and applications*
3. *Frame relay services and applications*
4. *ATM services and applications*

We also covered the private/campus network DSL opportunity, defining the campus as: organizations, institutions, corporations and agencies including government installations, hospitals, utility companies, college/university, and high-rise buildings. The following private/campus network DSL applications were covered:

- *LAN Extension*
- *College Dormitory*
- *High-rise Building/Shared Tenants*

It was also noted that MTU/MDU environments are expected to be one of the fastest growing market segments for competitive service providers. New B-LECs will offer high-speed services to tenants and utilize DSL or traditional private line connectivity back to the NSP.

Finally, we discussed emerging business-class DSL-based services that take advantage of the increased Quality of Service and service level management capabilities of today's DSL equipment. SLM-DSL supports numerous business-class applications including:

- *Voice over DSL (VoDSL)*
- *Virtual Private Networks (VPN)*
- *Service Level Management for Frame Relay over DSL*

Chapter 7

NETWORK MODELS

THE NEED FOR MULTISERVICES

DSL technology provides a cost-effective means for service users to gain access from the residence or office to very high-speed network services. DSL transmission technologies can operate in the 64 Kbps range up to the multimegabit range. New service deployment for high-speed Internet access or remote LAN access creates new challenges for service providers. Specifically, we need to consider how end-to-end networks are configured and managed and which protocols and technologies should be utilized to deliver the lowest-cost, highest-function service possible.

The high-speed services required for these customers and environments include:

- *IP/LAN services such as Internet access, remote LAN access or VPN*
- *Frame relay services*
- *Nx64 services*
- *ATM services*
- *Voice services*

Each of these services exists today, albeit at higher costs than possible when utilizing DSL access technology. DSL is, therefore, an enabling technology that facilitates superior price and performance for both existing and new services.

We will show how a singular access network infrastructure is used for provisioning many types of services to make use of a common network structure, creating additional revenue opportunities for the service provider.

DSL-BASED SERVICES REFERENCE MODEL

In this chapter, we develop a reference model for DSL-based service deployment. The model is intended to allow us to more closely examine both the physical network and the logical network topologies of a multiservices network architecture.

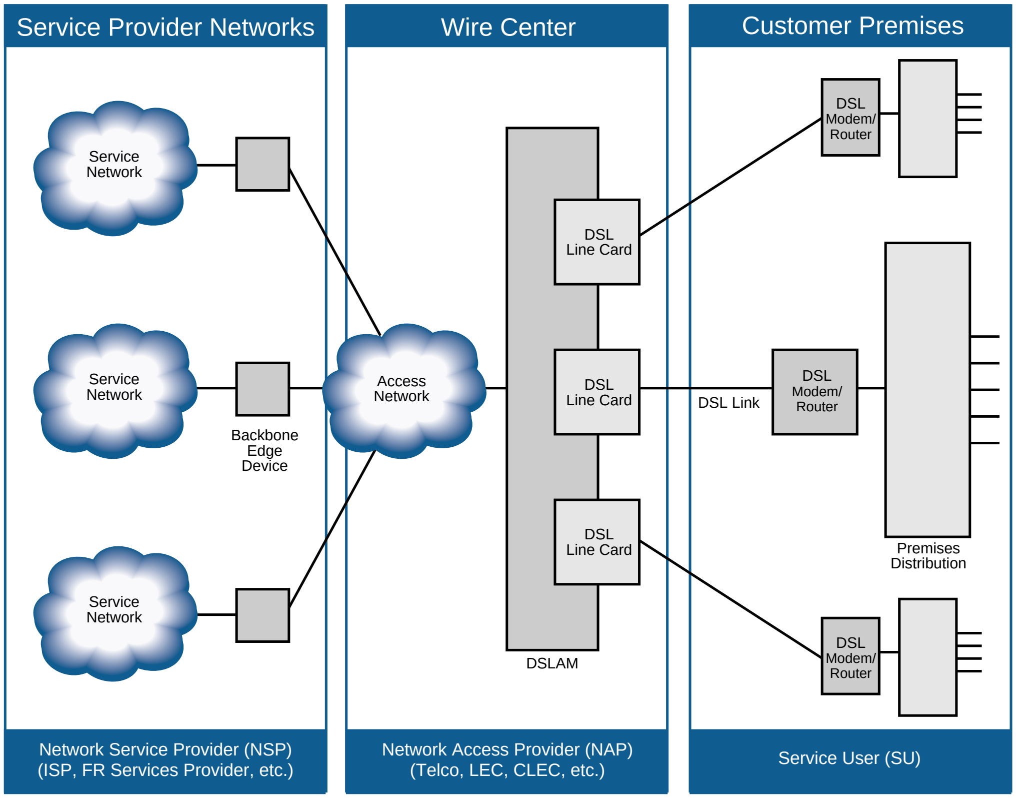
First, let's define the term multiservices. Often, this term is mistakenly interpreted as meaning "supportive of multiple line codes such as 2B1Q, CAP or DMT." Multiple line code capability does not equate to multiservice capability. Rather, we must look to the logical construction of the network in order to gain a better appreciation of multiservices. A DSL system is said to be multiservice capable when it contains the necessary logic to allow the service provider to roll out frame relay, IP/LAN, voice, Nx64 and ATM services on a single DSLAM platform. This concept will become clearer as we move through the material in this chapter.

Our reference model is presented in the figure below. Three domains are depicted:

1. *Service user (SU) domain*
2. *Network service provider (NSP) domain*
3. *Network access provider (NAP) domain*

As shown, the DSLAM contains multiple instances of DSL line cards.

FIGURE 7-1
DSL-Based Services Reference Model



Service users need to use services provided by NSPs. The NAP's role is to provide interconnection between SUs and NSPs. In many cases, the NAP and the NSP will be different companies. We have also seen instances where the NSP and the NAP are the same legal entity. Nevertheless, we separate them here because they provide distinctly different functions within the overall scheme.

Service users connect to the NAP via a DSL-provisioned local loop. At the wire center, digital data is concentrated before it is backhauled across the access network. Typically, traffic from the DSLAM will be backhauled to the access node within the access network before interconnection to one or more NSPs. At the NSP, a backbone edge device is used as the demarcation between the NSP and the NAP.

Because the reference model in Figure 7-1 provides simultaneous access to multiple, independent service networks, security and access control are extremely important considerations. Security and access control are realized because each service network must extend across the NAP to the customer location, effectively forming separate private networks.

The reference model shown in Figure 7-1 holds true regardless of the specific service structure. This will become apparent as we continue.

FRAME RELAY SERVICES PROVISIONING

Now, let's use DSL to provision high-speed frame relay services. The reference model in the following figure is revised to reflect the frame relay application.

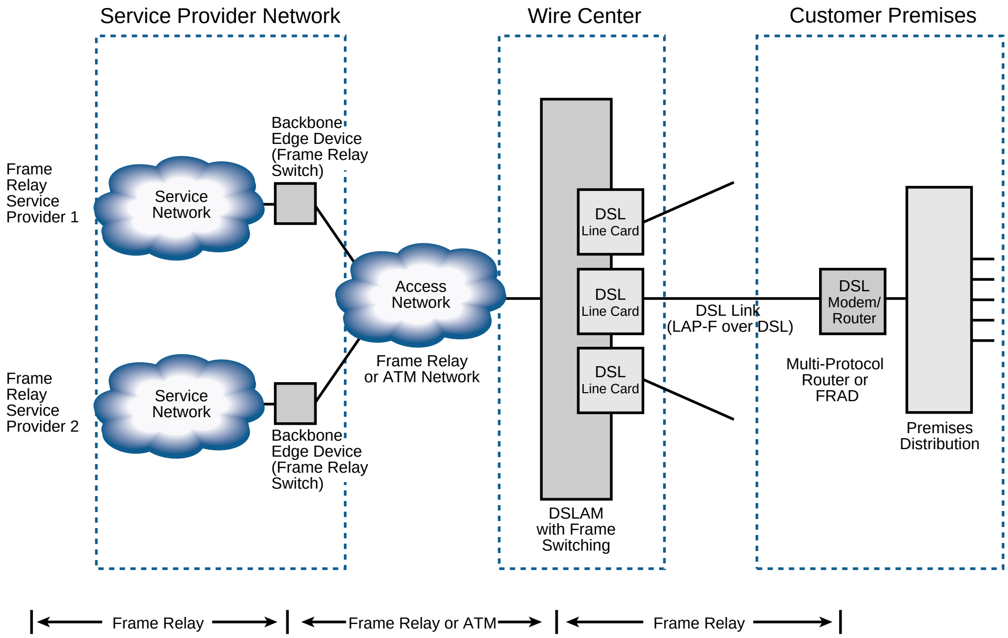


FIGURE 7-2 DSL-Based Services Reference Model – Frame Relay

Notice that in this example, frame relay protocols are carried across the DSL link and concentrated in the DSLAM before being backhauled across the access network. Also, the backhaul network can be frame-relay-based or ATM-based (if the DSLAM provides frame relay to ATM interworking functions).

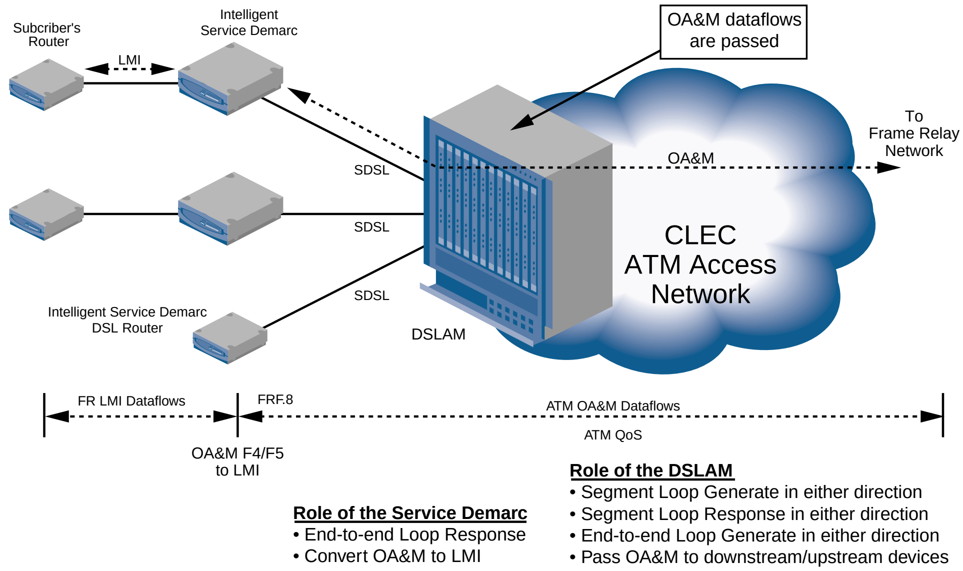
In this case, the backbone edge device is simply a frame relay switch. This switch could also be outfitted with an ATM line interface port to support frame relay over ATM. You will also note that the DSLAM is required to provide frame relay concentration functions and ATM interworking functions in order to efficiently carry traffic across the access network. In this reference model, data is mapped onto predetermined PVCs, providing security and access control.

As can be seen here, the multiservices DSLAM has not only provided high-speed loop communications, but has also provided packet concentration using integrated frame relay technology. As stated previously, for lower-speed applications such as IDSL, the introduction of packet technology within the DSLAM provides superior bandwidth efficiencies within the access network. Compare and contrast this to the more traditional technique of using TDM technology (e.g., DACS) to interconnect frame relay service users with frame relay service providers.

This model may be implemented using symmetric line codes like M/SDSL, SDSL/G.shdsl, and HDSL/HDSL2, or by RADSL in symmetric mode, as frame relay is often used for LAN interconnection where the upstream and downstream data flows are near equal.

A newer model for providing frame relay uses ATM transport throughout the DSL network in order to maintain service level management, as discussed in the previous chapter. In this system, a native frame relay interface is located within the ATM SDSL endpoint where the FRF.8 interworking occurs. End-user frame relay CPE can interface with a frame relay DSL endpoint/router, much in the same manner as the CPE interfaces with the frame relay network port today. PVCs are established and LMI is exchanged at the frame relay endpoint as is done with today's frame relay network.

FIGURE 7-3 DSL-Based Services Reference Model – Frame Relay Management – ATM



Frame relay traffic is then encapsulated into ATM traffic using FR/ATM service interworking, enabling service providers to leverage the aggregation and QoS capabilities of ATM through to the DSLAM and onto the frame relay network. At the backplane of the DSLAM, ATM is used to direct frame relay traffic onto an ATM PVC for delivery to the core frame relay network. With the native frame relay DSL endpoint, all service level management capabilities will be maintained, allowing service providers and end users the ability to perform diagnostics and obtain reporting capability. SLM functionality of the native frame relay endpoint is integrated with the network management system to provide end-to-end SLM capability and integrated diagnostics.

Nx64 SERVICES PROVISIONING

Often, business service users require Nx64 Kbps services utilizing TDM capabilities. From time-to-time, we have referred to TDM services as "traditional" services. The need for traditional services is not eliminated with the introduction of other advanced service types. Rather, these services allow data and voice to be cost effectively combined on the same link for transport across the access network. In the figure below, we show how these services can be provisioned together with advanced services in a multiservices architecture.

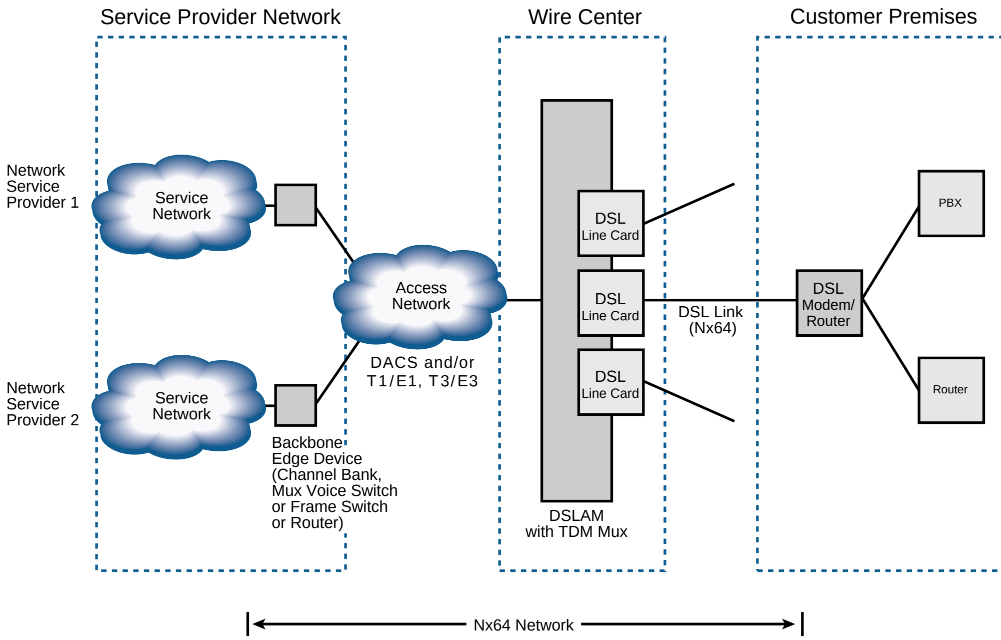


FIGURE 7-4 DSL-Based Services Reference Model – Nx64 Kbps

A channelized T1 or E1 framed service runs over the DSL link. The DSLAM may provide a one-to-one interconnection to corresponding T1/E1 WAN service interfaces, or access concentration utilizing traditional time-slot interchange techniques before transport across the access network as shown. In this case, a channel bank, voice switch or multiplexer is utilized as the backbone edge device. Alternatively, a frame switch or router can be used to terminate the service at the backbone edge device.

In the above reference model, similar to the frame relay model, predetermined TDM interchanges provide a level of security and access control.

In this case, due to the inherent symmetric nature of TDM traffic, MSDSL, HDSL/HDSL2 or SDSL/G.shdsl line codes are applicable.

IP/LAN SERVICES PROVISIONING

Because of the popularity of the Internet and the sheer volume of emerging IP applications, IP/LAN services provisioning continues to generate growing interest. IP/LAN service modeling has been the subject of vigorous debate within the vendor community and relevant standards bodies. In order to provide the widest range of possible choices, we present and discuss three separate models for the deployment of IP/LAN services. It should also be noted that some DSLAM architectures offer the flexibility to support multiple network models within a single DSLAM. Of interest are the:

- *Layer 2 model*
- *Layer 3 model*
- *ATM model*

Each approach has strengths and weaknesses depending on the specific services supported. Selection of the appropriate model is entirely dependent upon multiple factors including:

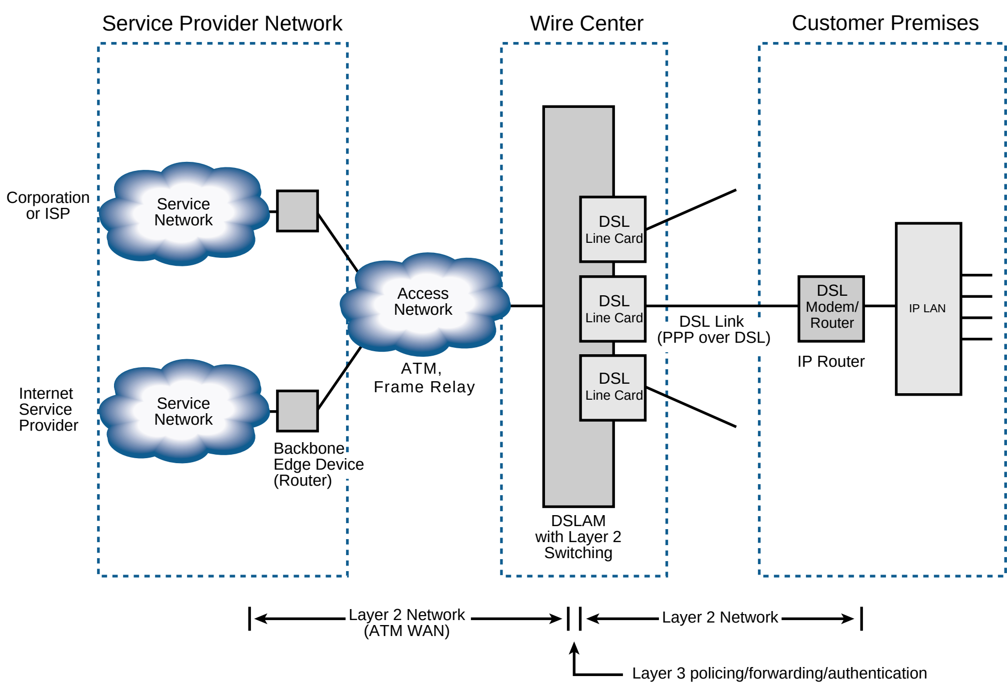
- *Timetable for deployment*
- *Existing network infrastructure*
- *Structure of the network (i.e., are multiple service providers connecting across a single access network or is there only one service provider?)*
- *Risk avoidance*

IP/LAN SERVICES PROVISIONING USING A LAYER 2 MODEL

In this approach, PPP (Point-to-Point Protocol) is utilized between the DSL endpoint and the DSLAM. The DSLAM concentrates subscriber data utilizing Layer 2 MAC (Media Access Control) switching. Data is concentrated at Layer 2 onto a frame relay PVC or an ATM PVC across the access network.

Individual service users are placed in virtual networks according to subscription policies or dynamic service selection mechanisms as provided by the DSLAM implementation.

FIGURE 7-5 IP/LAN Services Based Upon Layer 2 Model



Notice in Figure 7-5 the inclusion of a function entitled "Layer 3 policing, forwarding and authentication." As stated previously, in addition to concentration functions, the DSLAM may be required to perform other functions necessary for a robust implementation. In this case, the DSLAM monitors packet flow across each DSL line interface in order to facilitate access authentication, to enforce security policies and to allow for dynamic IP address assignment using DHCP protocols. These added functions are key for practical service deployment.

This architecture is highly scalable and provides efficient use of the WAN facilities. Traffic from multiple DSLAMs can be aggregated through the use of external devices and can easily share WAN links.

Another benefit of this implementation is that it requires a small number of PVCs to be provisioned in the access network.

IP/LAN SERVICES PROVISIONING USING A LAYER 3 MODEL

The Layer 3 model implementation is shown to be very similar to the Layer 2 model with the exception that we introduce routers into the access network, as shown in the figure below.

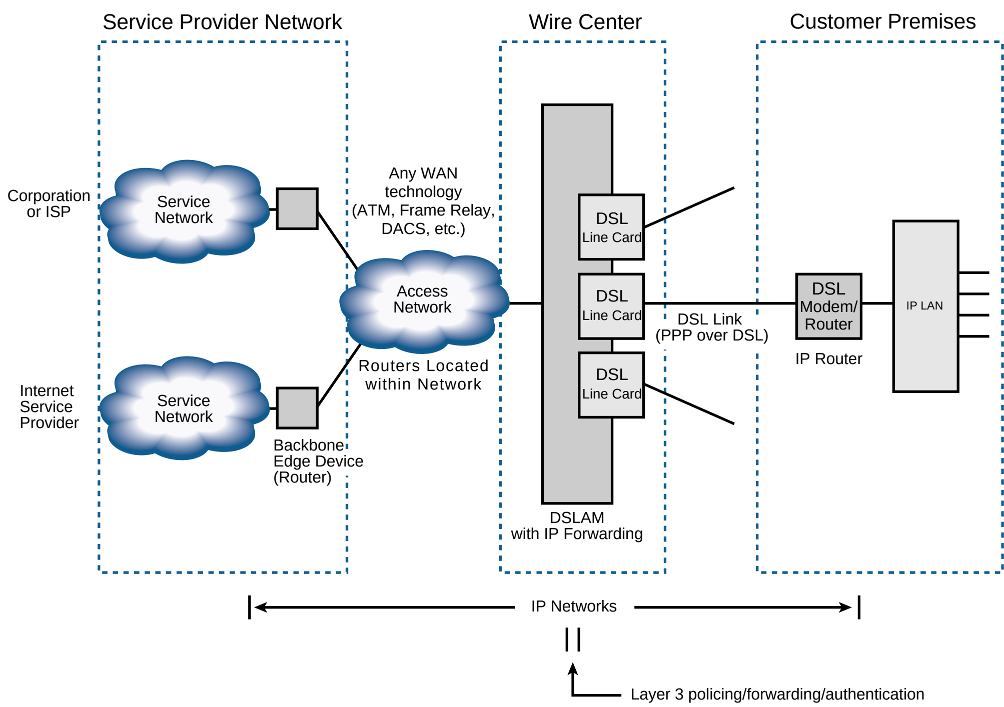


FIGURE 7-6
IP/LAN Services Based Upon Layer 3 Model

Note that we still have the requirement for Layer 3 policing, forwarding and authentication functions. With the introduction of routers into the access network, we notice several things. First of all, we can utilize a number of different WAN technologies within the access network including frame relay, ATM or simple leased lines using DACS. Second, if for example the access network is indeed ATM or frame relay, the number of PVCs required is reduced. In the simplest case, where a single router is utilized at the access node to interconnect all DSLAMs to all service providers, the number of PVCs required is calculated by adding the number of DSLAMs to the number of service providers. That is, each DSLAM and each service provider must be connected to the central router via a PVC.

A drawback of this approach is that many NAPs have expressed concern over introducing Layer 3 routing functions within the access network. Additionally, many NSPs have expressed concern over the existence of routers between their network and their customers that are not managed by themselves. Therefore, one must weigh the benefits of a Layer 2 versus a Layer 3 implementation carefully.

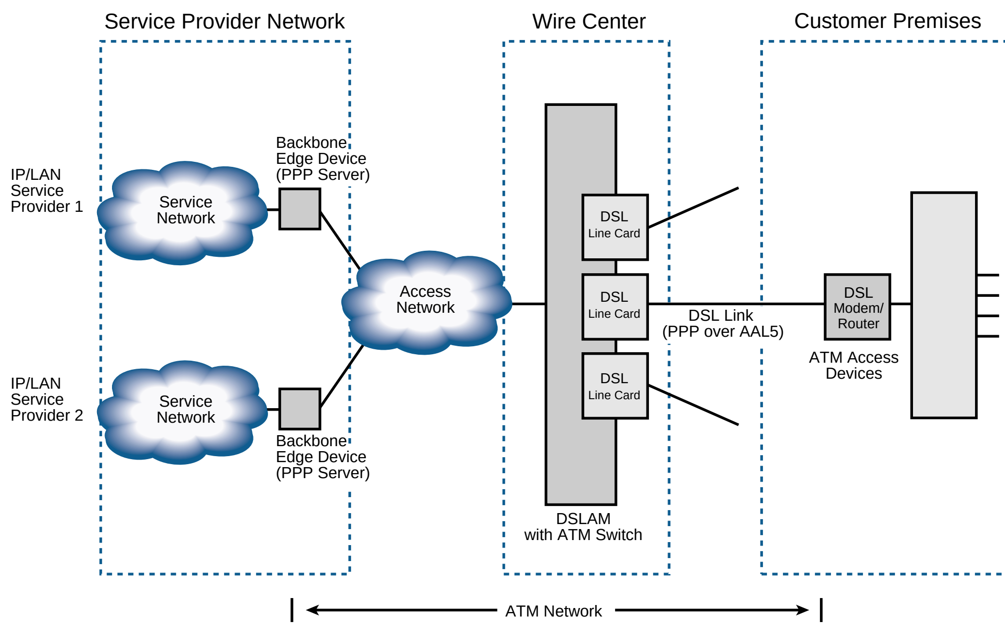
Given the pros and cons of each approach, we have seen applications for both models. In general, the Layer 2 model is preferred when the NSP and the NAP are two separate legal entities. That is, the NAP acts as a transit provider for one or more NSPs. In contrast, when the NAP and the NSP are one and the same, the physical location of routers within the network is a non-issue and the Layer 3 model is applicable.

IP/LAN SERVICES PROVISIONING USING AN ATM MODEL

As shown in the Layer 2 model (see Figure 7-5), an ATM access network can be utilized for the provisioning of IP/LAN services. In the implementation above (Figure 7-6), ATM PVCs are terminated at the DSLAM. Packet services are then extended to the premises, and all packet/cell interworking functions are performed within the DSLAM.

An alternate approach is shown below. The ATM model extends the ATM PVC through the DSLAM over the DSL link to the service user. Cell/packet interworking functions take place within the DSL CPE.

FIGURE 7-7 IP/LAN Services Based Upon ATM Model



The DSL CPE features routing functions and interfaces to the DSL link using ATM. A PPP session runs on top of ATM Adaption Layer 5 (AAL5) and is terminated at the backbone edge device using a PPP server with an ATM interface.

Advantages cited for the implementation shown in the figure above:

- *A single Layer 2 structure (ATM) is utilized in the access network, thereby eliminating the need for routers.*
- *This implementation will be supportive of ATM-based multimedia applications such as MPEG video.*

- *Mechanisms for access authentication and security using PPP are well known. Implementations can make use of much of the work that has been done in the traditional dial-server environment.*
- *ATM supports QoS. (Note: This must be compared to the continued progress made in the IP domain for QoS support.)*

Multi-Protocol Label Switching (MPLS)

MPLS offers a method of combining the strengths of IP with the strengths of ATM. Some of the primary benefits of MPLS are:

Virtual Private Networks

The connectionless nature of IP offers many security pitfalls. On the other hand, the connection-based nature of ATM is inherently secure. The problem with setting up a large VPN network with ATM is the large number of VCs that must be provisioned (this is referred to as the "N squared" problem). MPLS provides a way to take advantage of the connection-based security of ATM – while eliminating the large mesh of VCs.

Traffic Management

Standard IP routing protocols do not consider traffic load in their algorithms. Thus, some parts of an IP network can become overloaded while other parts are underutilized. With MPLS, network operators can "traffic engineer" their network by redirecting traffic to underutilized parts of the network.

QoS

With the advent of Differentiated Services (Diffserv), IP networks are migrating to support multiple traffic classes rather than a single "best effort" class. ATM has always been strong in its ability to provide QoS with its rich set of traffic classes and traffic parameters. MPLS provides an easy way of mapping IP Diffserv to ATM QoS.

AN OVERVIEW OF ISSUES FOR IP/LAN SERVICES

While a comprehensive review of the material is beyond the scope of this document, we submit that the IP/LAN services model must meet the following requirements:

1. The overall architecture should support simultaneous access to multiple NSPs.
2. Since multiple services providers will be providing services to multiple services users, the system design must support the ability to provision discontiguous IP domains. This allows better management of the IP address space.
3. The solution must be scalable.
4. The solution should be easy to provision and must support dynamic connections between service users and service providers.
5. Dynamic IP address assignment as well as static IP address assignment is required.
6. Issues of security should be addressed.
7. NSPs must be able to authenticate services users.
8. Both commercial service users and network service providers have significant investments in their LAN infrastructures today. Therefore, any DSL-based service should not require significant changes in existing customer environments.
9. Private IP addresses must be supported since many companies utilize unregistered addresses.
10. Solutions should support non-IP protocols.
11. Multicasting will become a requirement.
12. The network implementation should support traffic classes and grades of service.
13. The solution must fit within regulated environments

We conclude our discussion about IP/LAN services deployment with a comment about transceiver technologies. As in the case of frame relay, IP/LAN services may be provisioned with any transceiver technology including ADSL, SDSL/G.shdsl, IDSL, HDSL/HDSL2, RADSL and ReachDSL. The choice of transceiver technology is most dependent upon the expected traffic patterns.

A WORD ABOUT VIRTUAL PRIVATE NETWORKS

Over the past few years, service providers have begun offering VPN services as an alternative to traditional private networking. A VPN is a private network that is implemented over a public network. Data is transferred across the network using tunneling techniques that create virtual paths between and among various nodes.

There are multiple techniques and protocols for developing a VPN, but most have a few things in common. Specifically, a VPN will include:

- *Tunneling: VPNs use a tunneling protocol or system that establishes a "tunnel" or path through the Internet or other public network to allow the transfer of data between network nodes. Among the primary protocols used for VPN tunneling are Point-to-Point Tunneling Protocol (PPTP), Layer 2 Tunneling Protocol (L2TP) and IP Security Protocol (IPSec).*
- *Encryption: Since VPN traffic travels over a public network, particularly when the traffic travels over the public Internet, VPNs include encryption technology in order to provide security for confidential and proprietary data.*
- *Authentication and Access Control: Because thousands or even millions of users may be sharing the network utilized by a VPN, it is imperative to utilize a robust authentication and access control system to keep unwanted users from entering the VPN. Some VPN solutions utilize simple password authentication, while more sophisticated methods use key exchange systems like Diffie-Hellman key exchange.*

Regardless of which protocols are used, VPN services are provisioned using one of two approaches:

1. *LAN-to-LAN Tunneling – In this case, a VPN device is connected between each LAN and the network access device. Data sent through this connection is automatically sent through the VPN, with no action or special software required for individual computers or users. This method is typically used to connect offices together within an intranet or extranet solution.*

2. *Client-to-LAN Tunneling – In this scenario, individual PCs and applications utilize a VPN client (either software or hardware based) to connect through the public network or Internet to the VPN. The most common application for this method is for connecting DSL teleworkers or mobile employees to the corporate VPN.*

In both of these cases, the VPN protocol can be applied either in software or hardware. For example, many DSL endpoint routers are beginning to incorporate hardware VPN functionality within the router itself, while other vendors provide VPN services through a separate network device connected between the DSL endpoint and LAN or individual PCs. Software-based VPNs – most commonly used for Client-to-LAN VPN applications – are typically small client software programs installed on the PC or even included within the PC's operating system itself (as is the case with Microsoft's Windows 2000, which includes an IPSec client, while other versions of Windows support PPTP).

None of the IP/LAN provisioning models presented here preclude the use of VPNs. That is, VPN software as currently being developed and deployed will operate transparently on top of DSL access networks.

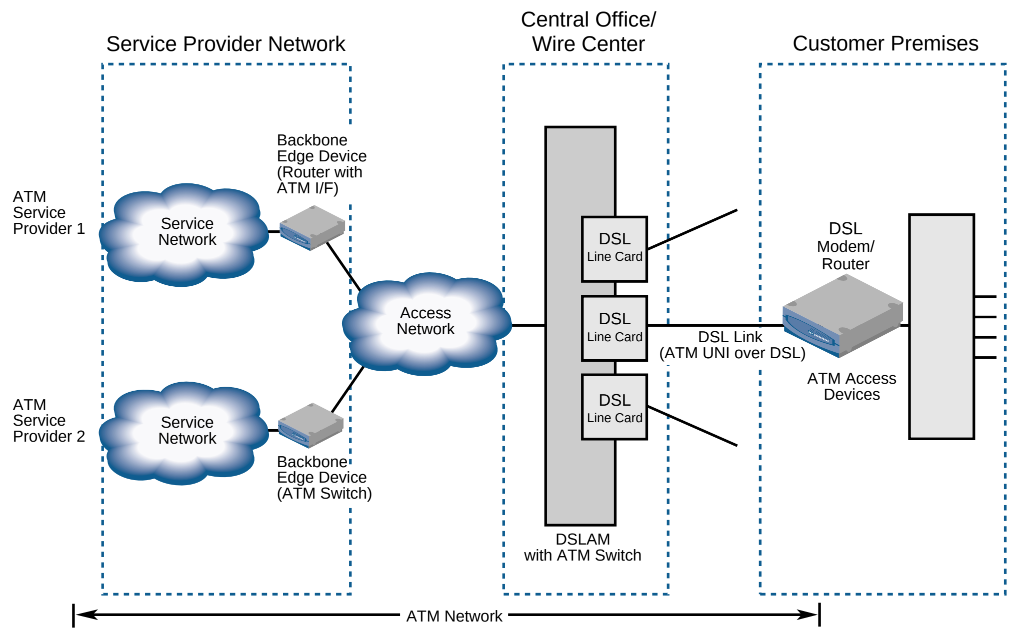
ATM SERVICES PROVISIONING

Below, we discuss ATM services provisioning. This may seem somewhat confusing since the subject of ATM modeling has been presented previously. Yet, the story was not complete.

In the earlier example, ATM was used as a means of deploying IP/LAN services. Now, we address the issue of ATM as the target service. The best way to describe the target service is to compare it with frame relay. As with frame relay, a "protocol transparent pipe" is offered to the service user, and the service network itself is ATM-based.

We expect to see ATM services roll out as a high-bandwidth alternative to frame relay. Therefore, a multiservices DSLAM should be capable of supporting ATM services as well as frame relay services. The model is presented in the following figure.

FIGURE 7-8
DSL-Based Services Reference Model – ATM



As can be seen in Figure 7-8, ATM technologies are integrated into the DSL endpoint device and within the DSLAM. PVCs are provisioned between the NSP and the service user across the access network and across the service network.

MULTISERVICES ARCHITECTURE

Throughout the Sourcebook, we have explored network models required to provision various network services. In some ways, these models are quite similar; in other respects, they differ substantially.

We now explore the true benefits of a multiservices architecture. A multiservices architecture supports the deployment of different services simultaneously from a common system that may combine the services over a common backhaul network or interface to different networks. The network shown in the figure below demonstrates the power of a multiservices architecture.

IP/LAN, frame relay, and ATM services are provisioned using the same DSLAM. A singular ATM access network is utilized to interconnect service users to their target NSP regardless of the type of service that is being provided by the service provider.

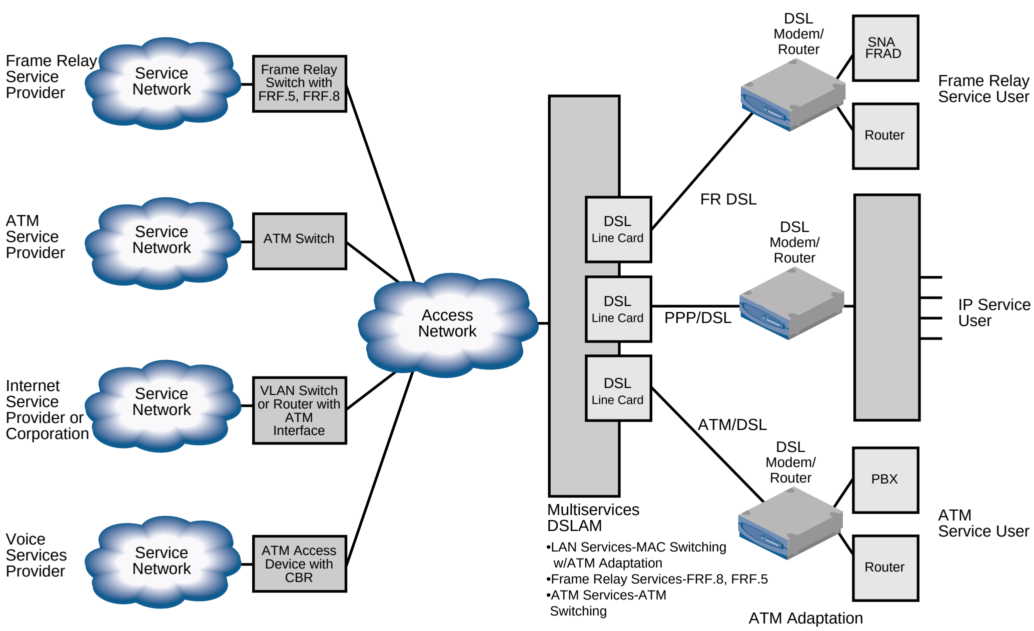


FIGURE 7-9 DSL-Based Services Reference Model – Multiservices

Why is a multiservices approach to service deployment important? First, more services equates to more revenue opportunities. Also, the ability to use a common equipment platform across multiple service types equates to lower cost per user to give the network owner greater profit potential.

Chapter 7 Summary

In this chapter, we explored alternative network models required to provision various network services. We first presented a reference model to allow us to examine both the physical network and logical network topologies of a multiservices network architecture.

We defined a true multiservices DSL system as one that contains the necessary logic to allow the service provider to deliver frame relay, IP/LAN, Nx64 and ATM services on a single DSLAM platform. We presented the following network models:

- *Frame Relay Reference Model*
- *Nx64 Reference Model*
- *IP/LAN Reference Models*
- *Layer 2 Model*
- *Layer 3 Model*
- *ATM Model*
- *ATM Reference Model*
- *Multiservices Architecture Model*

We described the benefits of a multiservices model as providing the ability to leverage a common equipment platform across multiple service types, equating to lower cost per user.

Chapter 8

SOURCEBOOK IN REVIEW

IN CLOSING

The Sourcebook identified the DSL deployment opportunities available today. DSL-based services, emerging business-class applications, requirements and benefits were discussed, along with a variety of network deployment models.

We hope you agree that the DSL opportunity is indeed compelling and that you can take advantage of the price and performance benefits available with DSL-based services today.

CONSIDERATIONS FOR DSL DEPLOYMENT INITIATIVES

The following checklist will help you in your DSL planning process:

- ✔ Will services be deployed to the commercial or residential sector initially and over time?
- ✔ What applications and QoS guarantees does your audience require?
- ✔ Does the DSL solution under consideration offer a next-generation non-blocking architecture to deliver multiple service types and differentiation in support of commercial and residential applications?
- ✔ Does the DSL solution offer optimization within a central office (collocation or cageless collocation) environment?
- ✔ Does the DSL solution support the network model that you'll need today and going forward as critical mass is achieved?
- ✔ Does the DSL solution provide a cost-effective, scalable architecture with low entry costs as well as large-scale economies?
- ✔ Does the solution provide network management functionality and ease the provisioning process by using Internet technology components such as XML?
- ✔ Does the solution offer partitioning capability to allow service providers to independently manage their service end to end?
- ✔ Does the solution provide the WAN interfaces that your implementation and existing WAN services will support (i.e., 10/100Base-T, T1/E1 IMA, T3/E3, OC-3, OC-12 and others)?
- ✔ Does the solution provide a variety of endpoint options (both vendor-provided and third-party CPE) to support a wide range of service-user requirements?
- ✔ Does the solution provide the option to use the existing POTS line, or does it limit your services to second-line implementations only? What is the ability of the system equipment to allow upgrade to POTS at a later time?
- ✔ Is the DSL solution optimized for private/campus network environments?
- ✔ Does the DSL line code provide reliable service in the presence of other network services and associated crosstalk?
- ✔ Does the DSL system provide the loop reach required to serve the majority of your customers?
- ✔ Can it reliably support distances beyond 20,000 feet to ensure you don't have to turn away subscriber requests?
- ✔ Does the solution provide the level of security and authentication to protect your customers?

- ✔ Does your DSL vendor have an understanding of all related technologies (DSL transceiver technology, internetworking technology, network management, service level management, CPE product design interoperability certification) and extensive experience in interfacing with existing WAN services?
- ✔ Does your DSL equipment supplier have the experience, reputation, and longevity to support your DSL service deployment? There will be many small start-ups surfacing with no proven track record and limited venture funding. Choose carefully.

COMMON QUESTIONS AND ANSWERS ABOUT DSL

1. Is DSL a service?

No. DSL is a transmission technology that can be used to support a wide variety of services. Different DSL equipment implementations are required to support different services.

2. Does DSL work through the existing PSTN?

No. DSL is a local loop transmission technology that can be provisioned over the existing local loops, either from the CO to the service user or point-to-point in campus environments. DSL can be optionally configured to operate concurrent with existing POTS. However, DSL does not traverse the PSTN. DSL-based services are redirected to other WAN services prior to interfacing with the switched network.

3. Will I need separate, dedicated networks to support video, voice and data services?

No. Advancements in compression for networking technologies allow support of both traditional data, voice, and even video services over ATM and IP networks. Advancements in QoS initiatives will continue to enhance the level of quality of these services.

4. Is end-to-end ATM required to provide an appropriate level of QoS?

This depends on the service objectives. Clearly, ATM is able to provide a very high QoS for many applications. In addition, the Internet Engineering Task Force (IETF) continues to work toward QoS standards for IP.

5. What is meant by business-class DSL?

Business-class DSL applications (such as VPN, VoDSL, and FRoDSL) essentially carry service performance guarantees to safeguard mission-critical business applications in contrast to the "best effort" performance of simple high-speed Internet access. Service Level Management capabilities are required for business-class DSL and customers will generally pay a premium for a specified Quality of Service guarantee. In short, Total Business DSL supports a full range of services (IP, FR, TDM and ATM). It supports multiple traffic types and applications (voice, data, integrated voice and data, and video) with optimized coverage (for example, ReachDSL to deliver high-speed DSL services at extended geographic distances) and with full management support.

The chart below outlines the evolution from earlier, "best effort" service support to today's Total Business DSL.

Evolution of Total Business DSL		
Characteristics	1998	2000 and Beyond
Services	IP	IP, FR, TDM, ATM
Applications	Internet Access	Internet Access, Voice/Telephony, Frame Relay and Advanced Data Applications
QoS	Best Effort - UBR	Guaranteed. VBR, CBR, UBR
Transport	SDSL, IDSL	SDSL, IDSL, ADSL, Symmetric Line Sharing DSL, T1/E1
Service Coverage	Best Effort	Guaranteed to Multiple Locations
Service Level Management	Basic IP Management	Full SNMP Management Service Level Management and Reporting, Guaranteed Throughput
Wholesale NSP	ISPs	ISPs, IXCs, Voice Carriers, FR NSPs
Special Requirements	Third-Party IP Endpoints	Third-Party Endpoints, Partitioned Data, Independent Management

FIGURE 8-1
Evolution of Total Business Chart

6. Are RADSL and ADSL the same thing?

No. RADSL is Rate Adaptive DSL, while ADSL is Asymmetric DSL. RADSL systems can be configured for the same high-speed asymmetric services as ADSL. RADSL can also be configured for a variety of symmetric services offering up to 1 Mbps capabilities. RADSL was cited along with ADSL and MVL by the FCC as line-sharing compatible technologies.

7. Is DSL a single technology that addresses a single customer application?

No. DSL is a family of technologies that address a full range of multiservice applications for service users based on specific requirements. While supporting both symmetric and asymmetric transmission, DSL also lends itself to applications to support IP, frame relay or Nx64 services. See Chapter 3, DSL Basics, for more information on the various DSL technologies.

8. Does DSL support industry transmission standards?

Yes. Formats and bit rates such as T1 (1.544 Mbps) and E1 (2.048 Mbps) are easily transmitted. Since DSL in itself is not a service so much as it is an enabler of high-speed services and applications, the list of existing standards it can accommodate includes POTS, H.320, MPEG, frame relay and IP.

9. Are DSL-based services available today?

Yes. As mentioned in Chapter 5, Market Evolution and Deployment Realities, there are over one million lines of DSL already in service today. Some vendors (Paradyne for example) have deployed port capacity well in excess of this figure. Generalizing by country, city or region is difficult at this time, but you can contact your network service provider to determine if services are available now or when services will be available in your area.

ABOUT PARADYNE

Founded in 1969, Paradyne is a recognized pioneer in network access. Your decision to use Paradyne would put you in very good company as evidenced by wide industry acceptance of our solution. As of the end of the third quarter 2000, Paradyne customers have deployed in excess of 12,000 Hotwire DSLAMs with existing capacity exceeding three million ports. We are in all 50 states, eight Canadian provinces and in over 100 countries worldwide. Paradyne's market leadership is the result of a clear focus on developing and delivering robust, easily deployable solutions that provide our customers rapid market entry and broad services coverage.

While Paradyne has placed a major focus on establishing leadership in the DSL market, we have also continued to innovate and maintain market leadership in the traditional digital access markets, with particular success in the frame relay managed services market. Paradyne's core competence in DSL and in service level management put us in the enviable position of blending the two technologies to deliver FrameSaver® DSL – the first and only Frame Relay over DSL (FRoDSL) application in the industry to deliver on both sides of the value proposition – low cost access to the frame relay network plus end-to-end service level management to safeguard and guarantee network performance.

As one of the largest independent manufacturers of network access products in a dynamic market, Paradyne emerged as an industry leader, delivering numerous other industry firsts relative to DSL:

- *Shipped revolutionary Hotwire® ReachDSL (including MVL), cost effectively extending commercial Hotwire xDSL-based services into the mass market.*
- *Shipped industry's first commercial RADSL system.*
- *Delivered industry's first full-duplex 384 Kbps SDSL over POTS product line to support advanced multimedia service trials including video conferencing, high-speed Internet access and remote LAN access.*
- *Delivered industry's first two-wire ADSL and SDSL modems in the form of a PC NIC operating at 1.5 - 2 Mbps.*
- *Offered the first SNMP-managed DSL system.*
- *Delivered first multiservices DSLAM platform in support of IP, frame relay and channelized services with the highest port density in the industry at the time of its availability.*
- *Delivered first stackable multiservices DSLAM architecture in the market to enable DSL deployments ranging from 4-68 ports for multiple Service Wire Center (SWC) penetration.*
- *Introduced first intelligent endpoints capable of providing management control to either the NSP or the corporate IS manager. These endpoints are also the most compact on the market.*

- *Introduced the industry's first DSL Partner's Program to assist incumbent and competitive service providers in business case creation for DSL-based service deployment initiatives.*
- *Delivered first DSLAM to support network management partitioning, allowing NSPs and NAPs to independently configure, test, and control the parts of the system that are relevant to a specific customer.*
- *Developed the industry's most comprehensive array of endpoints, with different models supporting a variety of IP, frame relay and T1/E1 services.*

In summary, Paradyne offers standards-based solutions while continuing to innovate on many fronts (e.g., ReachDSL, Total Business DSL). Paradyne's Total Business DSL supports the evolution from early Internet access for small autonomous business customers to today's advanced business applications for large, multi-location enterprise or Wide Area Network services. Total Business DSL delivers new levels of service quality and service management capabilities while offering support for legacy enterprise systems and applications.

Paradyne's approach allows the delivery of IP, FR, ATM, TDM and POTS services for voice, video and data applications. These services are all delivered via ATM to the endpoint. The ATM cells are then converted and presented to the end user via the endpoint as a specific service type – the way enterprise customers have historically operated via a DSU/CSU. The system implements all of the relevant ATM service classes necessary to efficiently support the specific service: UBR, rt-VBR, nrt-VBR and CBR.

Network management is a key difference between the Paradyne solution and others. A new, carrier-class management path delivers service providers ad-hoc management access to DSL CPE with the same ease and consistency that are supported in TDM access networks. This management connectivity is accomplished via a sideband management communication that is implemented via the Hotwire GranDSLAM, independent of the data path. This approach assures reliable management connectivity even if data services are down. Other DSLAM approaches only provide management connectivity via the data path, which results in lost management control in times of network outages. This is one of the fundamental enablers that is allowing Paradyne's Total Business DSL service support to move from small business via ISPs to large multi-location business services via large IXCs.

Finally, Paradyne delivers service level management tools to measure and report performance-specific Service Level Agreements. The Hotwire GranDSLAM is available immediately, with the necessary DSL port cards and endpoints to support the full portfolio of WAN services including: IP, FR, ATM, and TDM for support of voice, video and data networking services.

Paradyne develops industry-defining digital access products and technologies that facilitate high-speed network access. With over 250 patents and 30 years of achievements, Paradyne has more experience delivering access products into business-critical data networks worldwide than any other vendor.

Paradyne's corporate headquarters and manufacturing facilities are located in Largo, Florida, with approximately 900 employees throughout the United States, and regional offices in Canada, United Kingdom, Russia, Hong Kong, Japan, Singapore, China, the Middle East, and France. The company's research and development centers are located in New Jersey and Florida.

Core Competencies

- *Transmission technologies and applications in Digital Signal Processing, channel coding and a thorough understanding of the core telephone company network infrastructure. This expertise is one of the critical elements driving Paradyne's success in the emerging DSL market.*
- *LAN and WAN network design history, which allows Paradyne to deliver products in the frame relay and IP market space.*
- *Comprehensive, end-to-end network management solutions and service level management solutions.*

Technology Innovations

Paradyne is a pioneer of the DSL business. As a subsidiary of AT&T, Paradyne pioneered GlobeSpan™ technology, the leading industry source of DSL chipsets, which includes applications like ADSL, RADSL, SDSL and HDSL. On August 20, 1996, GlobeSpan Technologies Inc. announced its launch as a separate DSL semiconductor chip business, emerging with Paradyne from AT&T Corporation and Lucent Technologies.

NEXT STEPS

If you would like more information regarding DSL-based service deployment or how to utilize DSL for business, private network or residential applications, please contact Paradyne at 1-800-PARADYNE or 727-530-8623, or visit the Paradyne Web Site at www.paradyne.com.

DSL SOURCEBOOK GLOSSARY

A

AAL5	ATM Adaption Layer 5. AAL5 has been adapted by the ATM Forum for a Class of Service called High-Speed Data Transfer that supports connection-oriented, delay-tolerant data traffic.
ADSL	Asymmetric Digital Subscriber Line. A high-speed transmission technology using existing twisted-pair lines that permits simultaneous POTS and high-speed data communication. A much higher data rate is employed downstream (to the customer site) than upstream (to the service provider).
AMI	Alternate Mark Inversion. A line coding technique used to accommodate the ones density requirements of E1 or T1 lines.
AN	Access Node. See Node.
ANSI	American National Standards Institute. Accredits and implements standards. Member of ISO.
API	Application Program Interface.
ASP	Application Service Providers.
ATM	Asynchronous Transfer Mode. A high-bandwidth, low-delay, connection-oriented switching and multiplexing technique using 53-byte cells to transmit different types of data concurrently across a single physical link.
attenuation	Attenuation is the dissipation of the power of a transmitted signal as it travels over a wire.
AWG	American Wire Gauge. An indication of wire size. The heavier the gauge, the lower the AWG number and the lower the impedance.

B

backbone	Equipment that provides connectivity for users of a distributed network and includes the network infrastructure.
backbone LAN	A transmission facility designed to connect two or more LANs.
backhaul	The act of, or mechanism for, transmission from a remote site to a central site.
bandwidth	The difference between the highest and lowest frequencies of a band that can be passed by a transmission medium without undue distortion or the range of electrical frequencies a device is capable of handling.
baseband	A category of transmission in which a single signal is sent over a single medium without frequency division.
B-channel	Bearer Channel. The ISDN channel that carries customer information like voice calls, circuit-switched data, or packet-switched data.
BER	Bit Error Ratio. Measure of transmission quality indicating the number of bits incorrectly transmitted in a given bit stream compared to the total number of bits transmitted in a given duration of time.
B-LEC	Building LEC.
bps	Bits per second. Indicates the speed at which bits are transmitted across a data connection.
BRI	Basic Rate Interface. An ISDN service rate of 144 Kbps, provided as two B-channels of 64 Kbps for data transfer and one D-channel of 16 Kbps for control and signaling.
bridged tap	Any part of the local loop that is not in the direct transmission path between the CO and the service user.
BT	Burst Tolerance. The limit parameter of the Generic Cell Rate Algorithm (GCRA).
bus	An assembly of conductors that carries signals to and from devices along its path.

C

cable binder	A cable binder is used to bundle multiple insulated copper pairs together in the telephone network.
CAP	Carrierless Amplitude & Phase Modulation. A transmission technology for implementing a DSL connection. Transmit and receive signals are modulated into two wide-frequency bands using passband modulation techniques.

CAP	Competitive Access Provider.
CAT5	Category 5. A level of unshielded twisted-pair wiring performance as defined by EIA/TIA-568. CAT5 cable is used for transmission speeds up to 100 Mbps.
CBR	Constant Bit Rate. An ATM service category with a guaranteed rate, used for video, voice, and other applications where timing is critical.
CDV	Cell Delay Variation. In ATM, differences in cells' transmission times caused by buffering and cell scheduling.
CES	Circuit Emulation Service.
CEU	Commercial End User. See SU, Service User.
CIR	Committed Information Rate. The CIR is used by the service provider for rate enforcement when the network allocates bandwidth in a frame relay virtual circuit.
CLEC	Competitive Local Exchange Carrier. A provider of local access and long distance services that is not the LEC. CLECs must register with the Public Utility Commission and FCC.
CLR	Cell Loss Ratio. A network specific QoS parameter in ATM, CLR is the number of lost cells compared to the total number of cells transmitted.
CO	Central Office/Central Site. In North America, a CO houses one or more switches to serve local telephone subscribers. Known as a public exchange elsewhere.
CoS	Cost of Service.
CPE	Customer Premises Equipment. Communications equipment that resides at the customer's location.
crosstalk	Line distortion caused by wire pairs in the same bundle being used for separate signal transmission.
CSA	Carrier Serving Area.
CSU	Channel Service Unit. A device that connects service user equipment such as a DSU to the local digital telephone loop, protects the line from damage, and regenerates the signal.
CTD	Cell Transfer Delay. In ATM, the time it takes a cell to go from one ATM node to another.

D

DACS	Digital Access and Cross-Connect System. A device that allows DS0 channels to be individually routed and reconfigured.
DCE	Data Communications Equipment. The equipment that provides the signal conversion between the DTE and the network.
D-channel	Data Channel. The ISDN channel that carries signaling information to control call setup.
DDS	Digital Data Service. Provides private digital communication circuits, typically deployed at either 56 or 64 Kbps.
demarc	Demarcation point between the telephone company communications facilities and the terminal equipment, CSU/DSU protective apparatus, or wiring at a subscriber's premises.
DHCP	Dynamic Host Configuration Protocol. A TCP/IP protocol that provides static and dynamic address management.
DLC	Digital Loop Carrier. A fiber-based transport technology that permits remote terminals to support the copper loops to subscribers, thus consolidating access back into the CO. The only form of DSL that can run over DLCs is IDSL (ISDN DSL).
DLCI	Data Link Connection Identifier. The virtual circuit number corresponding to a particular connection between two destinations. This number is used as part of the frame relay header.
DMT	Discrete MultiTone. DSL technology using digital signal processors to divide the signal into 256 subchannels.
downstream	Refers to the transmission direction from the CO to the customer premises.
DRAM	Dynamic Random Access Memory. Memory used to store data in PCs and other devices.

DSL	Digital Subscriber Line. A copper loop technology enabling high-speed access in the local loop, often referred to as the last mile between the NSP and the customer.
DSLAM	Digital Subscriber Line Access Multiplexer. A platform for xDSL that provides high-speed data transmission over traditional twisted-pair wiring.
DS1	Digital Signal level 1. A digital signal transmitted at the rate of 1.544 Mbps for T1 service.
DSP	Data Signal Processor. The microprocessor that handles line signaling in a modem.
DSU	Digital Service Unit. Data communications equipment used to terminate a digital WAN service by providing timing, signal regeneration, and an interface to data terminal equipment.
DSX-1	Digital Signal Cross Connect level 1. An interconnection point for terminals, multiplexers, and transmission facilities.
DTE	Data Terminal Equipment. The equipment, such as a computer or terminal, that provides data in the form of digital signals for transmission.

E

E1	A wideband digital interface operating at 2.048 Mbps, as defined by the ITU recommendations G.703 and G.704. Generally available outside North America.
E3	A wideband digital interface operating at 34.368 Mbps. Generally available outside North America.
EIA/TIA	Electronic Industries Association/Telecommunications Industry Association. This organization provides standards for the data communications industry to ensure uniformity of the interface between DTEs and DCEs.
ERP	Electronic Resource Planning.
Ethernet	A type of network that supports high-speed communication among systems. It is a widely-implemented standard for LANs.
ETSI	European Telecommunications Standardization Institute. An organization that produces technical standards in the area of telecommunications.
EU	European Union. Formerly known as EC, European Commission.
extranet	The portion of an enterprise intranet accessible from the Internet.

F

FCC	Federal Communications Commission. The agency of the U.S. government that regulates all forms of communications that originate in the U.S., including telecommunications and telephony.
FDDI	Fiber Distributed Data Interface. An ANSI 100 Mbps LAN standard for fiber optic cable networks.
FDI	Feeder Distribution Interfaces. Points where cable bundles from the telephony switch use drop lines that extend out to the customer premises.
FDM	Frequency Division Multiplexing.
FEXT	Far End CrossTalk. Crosstalk that occurs at the remote end of a link.
FRAD	Frame Relay Access Device (sometimes referred to as Frame Relay Assembler/Dissembler). A FRAD connects non-frame relay devices to the frame relay network.
frame relay	A high-speed connection-oriented packet switching WAN protocol using variable-length frames.
FRF	Frame Relay Forum.
FRoDSL	Frame Relay over DSL.
FRSP	Frame Relay Service Provider.
FTP	File Transfer Protocol. A TCP/IP standard protocol that allows a user on one host to access and transfer files to and from another host over a net work.

G

G.dmt	A name for the line modulation specified by ITU recommendation G.992.1
G.lite	A name for the line modulation specified by ITU recommendation G.992.2.

GranDSLAM	A Hotwire high-density DSLAM supporting a variety of DSL transport types and network services.
G.703	An ITU-T recommendation for the physical and logical characteristics of hierarchical digital devices.
G.704	An ITU-T recommendation for synchronous frame structures.
G.shdsl	Symmetric, single pair DSL technology. Intended as a replacement technology for SDSL.
GUI	Graphical User Interface.

H

HDB3	High Density Bipolar Three Zeros Substitution. A line coding technique used to accommodate the ones density requirements of E1 lines.
HDSL	High-bit-rate Digital Subscriber Line. A technique for high bandwidth, bidirectional transmission over copper wire for T1 and E1 services.
HDTV	High Definition TV.
hertz	Frequency measurement. 1 hertz = 1 cycle per second.
HomeLink	A feature of Hotwire MVL that provides peer-to-peer communications for PCs attached to different MVL modems at the customer premises.
HomePNA	Home Phoneline Networking Alliance.
H.320	ITU standard for digital ISDN for multimedia.
HTML	HyperText Markup Language. An authoring software used on the Internet's World Wide Web. HTML is basically ASCII text with HTML commands.
hub	A device connecting several computers to a LAN.

I

IAD	Integrated Access Device. Customer premises equipment used for aggregrating diverse traffic types, such as voice and data.
IDC	Insulation Displacement Connection. A wire connection device.
IDSL	ISDN DSL. Uses 2B1Q line code.
IEEE	Institute of Electrical and Electronics Engineers.
IETF	Internet Engineering Task Force. An open international organization concerned with the evolution of the Internet.
ILEC	Incumbent Local Exchange Carrier. Refers to the primary existing central office carrier, as distinguished from new competitive carriers established after deregulation. In common usage, ILEC and LEC are interchangeable.
interoperability	The ability of equipment from multiple vendors to communicate using standardized protocols.
intranet	A private network or Internet using Internet standards and software, but protected from public access.
IP	Internet Protocol. An open networking protocol used for Internet packet delivery.
IPX	Internetwork Packet Exchange. A LAN communications protocol used to move data between server and workstation programs running on different network nodes.
ISA	Industry Standard Architecture. A standard for connections of personal computer bus architecture.
ISDN	Integrated Services Digital Network. Telecommunication service that uses digital transmission and switching technology to provide voice and data communications on a B-channel while sending signaling on a D-channel.
ISO	International Standards Organization.
ISP	Internet Service Provider. A vendor who provides direct access to the Internet.
ITU	International Telecommunications Union. The telecommunications agency of the United Nations, established to provide standardized communications procedures. (Formerly known as CCITT.)
IXC	IntereXchange Carrier. A provider of telecommunications services between exchanges; also known as Other Common Carriers.

K/L

Kbps	Kilobits per second. One kilobit is usually taken to be 1,024 bits.
LAN	Local Area Network. A privately owned and administered data communications network limited to a small geographical area.
LAPF	Link Access Procedure. ITU standard for frame relay layer 2 protocol.
last mile	Refers to the local loop. The last mile is the difference between a local telephone company office and the customer premises; a distance of about 3 miles or 4 kilometers.
latency	The time it takes to transfer data from its source to its destination.
layer	OSI reference model. Each layer performs certain tasks to move the information from the sender to the receiver. Protocols within the layers define the tasks for the networks.
LEC	Local Exchange Carrier. A company that provides intra-LATA (local access transport area) telecommunications services.
local loop	A twisted-pair cable that connects the CO and the customer premises.
L2TP	Layer Two Tunneling Protocol.

M

MAC	Media Access Control. Protocol for controlling access at the data link Layer 2.
Mbps	Megabits per second. One megabit is 1,048,576 bits.
MDF	Main Distribution Frame. The point where all local loops are terminated at a CO.
MDU	Multiple Dwelling Unit.
MIB	Management Information Base. A database of managed objects used by SNMP to provide network management information and device control.
MPEG	Motion Picture Experts Group. Group developing ISO standards for full motion video.
MPLS	Multi-Protocol Label Switching. Combines the strengths of ATM with the strengths of IP.
M/SDSL	Multirate SDSL.
MSO	Multiple System Operator. A cable company that operates more than one TV cable system.
MTBF	Mean Time Between Failures.
MTSO	Mobile Telephone Switching Office. A generic name for the main cellular switching center which supports multiple base stations.
MTU	Multiple Tenant Unit.
MUX	Multiplexer. A device that can send several data streams over a single physical line.
MVL	Multiple Virtual Lines. A proprietary local loop access technology that permits POTS and data services to concurrently use a single copper wire loop.

N

NAP	Network Access Provider. The provider of the physical network that permits connection of service subscribers to NSPs.
NEBS	Network Equipment Building System. A set of requirements for the reliability and usability of equipment, established by Bellcore.
NEXT	Near End CrossTalk. Crosstalk in which the interfering signal is traveling in the opposite direction as the desired signal.
NIC	Network Interface Card. The circuit board or other hardware that provides the interface between a DTE and a network.
NID	Network Interface Device. A device connects the local loop to the customer premises and includes the demarcation point.
NMS	Network Management System. A computer system used for monitoring and controlling network devices. Implements functions at the Network Management Layer using a network management protocol, such as SNMP.
NOC	Network Operations Center. The point at which a network is monitored and controlled.

node	A connection or switching point on the network.
NSP	Network Service Provider. A vendor, such as an ISP, local telephone company, CLEC or corporate LAN, that provides network services to subscribers.
NTU	Network Termination Unit. Equipment at the customer premises which terminates a network access point.
Nx64	Describes a continuous bit stream to an application at the Nx64 Kbps rate.

O

Oc*n*	Optical Carrier level *n* signal. The fundamental transmission rate for SONET. For example, OC3 represents a transmission rate of about 155 Mbps.
OpenLane	A standards-based network management system providing diagnostics, real-time performance monitoring, historical reports, and health and status indications for Paradyne's SNMP-managed devices.
OSI	Open Systems Interconnection. The OSI Reference Model is a seven-layer network architecture model of data communication protocols developed by ISO and ITU.
OSS	Operating System Support.

P

passband	A category of transmission in which multiple signals are sent over a single medium by restricting channels to specific frequency ranges.
PBX	Public Branch Exchange. Telephone switching equipment dedicated to one customer. A PBX connects private telephones to each other and to the public dial network.
PCI	Peripheral Component Interconnect. A 32-bit bus.
POP	Point-of-Presence. An IXC’s or NSP’s equivalent of a CO.
POTS	Plain Old Telephone Service. Standard telephone service over the PSTN, with an analog bandwidth of less than 4 khz.
POTS splitter	A device that filters out the DSL signal and allows the POTS frequencies to pass through.
PPP	Point-to-Point Protocol. A protocol for packet transmission over serial links, specified by Internet RFC 1661.
PPTP	Point-to-Point Tunneling Protocol.
PSC	Public Service Commission. State-level regulators of the local phone company in the United States.
PSTN	Public Switched Telephone Network. A network shared among many users who can use telephones to establish connections between two points. Also known as the dial network.
PTO	Public Telephone Operator.
PTT	Post, Telephone and Telegraph. A national communications authority, sometimes government-controlled, which acts as a common carrier.
PVC	Permanent Virtual Circuit. A virtual connection established administratively. Used in networks supporting ATM, frame relay, and X.25.

Q/R

QAM	Quadrature Amplitude Modulation. Modulation technique using variations in signal amplitude.
QoS	Quality of Service. In ATM, a level of service dependent on CLR, CTD, and CDV.
RADSL	Rate Adaptive DSL. A technique for the use of an existing twisted-pair line that permits simultaneous POTS and high-speed data communication at adaptive symmetric and asymmetric data rates up to 7 Mbps.
RFI	Radio Frequency Interference. All computer equipment generates radio waves. Levels are regulated by the FCC.
router	A device that connects LANs by dynamically routing data according to destination and available routes.

RT	Remote Terminal. The local loop can be terminated at RT. RTs are intermediate points closer to the customer premises to improve service reliability.
RTU	Remote Termination Unit. A DSL device installed at the customer premises that connects to the local loop.

S

SDH	Synchronous Digital Hierarchy. Based in part on SONET, SDH is an ITU standard for the interworking of ANSI and ITU transmission techniques.
SDSL	Symmetric DSL. Provides high bandwidth, bidirectional transmission over one copper wire pair for T1 or E1 services.
SLA	Service Level Agreement. A contract between a frame relay service provider and a customer.
SLM	Service Level Management. Managing and monitoring of network parameters to ensure QoS as defined in a SLA between an NSP and an end user. Includes monitoring, diagnostics, and reporting of critical network parameters such as availability, latency, and throughput.
SLV	Service Level Verifier. A feature that monitors and ensures frame relay network service levels.
SNA	Systems Network Architecture. A description of the logical structure and protocols that transmit information and control the operation on an IBM network.
SNMP	Simple Network Management Protocol. Protocol for open networking management.
SOHO	Small Office/Home Office. Used to denote a single-building networking environment, as distinguished from a campus environment.
SONET	Synchronous Optical NETwork. An ANSI standard for the transmission of digital data over optical networks.
STS-1	Synchronous Transport Signal 1. The fundamental SONET standard for transmission frame and payload rate at 51.84 Mbps.
SU	Service User. The end user at the customer premises.
SVC	Switched Virtual Circuit. In ATM, a connection established through signaling.
SWC	Service Wire Center.

T

TCP/IP	Transmission Control Protocol/Internet Protocol. The dominant protocol suite in the worldwide Internet, TCP is Layer 4, the transport layer. IP is Layer 3, the network layer.
TDM	Time Division Multiplex/Multiplexer. A technique/device that enables the simultaneous transmission of multiple independent data streams into a single high-speed data stream.
Telnet	Virtual terminal protocol in the Internet suite of protocols. Allows the user of one host computer to log into a remote host computer.
T1	A term for a digital carrier facility used to transmit a DS1 formatted digital signal at 1.544 Mbps. It is primarily used in North America.
T3	A term for a digital carrier facility used to transmit a DS3 formatted digital signal at 44.746 Mbps. It is primarily used in North America.

U

UAWG	Universal ADSL Working Group.
UBR	Unspecified Bit Rate. An ATM service category with no commitment of bandwidth.
UNI	User to Network Interface. The interface of an ATM end user and an ATM switch, or the interface of an ATM switch and a public carrier.
upstream	Typically refers to the transmission speed from the customer premises toward the telephone network.
URL	Uniform Resource Locator. An Internet standard addressing protocol for location and access of resources.
USB	Universal Serial Bus.
UTP	Unshielded Twisted Pair. See CAT5.

V

V.35	An ITU-T standard for a high-speed, 34-position DCE/DTE interface.
VBR	Variable Bit Rate. An ATM service category that supports average and peak traffic rate parameters.
VC	Virtual Circuit. A logical connection or packet-switching mechanism established between two devices at the beginning of a transmission.
VDSL	Very-high-bit rate DSL. Generally refers to a data transmission speed from 25 to 50+ Mbps over very short distances.
VLAN	Virtual LAN. Workstations on different LANs can be connected using VLAN tagging.
VOD	Video On Demand. A service allowing many users to request the same video at the same time.
VoDSL	Derived Voice over DSL.
VPN	Virtual Private Network. Software-defined private network.

W/X

WAN	Wide Area Network. A network that spans a large geographic area.
WIPO	World Intellectual Property Organization.
xDSL	Refers to all DSL-based services.
XML	eXtensible Markup Language.

#

10Base-T	A 10 Mbps Ethernet LAN that works on twisted-pair wiring.
100Base-T	A 100 Mbps Ethernet LAN that works on twisted-pair wiring.
2B1Q	Two Binary, one Quaternary. A line coding technique that compresses two binary bits of data into one time state as a four-level code.

Paradyne's master glossary of terms and acronyms is available on the World Wide Web at: www.paradyne.com. Select Library/Technical Manuals/Technical Glossary

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