Study Guide

LCTE Exam 1M0-401:
DSL Theory, Protocols and Standards

Revision 1

LCTE Exam 401 Study Guide:

Networking and Telecommunications Fundamentals

Lucent Certified Technical Expert (LCTE) Program

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Guide Introduction

Information and resources for the 1M0-401 exam:

LCTE Certification Information – Available from the LCTE Program website
http://www.lucent.com/certification/candidate.html

References to web resources and books are listed in the LCTE Candidate Resource Guide are provided in Appendix B at the end of this guide.

How to use this Guide

This study guide will help you prepare for the LCTE Exam 1M0-401- *DSL Theory, Protocols and Standards*. This guide is intended to provide a review of summary information on DSL systems, standards and troubleshooting for professionals already working in the data communications and telecommunications industries. This guide is **NOT** intended to replace any formal training, experience and reference materials. In addition, 6 months experience on communications equipment is highly recommended prior to attempting any Lucent Certified Technical Expert exam series. Suggested Lucent Learning coursework available to help prepare for exams is listed below.

Lucent Certified Technical Expert exams follow a rigorous development and review process. Subject Matter Experts (SME) create the scope of the exam, objectives, content and definition of the minimally qualified candidate via Job Task Analysis and Item Development Workshop processes. The LCTE development team requires a third party review of examination objectives, development, and delivery methods, along with extensive psychometric and statistical analysis of exam content prior to final release.

This guide is organized in sections to represent primary objectives used by SMEs in the development of exam content. At the end of each section, questions are posed for topic review as ***Additional Considerations***. Additional considerations are questions encountered in various "real world" scenarios for applied knowledge and answers may reach beyond the scope of the study guide text or exam content. The questions are asked to provide self-evaluation in topic understanding, and answers are found within either the ***Additional Resources*** listed at the end of each section or in Appendix B.

Written feedback on this study guide is welcome. Please submit comments and contributions in writing to the Lucent Certifications Program team at: lcte@lucent.com.

Lucent Learning Resources

Lucent Learning: ***http://www.lucent.com/training/***

E-Learning – Data Products

- Introduction to DSL
- ATM Technology Overview 1: Switching Basics
- ATM Technology Overview 2: Interfaces and Protocols
- ATM Technology Overview 3: Management

http://www.lucent-product-training.com

InterNetworking Systems:

- ATM Overview
- ATM Broadband Networks

http://www.lucent.com/knowledge/resourcelib/0,,,00.html

Lucent Technologies Public Resource Library
White Papers, Case Studies, Course Material

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Section

1

Understand DSL Technology

Understand the components of DSL technology.

Describe the purpose, features, and functions of these DSL components (CPE, COE, CO, MDF, DLC, etc.):

Customer Premise Equipment (CPE) provides the termination of the DSL network at the user's location. CPE is also called xDSL Terminating Unit-Remote (XTU-R) or a DSL modem, router or bridge. When the CPE provides voice as well as data services, the CPE is called an Integrated Access Device (IAD).

Central Office Equipment (COE) includes the large Telco switching equipment and DSL Access Multiplexor (DSLAM). The DSLAM aggregates traffic from multiple CPEs and switches it to the bearer network, either for voice or for data. The DSLAM is also called an xDSL Terminating Unit-Central (XTU-C).

A Central Office (CO) is the Telecom facility that houses the COE and the MDF.

Main Distribution Frame (MDF) refers to the termination racks for all the all copper pair and physical plant coming into the CO. The MDF also provides several cross-connects that enable various equipment in the CO to provide local services.

Digital Loop Carrier (DLC) systems are voice-grade mulitplexors that improves efficiency in TDM traffic streams that carry voice services to a customer's location through extending fiber to the local copper distribution plant. A traditional voice DLC prevents most DSL services from working as the transmission frequencies are blocked, however the upgrade for most DLC equipment to allow ADSL is available. IDSL is not impeded by the DLC as the signaling is serviced through traditional ISDN voice streams.

Remote Terminal (RT) equipment are DSLAM concentrators deployed on the fringe of the service provider's copper plant to provide service to sites that are outside of DSL coverage area serviceable from the CO.

Specify differences between local exchange carrier (LEC), incumbent local exchange carrier (ILEC), and competitive local exchange carrier (CLEC):

Local Exchange Carriers (LEC) provide telephone services to end users in their home calling area and are also referred to as the last mile provider. Services are primarily local telephone service, but can include the final segment of data services, such as Switched 56 data service, ISDN, ATM, Frame Relay, leased data lines and Digital Subscriber Line (DSL).

Incumbent Local Exchange Carriers (ILEC) are monopolistic utilities that own the physical copper plant to the customer's premises, and are also known as regulated local carriers. The incumbent carrier provides direct services to the customer and is required to lease the lines to CLECs at the request of the customer.

Competitive Local Exchange Carrier (CLEC) – Reseller of local exchange services allowed by US telecommunications deregulation.

Network Access Providers (NAP) provide data internetworking services to individuals, small businesses and corporations. The services may be Internet access or intranet service between locations using virtual private networks. A local Internet Service Provider (ISP) is a type of NAP that may purchase wholesale network port access over a large geographic area, and resell the service to end-users.

Network Service Providers (NSP) are data companies that own the physical plant and/or backbone services to access providers. Most NSPs have several large interconnects to the public Internet, providing direct access to large accounts, port wholesaling services and physical access to copper plant access lines.

NAPs are at a disadvantage for providing DSL service, unless they also perform as the local telephone company, as existing copper infrastructure to homes and businesses are often owned by the ILEC. In many countries, third party services were not able to provide DSL until recently, when Tarriff's and legal efforts prevailed to require access to competitive carriers. Although the NAP has the ability to use the existing copper plant, costs for leasing the service or lines are often passed on to the end-customer through monthly billing rates.

Explain how customer premise devices (modems, routers, IADs) integrate in a DSL solution:

The equipment required at the customer premise location is determined by the type of service provided by the DSLAM and the desired functionality at the customer location.

A DSL modem is usually able to provide the a single physical and logical connection, appropriate for the small office / home office (SOHO) environment. Small networks are added to the network through the use of a small router providing the NAT and/or router-to-network PPPoE services to mask the additional users.

DSL routers and IADs incorporate the DSL modem functions with the OSI layer 2/3 demands of the networked environment. Router and IAD units are associated with small business functionality and office environments slightly larger than the SOHO market.

Compare and contrast DSL modems (bridges), routers, and IADs:

DSL Modems – Modems provide encoding and decoding from the digital signal of a PC to the digital over analog waveform of DSL signals. Digital modems are likely communicating with the PC via Ethernet connectivity, quite unlike the analog modem with the serial interface between devices.

DSL Bridges provide data transport with no routing, and are often configured for single data network interface between Ethernet and ATM protocols.

DSL Routers may provide OSI communication between the Ethernet connectivity to the workstations (network) at the customer premise and the ATM or Frame Relay functionality of the DSL network. A router may also use an existing DSL modem to terminate layer 3, and provide the simple bridging functions, routers include the OSI layer three routing functions, often including NAT, and PPPoE termination.

Integrated Access Devices (IADs) provide interfaces for both data and voice over DSL on the link. Typically the IADs do voice compression in addition to voice encoding/decoding.

Explain the wire, modulation, and distance issues involved when using xDSL technology, including attenuation, encoding/decoding, and electromagnetic interfaces:

The maximum data transfer rate will depend on:

1. The frequencies used by the DSL technology applied, as higher frequency bandwidth has a higher attenuation rate, and therefore shorter distance.
2. The length of the wire or local loop distance, as the signal cannot be regenerated (IDSL is the exception).
3. The quality of the wire, as the rate of the full length of the circuit will only be to the lowest common factor in the gauge. Copper of a greater diameter provides higher bandwidth than wire of a smaller diameter, thus 24 AWG copper pair used in the DSL local loop will provide higher throughput than a 26 AWG copper pair.
4. The modulation technology, such as CAP, 2B1Q etc.

Cable bundles known as “Binder Groups” of 24 pair plus a spare pair of copper wires are used in the physical plant of the Telecommunications provider. Interference within a cable group may occur due to resonation of electrical signals over a variety of pairs within a closed environment, creating crosstalk. Conflicting circuits are a phenomenon referred to in the telecommunications industry as “disturbers”.

Troubleshooting techniques for DSL problems includes checking to see what circuits are in the same wire bundle as the problem DSL copper loop. Interference is commonly found in situations including:

1. ADSL in the same binder group as SDSL
2. T1 or ISDN lines in the same binder group as either ADSL or SDSL

Standards are being developed by the ANSI T1 committee to provide a maximum number of ADSL lines per binder group and maximum SDSL lines in a binder group to prevent interference from degrading service.

Compare and contrast DSL technologies and standards.

Describe the similarities and differences in data rate, mode, definition, range of frequency, and distance limitations among various DSL technologies and standards such as ADSL, HDSL, IDSL, SDSL, etc.:

ADSL

Asynchronous Digital Subscriber Line (ADSL) is highly dependant on distance, providing up to 8Mbps bandwidth in LAB simulation testing. ADSL is often used for Internet/Web access, and multimedia video reception due to the broadband transmission rates. The ADSL services are not designed for enterprise installations that will be hosting services, due to the significantly slower upstream transmission speed. ADSL is able to provide analog phone service by using splitters to separate data vs. voice frequencies. ADSL service uses either Carrier-less Amplitude/Phase (CAP) modulation or Discrete Multi-Tone (DMT) line coding method. Both encoding methods have strong support by competing product manufacturers, and the confusion between the two provides for incompatibility issues on ordering equipment.

G.lite or ADSL.lite is a industry standard recognition of ITU-T Recommendation G.992.2 supporting up to 512K upstream transmissions and 1.5Mbps downstream. The deployment of G.lite allows a splitterless service to incorporate simultaneous voice and data through the use of a low-pass filter imbedded in the DSL modem provided as the CPE device.

HDSL

High-bit-rate Digital Subscriber Line (HDSL) was derived between AT&T Bell Laboratories and Bellcore in 1986, appearing in service by incumbent Telco providers in early 1992. HDSL provides two copper-loop 784Kbps service circuits for 1.544Mbps DSL circuits, able to endure bridged taps and HDSL repeaters, but no loading coils.

This technology is often used for expansion of U.S. domestic T1 emulated service where expanding current infrastructure is prohibitive. Symmetric HDSL service is a point-to-point circuit without traditional switching, limiting the circuit to data stream only. Voice is provided from the customer's VoIP or VoFR implementations.

IDSL

ISDN Digital Subscriber Line (ISDL) is a 2 Binary Data, 1 Quaternary (2B1Q) algorithm, the nailed-up cousin to the switched ISDN service. ISDL can be configured in two configurations: Two 64K data channels, for a total of 128K usable bandwidth with 16K reserved, or the ISDL may be configured for 144 Kbps available bandwidth. ISDL is deployed in a campus environment using a host device and traditional ISDN terminal equipment/routers, as well as across Digital Loop Carriers (DLCs) that would otherwise be prohibitive to DSL services.

RADSL

Rate-adaptive Digital Subscriber Line (RADSL) is another term that refers to ADSL service that is able to determine the ultimate transport capacity of the local loop and optimize to provide the highest rate possible, similar to the rate adaption used by analog modems. RADSL provides voice service through splitters.

SDSL

Synchronous Digital Subscriber Line (SDSL) is able to deliver transmission speeds up to 2.3Mbps, with rate throttling mechanisms available to the provider, enabling regulated service packages. Actual speed is highly dependent on the copper facility of the local loop (the last mile) as well as the distance from the DSLAM, with a maximum distance of 3000 meters (22,770 ft). Voice Services are restricted to VoIP or VoDSL as voice frequencies are not concurrently available.

G.SHDSL is the ITU-T standard to address synchronous data services on a global basis, fully optimizing the 2.3Mbps and extending the deployment distance to double that of the American SDSL implementations. Synchronous services are recommended for business applications due to the fixed rate for upload and download speeds, enabling hosting of business information to remote business partners and customers.

VDSL

Very-high-data-rate Digital Subscriber Line (VDSL) is either symmetric or asymmetric technology and is in early stages to deploy transmission downstream rates above 50Mbps. Applications for VDSL include the deployment of fiber plus copper to business or residential developments for HDTV and multimedia programming over the public network. Cable distance rates cited vary, and ITU-T standards are not fully developed to enable universal deployment.

	2 or 4-wire Symmetry	Share copper pair with POTS	Line Code or Modulation	Bit-rate vs. Distance	Applications
IDSL	2-wire Symmetric	No	2B1Q	160 Kbps (2B+d+overhead) 18kft / 5.5km	Data or non-switched voice
HDSL	4-wire Symmetric	No	2B1Q or CAP	1.544 Mbps 12kft/3.6km 24 guage wire	DS1 transport; FR Repeaterless T1
SDSL	2-wire Symmetric	No	2B1Q or CAP	64Kbps – 2.3Mbps 18kft / 5.5km 24 guage wire	Business Access (inbound traffic requirements)
ADSL (RADSL, G.Lite)	2-wire Asymmetric	Yes	DMT (as well as CAP/QAM)	64Kbps/1.5Mbps 18kft / 5.5km 640Kbps/6Mbps 12kft/3.6km	Consumer-oriented data service, data service plus POTS
HDSL2	2-wire Symmetric	No	TC PAM (OPTIS)	1.544 Mbps 12kft/3.6km 24 guage wire	DS1 transport; FR Repeaterless T1
G.SHDSL	2-wire Symmetric	No	TC PAM	2.320 Mbps 24 guage wire	ATM / FR Nx64kbps VF Pairgain
VDSL	2-wire Symmetric Asymmetric	Yes	QAM or DMT	1.5 – 52Mbps up to 1000kft/305km	Digital video/data Requires FTTN or FTTC

Specify differences between asymmetric and symmetric xDSL standards:

Symmetric xDSL standards include SDSL, HDSL-2, and IDSL, and all use 2B1Q encoding or TC PAM encoding. SDSL is delivered primarily for business customers as office data flows tend to be more symmetric than home data flows due to inbound requests for FTP and web services. HDSL-2 may be used as a replacement for T1 services using a single pair instead of two pair. IDSL is essentially ISDN terminating at a DSLAM instead of a Public Switched Telephone Network (PSTN) node. IDSL is used when 56K modem is not fast enough and the local loop is too long for ADSL.

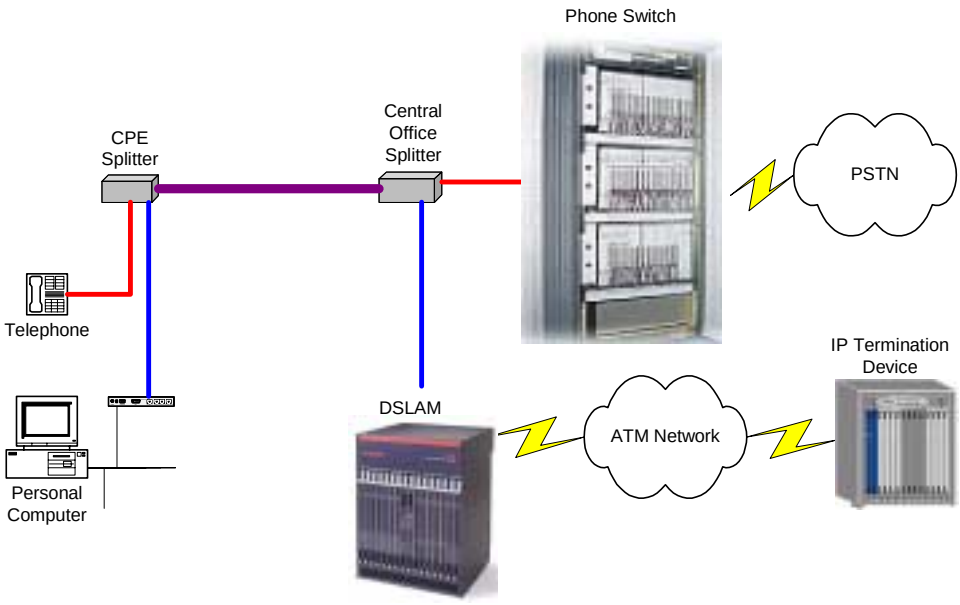
The end user must be geographically within a certain distance from the central telephone office, otherwise the noise and attenuation is too great. Attenuation limits either distance at a given rate or speed at a given distance with DMT traditionally able to carry further than 2B1Q.

Many existing lines have loading coils and bridge taps to extend phone service but these do not support most xDSL technologies, except for IDSL. IDSL uses 2B1Q signaling as a modification of the ISDN technology for up to 144Kbps transmission, and is more tolerant of interruptions to the circuit.

Describe the function and applications of POTS splitters and filters:

Filters, sometimes called micro-filters, are used to filter data frequencies out of the signal on the line to protect phone devices in the customer premises when G.Lite is being implemented. Micro-filters are low pass filters that allow 0 to 4KHz to pass to and from the phone, fax, or analog modem, but block frequencies above 20KHz to protect the POTS devices from the data signal on an ADSL G.Lite line. Micro-filters go in the home between the POTS device and the demarcation point (Demarc) and any bridge tap to the DSL modem.

A POTS Splitter is a passive device that divides a signal from the regular telephone line into two signals for data and voice, allowing them to function simultaneously on the copper pair by using different frequency ranges. The splitters are required on both ends of the local loop to provide frequency separation. At the telephone company's Central Office or Remote Terminal, the POTS splitter enables low-frequency voice signals to be sent on to the voice telephone network (PSTN - Public Switched Telephone Network) and the high-frequency data to a Digital Subscriber Line Access Multiplexer for transmission to the Internet. At the subscriber site, the POTS Splitter divides the incoming signal into low frequencies and allows to be sent to voice devices (i.e. telephone, fax) and high frequencies for data to the computer through the DSL modem.



Compare and contrast DSL vs. alternatives including bandwidth or data rate considerations.

Compare and contrast bandwidth and data rate considerations when using DSL vs. alternatives (Cable, Fixed Wireless Access, PSTN and leased line services):

Under prime conditions, DSL is more than 20 times faster than 2Mb satellite and fixed wireless connections, 60 times faster than uncompressed ISDN services, and 250 times faster than 33.6 Kbps analog modems.

DSL vs. Public Service Telephone Network (PSTN)

Analog PSTN services have dial up speeds are 56 Kbps and lower. The Plain Old Telephone Service (POTS) is flexible, and distance to the CO is not an issue, but technology such as digital padding applied to the line can dampen data rates. Tariffs may be levied on usage, and distance charges for multiple carriers may exist, or service may be provided as a fixed fee. Analog service is widely available, used for both voice and data transmission, which makes it a highly used service by travelers.

DSL vs. T1/E1

Primarily cost is the factor when providing DSL, as existing 2-wire copper plant can be used to provide the physical connection. T1 data services are available from competitive exchange carriers and incumbent Telco wishing to extend service beyond existing switch capacity by using HDSL-2 circuits. DSL provides bandwidth up 8Mb in the best circumstances, more than 4 times the speed of a T1 with 1.55Mb port speed.

T1/E1 circuits can be provisioned to accommodate traditional toll quality voice, and point-to-point or frame relay services, as well as switched POTS for remote access services simultaneously.

DSL vs. Cable Modem

Cable modem technology delivers shared bandwidth within the local neighborhood over a coax medium for analog radio frequency transmission. Cable modems use a 64/256 QAM RF receiver for delivery on one 6-MHz cable channel with total bandwidth up to 40Mbps for video, music and data, with data rates regulated at the CPE by the modem. Hybrid fiber/coax systems are required for full duplex communication of voice.

DSL delivers dedicated local bandwidth, and can split off voice into separate frequency transmission, or incorporate voice into a separate data stream such as VoIP and VoATM using the same copper as the dedicated ATM/IP data streams.

DSL vs. Fixed Wireless

Similar to cable modem technology, fixed wireless delivers shared bandwidth within the local neighborhood over an analog radio frequency transmission path. The 802.11 networks designed for the enterprise are configured in campus environments, whereas LMDS and MMDS circuits are designed with tower placement for greater range of service. Both services are limited by several factors with the most apparent being limited distance, requirement to be in "line of sight" for service, frequency re-use, and the environmental impacts such as weather.

Differentiate between encapsulation protocols related to xDSL.

Differentiate among various encapsulation protocols as they relate to xDSL (ATM vs. Frame vs. PPP; PPPoA vs. PPPoE; non-PPP/Multiprotocol over ATM—RFC1483):

DSL vendors initially used Frame Relay to provide a simple, well-known encapsulation for DSL traffic. In point-to-point configurations, one of the DSL routers was configured as a COE unit, maintaining a single default DLCI and Link Management Information (LMI) to monitor the line. ATM has a greater installation base due to the greater scalability and standardized QoS implementation within the DSLAM.

Campus environments often use PPP between DSL routers, or as a remote access server to modem for ease of configuration and management of an ISDL configuration. PPP is also used over the ATM (PPPoA) or Ethernet (PPPoE) standard for client to termination device communications.

PPPoE enables access and accounting (AAA) services without changes to the existing Remote Access services provided by Internet Service Providers (ISPs) and Network Service Providers (NSPs). PPPoE requires application software to reside on the workstation, or a small router may perform the PPPoE termination in a SOHO environment. DSL circuits provisioned for use with PPPoE are in a bridged configuration, and the DSLAM functions as a layer 2 switch.

PPPoA is similar to PPPoE with the difference that implementation is at the edge of the ATM cloud between the DSLAM and the workstation hosting an ATM adapter. It allows separate Switched Virtual Circuits (SVCs) for each PPP session for a broadband service-on-demand configuration.

Multiprotocol over ATM (MPoA) was designed to allow routing of various protocols and virtual LANs over the ATM switching fabric. MPoA adds QoS to LAN protocols such as IP and IPX, and Virtual LAN functionality as well as direct path connectivity between devices lacking in LAN Emulation (LANE) ATM networks. MPoA enables inexpensive

switched access for multiple LANs residing at the edge of the ATM network, but does not support the AAA features of PPPoE and PPPoA.

Describe DSL and industry services.

Describe the applicability and impact of these industry services as they pertain to DSL bandwidth and QoS management (H.320 (Video), Frame Relay, IP, H.323 (VoIP)):

The ITU-T H series of recommendations are focused on audiovisual and multimedia systems for streaming media. Recommendation H.320 provided videoconferencing over ISDN and other circuit-switched networks and services. H.323 incorporates the recommendation over packet-switched networks, such as corporate intranets and the public Internet. The H.323 protocol includes several components of the ITU-T G series and H series recommendations.

H.320 requires low delay and tolerates minimal loss. As a result, high throughput is required for smooth video transmission direction, lower transmission rates result in a staggered, or jerky video display. The DSLAM implements QoS methods to accommodate these requirements.

As the number of H.323 VoIP sessions increase, the portion of the DSL bandwidth required for toll-free quality increases. A movement within the IETF has been to simplify VoIP transmission by replacing the complex H.323 suite with Session Initialization Protocol (SIP) for peer-to-peer sessions. The SIP protocol defines a variety of server types, including redirect, registration and feature servers, integrating with existing voice/data standards for a smooth transition.

Frame Relay encapsulation is a simple, early implementation for layer 2 on DSL modems and DSLAMs. QoS is not implemented in Frame Relay, as the protocol relies on the Forward Explicit Congestion Notification (FECN) and Backward Explicit Congestion Notification (BECN) for routers on the network to slow the rate of data submitted to the network when there is insufficient bandwidth available. Failure of the routers to adjust accordingly results in packet loss, and higher retransmission rates.

IP data streams may use DIFFSERV or RSVP, with advance reservation of bandwidth on the network. This structure is highly inefficient for backbone networks; therefore, QoS in IP tends to be best effort.

Define the ATM Abstraction Layers (AAL) and specify their applicability to xDSL networks:

AAL1

Supports connection-oriented services that require constant bit rates and have specific timing and delay requirements. An example is interactive audio in the DSL network.

AAL2

This adaptation is a method for carrying voice over ATM. It consists of variable size packets with a maximum of 64 bytes encapsulated within the ATM payload. This was previously known as Composite ATM or AAL-CU. The ITU specification is ITU-T I.363.2 and is referred to as compressed voice, however, silence suppression, demodulated fax and bandwidth-on-demand are additional functions applied in the DSL network.

AAL3/4

This AAL is intended for both connectionless and connection oriented variable bit rate services. Originally two distinct adaptation layers AAL3 and 4 have been merged into a single AAL which is AAL3/4 for historical reasons. It has the highest overhead and is therefore not used in DSL networks.

AAL5

This AAL is also referred to as Simple Efficient Adaptation Layer (SEAL) as it supports connection oriented variable bit rate data services, including MPoA and PPPoA. It is a substantially lean AAL compared with AAL3/4 at the expense of error recovery and built-in retransmission. This tradeoff provides a smaller bandwidth overhead, simpler processing requirements, and reduced implementation complexity.

Describe the ATM signaling standards (PVC, SVC, SPVC, UNI, VP/VC switching, PNNI) as they pertain to xDSL networks:

Permanent Virtual Circuits (PVC) are used to create a persistent path between the CPE where data is encapsulated into ATM to the termination point where data is extracted.

Switched Virtual Circuits (SVC) are set up and torn down on demand using signaling initiated by the CPE. When resources for the circuit are released at the end of the call, they are available for other circuit's use, reserving bandwidth and IP addresses. Similar to PVCs, the SVC is often provided between the CPE where data is encapsulated in ATM cells to the termination point where data is extracted.

Soft PVCs (SPVC) are created by the switches at the edge of a network on behalf of the CPE. The SPVC is usually persistent, and will rebuild on failure in the circuit path, so the circuit performs as a PVC from the perspective of the CPE and a SVC from the perspective of the network.

User Network Interface (UNI) functions as the connection interface between a CPE and the DSLAM, as well as the DSLAM and the bearer network when PNNI is not used. UNI provides status and management information to the user device.

Virtual Circuit (VC) switching is a point-to-point virtual connection for individual data streams. End points are identified by both the Virtual Path Identifier (VPI) and Virtual Channel Identifier (VCI) pair when VCIs within the same virtual path terminate on different ports.

Virtual Path (VP) switching is a point-to-point virtual connection for data streams having the same VPI and but the virtual channels terminate at the same points. VP switching can improve switching speed, depending on the design of the switch as only the first part of the address is read when making routing decisions.

VP switching simplifies configuration as a single Virtual Path Connection (VPC) can provide switching for up to 65,535 Virtual Channel Connections (VCC) on the same VCI. This configuration is typically used trunk-to-trunk between subtending DSLAMs and from the DSLAM trunk across the bearer network to the VC termination equipment.

Private Network to Network Interface (PNNI) provides dynamic routing for SVCs and SPVCs. PNNI or Interim Inter-Switch Signaling Protocol (IISP) is required for standardized routing of ATM SVCs and SPVCs.

Additional Considerations:

1. Define the following: AFI, AREA, EFI, DCC, DSP, ESI, ICD, LANE and RD
2. How is QoS applied to ATM networks?
3. How does ATM address ARP requests? What are primary layer 2 technologies used with DSL?
4. Who are the primary manufacturers of DSL gear, both DSLAM and CPE?
5. When is an IAD used instead of a splitter?
6. What are bridge tap and loading coils used for? Why is DSL service not provided with lines that contain these items?

Additional Resources:

"Digital Subscirber Line Access Multiplexer (DSLAM)" DSL World Forum sponsor; International Engineering Consortium http://www.iec.org/online/tutorials/dslam/ (7 Nov 2001)

Finneran, Michael. "G.SHDSL – Going Both Ways". Business Communications Review. July, 2001 pp24-26

Ploskina, Brian. "Global DSL Standard Improves Business Services". Interactive Week, February 13, 2001. http://www.zdnet.com/zdnn/stories/news/0,4586,2685087,00.html. (13 Nov 2001)

"Providing Local Broadband Services - a Review of Five Last-Mile Technologies". Lucent Technologies. Whitepaper. 2000.

"SS7 Tutorial" Performance Technologies Inc. 22 Aug. 2001 http://www.pt.com/tutorials/ss7_tutorial_05_07_01.pdf (19 Oct. 2001)

Section

2

Qualify the Environment

Qualify a local loop for an xDSL connection.

Identify the steps to qualify a local loop for an xDSL connection (test the lines, CLT and LoopCare, meets physical criteria):

Provisioning a DSL circuit relies on verifying the copper pair(s) are able to meet quality standards and are free of impeding devices. Verifying the local loop is very similar to testing a circuit prior to ISDN provisioning.

Metallic loop test equipment reports on various data, including the electrical signaling (AC and DC), loop length, loop resistance, insertion loss, signal to noise, and wideband noise. Time-domain reflectometry (TDR) tests locate bridgetaps, load coils, water-saturated cable sections, short circuits, and cable faults while tone and signaling tests measure send and receive tones and detect signals and voice.

A single-ended test uses an external test head or integrated CO equipment, such as a copper loop test module from the COE. These tests provide over 90% accuracy and provide the majority of required prequalifications. Double-ended tests require testing equipment at both ends of the loop, so a technician must arrange to be onsite and test the local loop to equipment at the CO or DLC.

Due to time and expense of equipment, copper loop testing may be performed on request by customer for service provisioning, through batch pre-qualification processing, or on a regular maintenance schedule.

In the US market, regulations require access to the copper plant owned by ILEC companies to competitive carriers. The ILEC will provide a batch pre-conditioning test to certify all copper circuits to be leased out. The competitive carrier usually will verify the results prior to determining the strategic DSL options that will be made available to customers of a geographical area, and estimated service rates can be identified.

It is important to note that testing may be accomplished from the CO if a DLC is present on the circuit only after DLC equipment is configured to accommodate DSL & testing pass-through.

Identify appropriate applications for splitters and filters when qualifying a local loop for an xDSL connection:

Traditionally, splitters and filters must be removed for qualification testing. Splitters are installed to provide analog voice service after testing for full rate ADSL service and filters are installed after testing for G.Lite voice applications. Synchronous DSL technologies use alternate methods, such as VoIP or VoDSL to provide voice services.

In a line-sharing environment, the incumbent carrier places a splitter at the CO to control the copper loop to the switch, and test access must be available on each interface or traditional DSL loop testing will be affected. Testing apparatus that use narrowband test frequencies already used by carrier systems are not affected by the CO splitter.

Qualify the trunks.

Explain when and how to test the trunk in an xDSL installation:

Trunk circuits are used in several configurations, primarily between the DSLAM and the voice gateway, and between the DSLAM and the IP network. Testing of the trunk circuits normally occurs as part of the DSLAM installation process, adding additional circuits, and as problems are reported on the network.

Testing includes the Telco standard TDM testing, review of hardware port statistics and status messages, ATM Operations and Management (OAM) tests or Frame Relay LMI statuses and messages, as well as circuit continuity testing.

Verify Central Office (CO) requirements.

Given sample Central Office (CO) requirements, describe the procedure to verify the power source, ventilation, MDF, cabling, and NEBS compliance:

The Network Equipment Building System (NEBS) was developed by Bell Labs in the 1970s to assist manufacturers in reducing product development, installation and maintenance costs by providing telecommunications environment standards. The NEBS has migrated to a system of several levels, allowing manufacturers and telecom providers increased requirements flexibility.

NEBS compliance documents include the GR-63-Core for physical requirements and the GR-1089-Core for electrical safety and electromagnetic compatibility, with three levels of criteria compliance defined in the SR-3850 special report. The intent of the standards is to address several concerns:

1. Ensure safety of personnel
2. Reduce complexities in CO design & installation
3. Prevent interference and maintain signaling integrity
4. Minimize risk of fires to facilities and equipment
5. Provide earthquake survivability
6. Ensure compatibility in equipment electrical requirements
7. Ensure environmental standards including air quality, humidity, temperature, and vibration to maintain maximum uptime of equipment

Manufacturer NEBS compliance certification is provided by a National Recognized Testing Laboratories approved by the US Occupational Health and Safety Administration, and include the Underwriters Laboratory and Intertek Testing Services. Incumbent telecommunication providers in the US are required to provide a documented level of compliance for communication facilities in collocation structures.

The ILEC and/or NSP may require a NEBS compliance and equipment checklist for facilities and equipment to be completed during DSLAM installation and implementation. Specifications may include (among others) grounding, equipment footprint, load and heat release, acoustic noise, emissions, and fire resistance.

List the Central Office resources needed to support an xDSL installation (adequate power source, ventilation, MDF, cabling, NEBS compliance):

Several fundamental elements must be in place prior to DSLAM or RT installation in the DSL service installation. Facilities must ensure there is adequate lighting, power and space, including access equipment for installation and maintenance procedures. Integrated card slots are frequently accessed during troubleshooting procedures, which require adequate access for card removal and insertion while equipment chassis is installed.

In addition to temperature regulation, there must be adequate airflow and ventilation without risk of air contamination; such as installing an air intake in such a way that equipment airflow is not provided from another unit's exhaust.

Cabling providing connectivity from the copper plant to the DSLAM should meet non-interfering levels of disturbers in the same binder group.

Additional Considerations:

1. Are NEBS compliance requirements used internationally?
2. What are a few examples of equipment used for metallic testing?

Additional Resources:

"Copper Loop Management in a Digital Environment: Migration from an Analog to a Digital Local-Loop Network". Turnstone, sponsor; International Engineering Consortium http://www.iec.org/online/tutorials/copper/ (7 Nov 2001)

"Digital Subscirber Line (DSL) Testing". Cornet Technology sponsor; International Engineering Consortium. http://www.iec.org/online/tutorials/dsl_test/ (7 Nov 2001)

"Managing the Copper Loop in the 21st Century". Simpler Networks sponsor; International Engineering Consortium. http://www.iec.org/online/tutorials/man_copper/ (7 Nov 2001)

"Shared Loops: How Incumbent Local Exchange Carriers (ILECs) and Competitive Local Exchange Carriers (CLECs) Can Deliver Competitive Digital Subscriber Line Access Multiplexer (DSLAM) Appications". Nortel Networks sponsor; International Engineering Consortium. http://www.iec.org/online/tutorials/lec_dslam/ (7 Nov 2001)

Section

3

Design the Network

Analyze customer needs.

Explain the bandwidth management issues that must be considered when designing an xDSL network (real time services, over-subscription issues, IP networks):

In the design of a DSL network, the analysis of customer needs and quality expectations for high-bandwidth services including video and voice must be clearly stated. The typical DSL network is over-subscribed on the trunk side of the DSLAM to meet business profitability ratios. High-speed and high-bandwidth customers are aggregated to a comparatively small trunk, such as a DS3 or OC3c.

If the DSL provider is providing primarily residential services, end-user requirements are traditionally email, gaming and web services which require a high downstream and lower upstream rate. ADSL and G.Lite are best suited to this environment allowing for over-subscription via downstream traffic throttled back to 1.544Mbps or less, DHCP and SVC services. Allocation of bandwidth on the back-end is managed, along with authentication, IP address assignment, IP termination and billing services.

Providers of business DSL services have significantly different requirements and higher management standards, especially when quality of service and uptime guarantees are provided to enterprise customers. Enterprise customers are more likely to use synchronous data services, integrated voice and data equipment (VoDSL and VoIP), webcast, and video-on-demand services. The IP services industry is expanding rapidly to include virtual routing, Virtual Private Network (VPN), IP termination and data collocation for DSL and other private-to-public networks.

Compare and contrast the design implication differences in a public (for consumer market) versus a private (hospitality, multi-tenant units/multi-dwelling units, campus) xDSL network environment:

Traditional Internet access service has been provided through competitive bids for service and rates directly to consumers on the open market. Dialup services to bulletin boards and email has transitioned into a higher demand for broadband access due to the delivery of webcast, interactive web pages, gaming, music and streaming video.

The evolution of DSL has moved from a point-to-point service across a campus to widespread access of voice, data and video over the copper pair, creating new business opportunities for building owners of multi-tenant and multi-dwelling units.

Multiple tenant unit (MTU) DSL environments include:

1. Enterprise business campus
2. Multi-tenant business building
3. Educational campus deployment
4. Integrated services in hotel environment
5. Multi-dwelling apartment and condominiums

Design considerations between a DSL provider with the DSLAM at the CO and having a remote terminal installed in a MTU are fundamentally identical. The largest differences are in the selection of the DSLAM, connectivity to the CO MDF, and location of termination equipment for PPPoE and PPPoA services.

Describe the advantages and disadvantages of utilizing NAT, local pool, RADIUS, etc. in a DSL environment to meet a customer's/network IP needs:

There are several options in designing distributed DSL services, including the following general configurations:

1. Connect-on-demand and always-on broadband services for DSL modems as a bridge with DHCP allocation of a single IP address to a PPPoA or PPPoE client. Functionality is designed for single user services and a small DSL router is normally able to provide NAT and PPPoE/PPPoA connectivity
2. Connect-on-demand and always-on services for DSL modems and small router with a fixed IP address assignment - SOHO and remote office networks are able to use NAT for shared Internet access, and incoming access such as web, FTP, server access and remote-control applications.
3. Always-on fixed IP allocation of subnets for enterprise users, with smaller subnets or single IP address assignment for remote offices. Configuration similar to traditional leased-line Internet services.

Although more difficult to configure initially, using RADIUS provides the ability to apply default configuration parameters, as well as use AAA functionality for the ISP/NSP account management, authentication, IP address assignment, VPN data, and additional user-specific data for enhanced features.

NAT is used at the CPE end of the virtual circuit, providing Internet access to small networks without committing a registered subnet of IP addresses. Not all applications work effectively through NAT due to IP packet header changes or inbound dynamic port requests, and perceived performance problems with the circuit may result.

Describe how permanent virtual circuit (PVC) and IP address scalability considerations impact network numbering in a DSL environment:

Scalability is important in management of resources, as the ability to allocate bandwidth and services during peak periods is crucial to maintain quality of service and availability levels. Network ATM PVC requirements and IP address allocation is best considered as part of the scalability assessment in network equipment design. Re-allocation of IP

addresses after-the fact may substantially impact business customers, and a poorly designed PVC structure increases long-term management costs.

Describe how scalability will affect hardware requirements in an xDSL network:

The ILEC CO and cable plants are sized to support the customers they serve in a geographic area, and original estimates are based on business density, existing infrastructure and expected economic growth of the region. Scalability is required at each termination point in large networks and highly condensed business DSL deployments, which is a critical component when considering redundancy, quality of service and service level agreements (SLAs) to enterprise customers.

Network access focusing on the smaller accounts and SOHO market increases the number of termination points at the DSLAM, but reduces backbone connectivity needs. The bearer network will need to support increasing traffic from the DSLAM to VC termination devices as traffic exceeds desired over-subscription levels.

Compare and contrast IP services in an xDSL environment vs. dial-up connectivity (i.e. static vs. dynamic addressing, bridge-in-routing):

Refer to configuration options in earlier discussion of distributed DSL options.

Coordinate with network/Telco providers.

Identify the methods for providing DSL to customers regardless of local loop limitations (deploying remote/hardened DSLAM solution and/or Digital Loop Cabinet):

A limitation of DSL service due to distance has been a major drawback in broadband deployment. Three options exist for Network Access Providers with customers outside the service distance of ADSL and SDSL services:

- Deploy a remote hardened DSLAM in a remote terminal case on the far side of the DLC if present, allowing DSL between the CPE and remote DSLAM and use TDM services back to the bearer network interface.
- Investigate existing remote terminals in the Telco network, and determine if interface cards to extend DSL services are available as an upgrade to existing DLC equipment.
- Deploy IDSL services at 128Kbps or 144Kbps for synchronous connectivity to customers at the edge of ADSL/SLDSL service area.

Analyze network objectives.

Explain the usage of IP termination services in an xDSL network design:

The DSL data link is either Frame Relay or ATM and both services provide access to the network with transport layer as IP. The DSLAM is a layer two device, using the ATM switching fabric to direct traffic accordingly. IP termination services are required by the access provider for IP traffic to participate in higher level Internet and private data networks.

The IP termination device can be collocated with the DLSAM as a remote access device, an ISP POP where local Web servers, mail servers, and file servers, in corporate or in a campus data center where connections to the corporate Intranet, Extranet(s), and the Internet.

The termination device traditionally resides behind the DSLAM on a large ATM PVC for traffic incoming from the distributed network, and connects to the external service by an outbound Ethernet or ATM connection. Integrated DSLAM modules and smaller termination devices are available for smaller localized deployments.

The termination device may perform IP termination and redirection of packets between remote networks; however, larger data streams for extended networks may be served through direct PVC configurations on the DSLAM. When central IP termination is used between PVCs on a larger network, the IP service switch is able to provide application bandwidth management through IP and ATM QoS mechanisms, as well as Multi-Protocol Label Switching (MPLS). Use of MPLS at the core of the network provides three primary services, according to the MPLS forum*:

- Traffic Engineering
- Providing traffic with different qualitative Classes of Service (CoS)
- Providing traffic with different quantitative Quality of Service (QoS)
- Providing IP based Virtual Private Networks (VPN's)

Describe VPN and security considerations in the design of an xDSL network:

DSL services provide the opportunity for many customers to remain online at all times, which increases the vulnerability of the client PC or network. Remote offices connected through a network access provider's DSLAM have PVCs, but do not enjoy the privacy of a true point-to-point leased circuit. Competing VPN technologies provide different levels of security, and selecting the appropriate methodology is dependent on the primary function desired:

Layer Two Tunneling Protocol (L2TP) and Point-to-Point Tunneling Protocol (PPTP) from the IP service switch provides opportunities for port wholesaling of primary to secondary edge access vendors, as well as encapsulation of non-IP protocols for transport across public networks.

MPLS provides traffic shaping and virtual routing of private networks across the core IP/ATM network with quality of service guarantees.

IPSec provides encapsulation with encryption for enhanced security between networks, as well as from client to corporate enterprise.

VPN access to two separate VPNs using the same DSL Internet access.

When multiple users have access to the network with fundamental differences in access needs, security of information becomes even more of a concern. Consider, for example, an Internet café, kiosk, airport or business extended resource center; the business provides access to the Internet, often with a clientele that requires secure access to corporate resources. Another example is a SOHO DSL network, with clients that access two or more unique firms, where exchange of data could be considered a serious breach of security.

The primary concerns include to ability to keep VPNs secure to each client, and protecting the network as a whole. The use of firewall technologies and network address translation at the point of entry to the network, and UDP encapsulation for IPSec pass-through, as well as SOHO routers as tunnel termination point have been major improvements in deployment of broadband access.

Another major improvement to shared DSL access is through the use of IP service switching. A network access provider with port-wholesaling agreements can provide service to public or private access points within a large geographic regions with rapid authentication and authorization and accounting at the IP termination point. This enables a single point of entry for multiple IP services, security, quality of service and virtual routing to meet enterprise remote access requirements, all transparent to the individual clients.

Create network design plan and identify devices.

Explain the impact of ATM switching in an xDSL network design:

ATM can provide QoS assurances on the network for transmission of traffic, and as a result is the technology of choice for the typical bearer network for the DSL VCs. The use of ATM QoS provides managed use of bandwidth, limitations on performance degradation due to cell loss, decreased latency and decreased delay variation. All of these factors are essential in high-bandwidth resource applications such as video and packetized voice services.

Identify DSL applications that require multiple PVCs (simultaneous Intranet and Internet access, and advanced services*). *For future planning and scalability only:

DSL deployments to residential areas will typically use a single PVC to the CPE unit from the DSLAM, however, business applications may use multiple PVCs to a site to accommodate additional services. The DSL provider may select to configure additional PVCs to a site in an effort to accommodate the following:

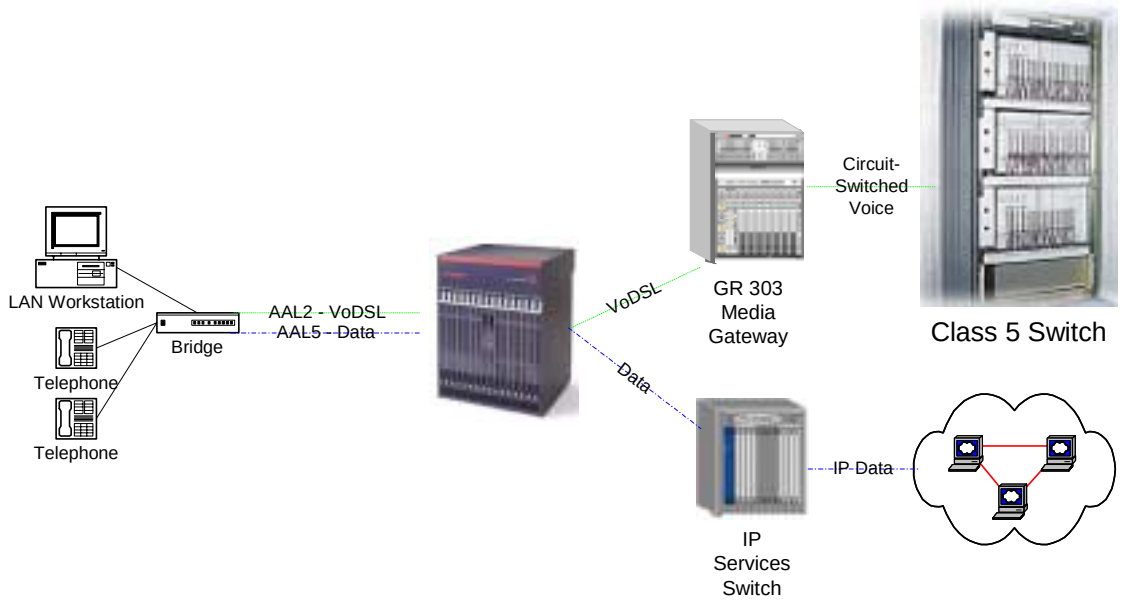
- Segmenting Internet traffic
- Providing point-to-point intranet and extranet traffic
- Voice over DSL between IAD and DSLAM/GR303 Gateway
- QoS management through different levels identified to unique PVCs

Given a network design plan, create a product independent layout scheme using generic DSL products and terminology (DSLAM, CPE, etc.):

The challenge for Telco providers considering DSL as an added service to customers is providing service at reasonable prices to businesses, low-use home consumers, and high-use SOHO users, while maintaining service quality guarantees. Integrated voice and data packages are one way to recover costs by implementing multi-service gateways for voice while maintaining the existing Telco infrastructure.

The provider may recommend DSL to ATM backbone access when very high speed is required with Quality of Service assurances, such as medical imaging and teleconferencing facilities. The options for large file transfer also include MPLS for IP network traffic on a provider's data network infrastructure.

Designing a network requires a full understanding of the area that will be served, the condition of the copper plant, and location of any existing RTs. A logical map of DSL with VoDSL services deployment is provided:



Additional Considerations:

1. Where on the network should firewalls be deployed?
2. What are virtual routers, and why are they important in DSL deployments?
3. What is the performance impact of applying NAT services to the IP service switch, and why?

Additional Resources:

Coffield, David "Once and Future DSL". Interactive Week. October 1, 2001. http://www.interactiveweek.com/article/0,3658,s%253D603%2526a%253D15500,00.asp (12 Nov 2001)

"Delivering Service Intelligent™ End-to-End IP Services Solutions". Lucent Technologies. http://www.lucent.com/livelink/174081_Whitepaper.pdf (10 Nov 2001)

Dooley, Michael. "Next Generation Broadband Access Architectures". Lucent Technologies. http://www.lucent.com/livelink/161910_Whitepaper.pdf (12 Nov 2001)

Hold, David. "The ATM & IP Report Guide: IP Service Switches". Broadband World. http://www.broadbandpub.com/broadbandworld/v3n2/survey2.pdf. (10 Nov 2001)

The MPLS Forum: http://www.mplsforum.org/ (10 Nov 2001)

"Quality of Service and Network Solutions". Microsoft. http://www.microsoft.com/hwdev/network/dsl/qos-dsl.htm (12 Nov 2001)

Section

4

Implement Network Design

Install hardware and software.

Explain the functions and applications of companion software in an xDSL network (NMS, AAA, PPPoE, VPN client, etc.):

There are several key applications required to fully deploy and manage a xDSL network to customers. Required software may include the following:

PPPoA and PPPoE client software provides the communication between an individual workstation and the network termination endpoint through PPP negotiation. Using the PPP client software enables AAA functionality within the network for auditing, billing and security purposes.

MPoA client software also provides encapsulation with termination of the virtual tunnel on an MPoA server. Encapsulation may also take place between routing devices, similar to IPSec, L2TP and PPTP VPNs. VPN software may reside on the CPE or as client software application to perform tunneling or encryption of data, or both.

The Network Management System (NMS) is the software tool used to monitor and report on the InterNetworking environment, to be used with defined procedures, systems, and operations maintenance required to maintain network efficiency. In an xDSL deployment, the NMS may manage the CPE, RT, DSLAM, bearer network, voice gateway, IP termination and/or the VC termination equipment.

Coordinate with network/Telco providers.

Explain the network/Telco provider services required to implement an xDSL network (POTS, ISDN, ATM backbone):

To fully implement the DSL solution, there are several elements of the Telco provider services used, the most obvious of which is the copper plant and access to the RT or CO. Collocation agreements are required for VoDSL and lifeline POTS in residential areas. POTS serving baseband access to the Telco network during a power failure is required in many regions. ISDL requires access to ISDL compatible circuits in areas on the edge of service, and for circuits bearing repeaters along the data path. Existing ATM facilities are used as the bearer network for traffic to the VC termination point.

Explain how to integrate an xDSL network into the existing network/Telco provider's services (POTS, ISDN, ATM backbone):

The first step for the DSL service provider to integrate the network design is to obtain necessary packet-switched and circuit-switched access to the Telco infrastructure. QoS guarantees are highly dependent on the available egress to the public network. The provider should be aware of any planned integration (if any) of the backhaul facilities and backbone infrastructure to accommodate intelligent networking of voice and data services.

Additional steps must be taken to verify the copper plant between the CO and the desired service area. This includes identifying distance limitations and any existing RTs to the functional network map. Pre-qualification testing should be employed on several existing copper pairs to determine viability of the circuits and broadband capacity prior to implementing the installation of the DSLAM with service cards.

The DSLAM installation includes the mounting on the physical rack or cabinet, connection to the MDF and power installation. Initial configuration begins with IP address and PVC or Ethernet interface to facilitate communication with the authentication, IP termination and network management systems. Further assembly may be performed on a circuit-by-circuit basis, or through scripting to automate several functions to manage standardization. Integration of the DSL equipment with the Telco network is complete when management of data traffic is successful, and data services are verified, as well as analog telephone service on ADSL, FRoDSL, VoDSL and video services are tested and working properly.

Additional Considerations:

1. What client PPPoA and PPPoE applications are currently available?
2. What are key elements of a Service Level Agreement (SLA)?

Additional Resources:

Borland, John. "Broadband Defectors on the Rise". CNET News.com, November 7, 2001. http://news.cnet.com/news/0-1004-200-7789746.html (12 Nov 2001)

"Voice-over–Digital Subscriber Line (VoDSL) Service—New Revenue from Existing Infrastructure". DSL Forum sponsor; International Engineering Consortium. http://www.iec.org/online/tutorials/vodsl_revenue/ (12 Nov 2001)

Section

5

Test Network Design and Implementation

Validate end-to-end connectivity.

Describe the steps required to check bandwidth and QoS in an xDSL network:

When enterprise requirements and SLAs are negotiated, the network access must understand limitations to providing the QoS standards. Base levels for traffic norms and strategies to manage available bandwidth and data paths are put in place accordingly. Steps to ensure QoS include the following:

1. Statistical sampling of current workstation performance and/or access
2. Document application specific requirements for monitoring (connect delay vs. elapsed time)
3. Determine procedural method for end-to-end testing of IP performance
4. Establish base levels for point measurement (specific device throughput and statistics)
5. Establish normal levels for circuit uptime and utilization statistics (via SNMP to the NMS)
6. Configure desired reports from NMS and Bandwidth management software

Determine need for load testing.

Given an xDSL network design, select an appropriate load/stress testing strategy:

In generating an appropriate load/stress test strategy, the first step is to define the scope and purpose of the testing. There are several elements to be considered, including the following:

1. Design performance of the collocation equipment with desired number of PVC/SVC for expected number of CPE units, with capacity for growth
2. Equipment performance of enhanced services, such as multi-casting, video, intranet access, Internet access, extranet access, VoDSL, VoIP, and lifeline baseband voice services
3. Quality of service testing to ensure backup and failover mechanisms

4. Available tools, including packet generation devices, TCL scripts, and statistical analysis of reports provided by software
5. Application specific requirements, to ensure testing is aligned with customer expectations for user environment

As an example: A Telco that has added xDSL services as a network access provider to residential customers has a greater understanding of backbone capacity available to data services. Testing in this situation will focus primarily on ensuring copper line preconditioning, equipment availability, DNS and DHCP services, and downstream data rates. A stable, predictable network enables sending standardized equipment to the customer for self-installation. Self-installation packages avoid technician truck-rolls to the customer site, and cuts deployment expense, as well as management cost and provisioning delays.

Additional Considerations:

1. What are the primary differences between QoS and ToS?
2. Why is RSVP favored at the edge of the network instead of the core?

Additional Resources:

"Asynchronous Transfer Mode (ATM) Testing". OSS Global Summit sponsor; International Engineering Consortium. http://www.iec.org/online/tutorials/atm_test/ (12 Nov 2001)

Pappalardo, Denise. "ISPs fail to fully follow through on QoS". Network World, 09/03/01. http://www.nwfusion.com/news/2001/0903carrier.html (12 Nov 2001)

Section

6

Maintain and Troubleshoot the Network

Detect and troubleshoot problem situations.

Given a CPE to DSLAM connectivity problem, analyze the situation, determine the probable cause, and recommend a solution:

Troubleshooting an xDSL network should start in the same manner as an enterprise LAN/WAN network installation; start with the physical issues and work up the OSI model to the applications involved.

As an example, after the installation of a customer's DSL service, the network management software reports there is no signal occurring at the DSLAM. The first step is to run tests on the copper loop, looking for problems such as bridge taps that make the loop too long, a break/short/open in the loop or load coils.

Network access providers with reports of ADSL, VoIP and VoDSL service failure must verify primary physical components and data is passing properly before addressing issues requiring additional components, such as the splitter, microfilter or gateway.

If there is physical signaling, and a db rating is within service norms but there is no data connectivity, it is most likely misconfiguration on the modem, DSLAM or termination equipment. Standardizing client parameters reduce the number of DSLAM and VC configuration errors, as the service technician is able to compare client profiles.

The next logical step in troubleshooting, once the physical element is eliminated as the cause of the problem, is checking the data link layer. The encapsulation and authentication parameters must match at both ends of the physical link, and traffic must be directed properly between DSLAM interfaces. For example, a quick check on the DSLAM can be made to determine if ATM cells are being sent and received on the PVC.

PPPoE and PPPoA client applications assist in troubleshooting, as the software may report errors such as "Unable to Connect" in the event of physical or data link issues, and "Invalid Password" in the event of authentication failure.

Given a DSLAM to backbone connectivity problem, analyze the situation, determine the probable cause, and recommend a solution:

During the installation of the network equipment, or during periods of service failure, the communication between the DSLAM and the service network backbone must be verified. Similar to the DSLAM to CPE connectivity tests, verification of the backbone starts with the physical layer. Elements to check include:

- Is a signal present on the interface? There could be a problem with the DSLAM interface port, a problem with the cable or fiber to the ATM or Frame Relay bearer network, or as simple as the port might not be enabled in the configuration.
- Is a loss of frame the indicated problem? If so, it could be due to incorrect framing configuration, an incorrect "ones density" rule, or a synchronization problem.
- Is there an Alarm Indication Signal (AIS)? Normally the receiver on the far side of the link is not connected or not working to trigger this alarm.

Data link troubleshooting varies between Frame Relay and ATM topologies. Frame Relay must determine if Link Management Information (LMI) is configured properly, and if the Data Link Control Identifiers (DLCIs) must match from either side of a UNI or NNI interface.

ATM configuration checks for the virtual path include checking the VPI/VCI pairs on each device on either side of a UNI or NNI interface to verify a match. Other troubleshooting checks for ATM include:

- Are QoS contracts being exceeded?
- Do OAM loopbacks confirm continuity?
- Are any OAM alarms indicating a problem?
- Is path selection through Connection Admission Control (CAC) preventing call set up?

When all performance checks are verified and traffic is passing properly, access to resources on the Internet, intranet, or extranet services backbone will not perform without proper configuration of the network layer properties. IP termination equipment and virtual routers can create extended LANs that require significant manual intervention to function properly. Fundamental questions to address at both sides of the link between the DLSAM and the backbone include:

- Does a local IP termination device resolve the issue?
- Are subnet masks overlapped?
  Has the domain been supernetted properly?
- Are virtual routers extending the network?
  If so, are IP addresses and routes configured properly?
- Are Virtual Private Networks for port wholesaling used?
  If so, is traffic being redirected properly? How can this be verified?

Synchronize operating system with NMS.

Identify the steps required to update the NMS after upgrading software on DSL hardware:

The installation of new software is generally done when performance issues are resolved by an engineering level patch from the manufacturer, or when a general release addresses known equipment issues and offers new features. The addition of a new version of software on the DSL equipment may introduce reporting variance to existing reports, and reporting features available through the release may be overlooked if the NMS hasn't been synchronized properly.

The first step in managing systems with new software is performance analysis, to detect any new issues that may cause a problem to network functionality. The second step is to determine if the NMS is able to provide vendor customization, or if the purpose is to provide standardized reports for a wide range of devices and non-standard equipment protocols.

If the new software is providing industry standard reporting already included in the NMS, the equipment data set may just need to be refreshed. Other NMS procedures may require additional network monitoring elements to be installed to take advantage of new software functions and features.

Identify the steps required to import and recompile MIBs after upgrading software on DSL hardware:

SNMP MIBs include objects defined by the IETF, which are based on ANSI and ITU-T definitions of measurable functions. The equipment covered in the scope includes the access provider equipment as well as subscriber equipment for remote management of terminals. Once software is upgraded on equipment, corresponding MIBs provided are compiled for use by the NMS, or are delivered in a pre-compiled format. Specific procedures for upgrading the NMS are dependent on the software, as strong vendor relationships or single-sourcing equipment and management applications will tend to reduce manual configuration requirements.

Additional Considerations:

1. What are common elements contained within an NMS?
2. What does it mean to "compile" the MIB?

Additional Resources:

Fleeman, Ashley and Antohy Foursha. "Winning via Management". Telephony. June 5, 2000. http://industryclick.com/magazinearticle.asp?releaseid=2813&magazinearticleid=14644&siteid=3&magazineid=7. (13 Nov 2001)

Schmidt, Kevin. "SNMP Agent Enables Real Time Management". Supplement in America's Network. October 2000 pp18s –20s.

Section

7

Monitor the Network Performance

Monitor the network using a generic NMS.

Given a generic NMS, identify the reports appropriate to monitor an xDSL network:

Network management systems are part of an overall plan to provide continuous service coverage, giving a provider adequate notice to potential and current failure within the network infrastructure. Reports provided through the NMS or Operational systems provide management tools including:

1. Bandwidth utilization report for successful traffic shaping and bandwidth bursting
2. Reporting consistent overage of service level agreements for enforcement
3. Reporting effect of cost control and data rate shaping mechanisms for smoothing bursty traffic patterns
4. Network prioritization, enabling ToS and subnet-specific hierarchical model
5. Fault avoidance reporting to determine need for accelerated maintenance schedules and failover testing (intermittent issues)
6. Real time failure notifications on managed equipment and associated circuits

Additional Considerations:

a) What fundamental functions are critical in selecting an NMS?

Additional Resources:

"The Path from Chaos to Control". Telephony Online. InFocus, Oct 31 2001 http://industryclick.com/newsarticle.asp?Newsarticleid=247961&SiteID=3&magazineid=7&mode=print (13 Nov 2001)

Sridhar, Manickam. "Optimizing Network Performance Without Additional Bandwidth". Computer Technolgoy Review. August 2001.

Appendix A

LCTE / 401 DSL Theory, Standards and Protocols Sample Exam (41 Items)

Objective: Describe the purpose, features, and functions of these DSL components: CPE, COE, CO, MDF, DLC, etc.

1. Central Offices (COs) are interconnected through an inter-CO network that consists of which two pieces of equipment? (Choose two.)
   a) Alternate Mark Inversion
   b) HDSL Termination Unit Remote
   c) T/E -carrier transmission equipment.
   d) Digital Access and cross-connect systems

Objective: Describe the purpose, features, and functions of these DSL components: CPE, COE, CO, MDF, DLC, etc.

2. What is an MDF?
   a) the DSL equipment deployed in the local access network
   b) the central point at which all local loops terminate in the Central Office (CO)
   c) the loss peak determinator that surrounds the frequency of the extension wavelength
   d) the local loop and associated equipment that connects the service user location to the Central Office (CO)

Objective: Explain how customer premise devices (modems, routers, IADs) integrate in a DSL solution.

3. How should a Network Interface Device (NID) be configured for ADSL in a regulated country?
   a) Active NID / Active ATU-R
   b) Active NID / Passive ATU-R
   c) Passive NID / Active ATU-R
   d) Passive NID / Passive ATU-R

Objective: Compare and contrast DSL modems (bridges), routers, and IADs.

4. What is a function of an xDSL modem?

   a) performing NAT

   b) filtering all incoming packets

   c) forwarding of data traffic between separate networks

   d) combining clients or network into a single larger single network

Objective: Explain the wire, modulation, and distance issues involved when using xDSL technology, including attenuation, encoding/decoding, and electromagnetic interfaces.

5. What is xDSL signal attenuation?

   a) a line coding technique used in modems for over 20 years

   b) unterminated extensions of a loop that cause additional loop loss on the copper wire line

   c) dissipation of the power of a transmitted signal as it travels over the copper wire line

   d) interference between two copper wires in the same bundle, caused by the electrical energy carried by each

Objective: Explain the wire, modulation, and distance issues involved when using xDSL technology, including attenuation, encoding/decoding, and electromagnetic interfaces.

6. How does loop length influence xDSL line rates?

   a) Loop length has no influence on the line rate.

   b) Increasing the loop length increases the line rate.

   c) Increasing the loop length decreases the line rate.

   d) Loop length and line rate can be increased without problems.

Objective: Describe the similarities and differences in data rate, mode, definition, range of frequency, and distance limitations among various DSL technologies and standards such as ADSL, HDSL, IDSL, SDSL, etc.

7. Which two xDSL methods use DMT line encoding? (Choose two.)

   a) ADSL

   b) HDSL

   c) SDSL

   d) HDSL2

   e) ADSL G.lite

Objective: Describe the similarities and differences in data rate, mode, definition, range of frequency, and distance limitations among various DSL technologies and standards such as ADSL, HDSL, IDSL, SDSL, etc.

8. Which two xDSL methods support T1 data rate? (Choose two.)

   a) ADSL

   b) HDSL

   c) IDSL

   d) HDSL2

   e) ADSL G.lite

Objective: Describe the similarities and differences in data rate, mode, definition, range of frequency, and distance limitations among various DSL technologies and standards such as ADSL, HDSL, IDSL, SDSL, etc.

9. Which three xDSL methods use 2B1Q line encoding? (Choose three.)

   a) ADSL

   b) HDSL

   c) IDSL

   d) SDSL

   e) HDSL2

   f) ADSL G.lite

Objective: Specify differences between asymmetric and symmetric xDSL standards.

10. What is the difference between ADSL and SDSL?

    a) SDSL requires a splitter; ADSL does not.

    b) SDSL includes a POTS line; ADSL does not.

    c) SDSL provides the same speeds for upload and download links; ADSL does not.

    d) SDSL is capable of a higher maximum downstream speed than ADSL.

Objective: Describe the function and applications of POTS splitters and filters.

11. Which xDSL method requires the installation of a filter next to the POTS device that shares the same line?

    a) G.lite

    b) ADSL

    c) HDSL

    d) IDSL

    e) RADSL

Objective: Compare and contrast bandwidth and data rate considerations when using DSL versus alternatives (Cable, Fixed Wireless Access, PSTN and leased line services).

12. What are two disadvantages of cable modem technology? (Choose two.)

    a) It is only used for home use.

    b) It is only used for business use.

    c) It is not available in every location.

    d) It has slow speeds for downloads.

    e) It uses a broadcast medium with one line shared by many users.

Objective: Differentiate among various encapsulation protocols as they relate to xDSL (ATM vs. Frame vs. PPP; PPPoA vs. PPPoE; non-PPP/Multi-protocol over ATM—RFC1483).

13. Which three statements about RFC 1483 are true? (Choose three.)

    a) It defines LLC encapsulation for routed protocols.

    b) It defines VC-based multiplexing of routed protocols.

    c) It defines the use of ATM AAL5 for framing PPP encapsulated packets.

    d) It describes the use of Frame Relay for framing PPP encapsulated packets.

    e) It defines two encapsulation methods for carrying network interconnect traffic over ATM AAL5.

Objective: Describe the applicability and impact of these industry services as they pertain to DSL bandwidth and QoS management: H.320 (Video), Frame Relay, IP, H.323 (VoIP).

14. Which two are benefits of using FRoDSL versus FR over a T1/E1? (Choose two.)

    a) FRoDSL is available through inexpensive COE and CPE device pair.

    b) FRoDSL uses duplex transmission with access speeds of up to 2.3 Mbps.

    c) FRoDSL uses duplex transmission with access speeds of up to 3.2 Mbps.

    d) FRoDSL provides QoS guarantees for multiple classes of service.

Objective: Define the ATM Adaptation Layers (AAL) and specify their applicability to xDSL networks.

15. Which statement is true of the ATM Adaptation Layers (AALs) with respect to xDSL networks?

    a) Customer Premise Equipment (CPE) uses AAL5 for RFC-1483 encapsulated data traffic.

    b) DSLAMs decapsulate the incoming AAL5 traffic to make their forwarding decision.

    c) DSLAMs decapsulate the incoming AAL1 traffic to make their forwarding decision.

    d) CPEs and the far-end termination devices do not use any AAL type for their applicability to xDSL.

Objective: Describe the ATM signalling standards (PVC, SVC, SPVC, UNI, VP/VC switching, PNNI) as they pertain to xDSL networks.

16. Which three methods are used to establish connections in xDSL networks? (Choose three.)

    a) BGP

    b) PVC

    c) SVC

    d) APS

    e) SPVC

Objective: Describe the ATM signalling standards (PVC, SVC, SPVC, UNI, VP/VC switching, PNNI) as they pertain to xDSL networks.

17. What is a benefit of using ATM signalling on a DSLAM?

    a) DSLAMs using PNNI can automatically reroute a connection.

    b) DSLAMs using APS can automate the provisioning of DSL circuits.

    c) DSLAMs using BGP can automate the provisioning of DSL circuits.

    d) DSLAMs using PVCs on a UNI Interface can automatically reroute a connection.

Objective: Identify the steps to qualify a local loop for an xDSL connection (test the lines, CLT and LoopCare, meets physical criteria).

18. Which two must be removed when using T1/E1 transmission equipment in an xDSL environment? (Choose two.)

    a) remote terminals

    b) load coils

    c) bridge taps

    d) copper wires

    e) cable splices

Objective: Identify appropriate applications for splitters and filters when qualifying a local loop for an xDSL connection.

19. Which statement is true about the impact of qualifying the local loop in a splitter-based xDSL environment?

    a) For loop qualification, the CO splitter must first be removed.

    b) Running a loop qualification has no impact on operational POTS service.

    c) In a splitter-based xDSL environment, loop qualification is not possible.

    d) Metallic access and DSL testing in front of the CO splitter have no impact on the POTS service.

Objective: List the Central Office resources needed to support an xDSL installation (adequate power source, ventilation, MDF, cabling, NEBS compliance).

20. You are setting up a new xDSL installation at a Central Office (CO). Which three requirements should be taken into consideration? (Choose three.)

    b) altitude of the CO

    c) adequate ventilation

    d) appropriate channel unit

    e) 12 volt AC power supply

    f) 48 volt AC power supply

    g) -12 volt DC power supply

    h) 48 volt DC power supply

Objective: List the Central Office resources needed to support an xDSL installation (adequate power source, ventilation, MDF, cabling, NEBS compliance).

21. What are Network Equipment Building Standards (NEBS)?

    a) an inclusive set of performance, quality, environmental, and safety standards pertaining to networking facilities

    b) a rigid and extensive set of electrical standards pertaining to telecom Central Office (CO) facilities

    c) a rigid and extensive set of electrical standards pertaining to networking facilities

    d) a rigid and extensive set of environmental standards pertaining to networking facilities

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Objective: Explain the bandwidth management issues that must be considered when designing an xDSL network (real time services, over-subscription issues, IP networks).

22. A new DSL provider is designing the network based on an over-subscription ratio of 1:1 for business customers and 3:1 for residential accounts. What is the impact to users if an over-subscription condition occurs?

    a) Residential users will not be able to connect to the Internet.

    b) Business accounts will not be able to connect to the Internet.

    c) All users will experience degradation in performance due to packet loss.

    d) Home users will experience degradation in performance due to packet loss.

Objective: Compare and contrast the design implication differences in a public (for consumer market) versus a private (hospitality, multi-tenant units/multi-dwelling units, campus) xDSL network environment.

23. What are two design differences in campus or multi-tenant environments as compared to a consumer DSL deployment? (Choose two.)

    a) Bridge taps are not present in campus or multi-tenant environments.

    b) LAN extensions can be provided between buildings by using COE and Customer Premise Equipment (CPE) within the campus.

    c) Campus installations do not require the use of an NMS for management as all accounts are local to the aggregation device.

    d) Customers within a multi-tenant structure can expect equivalent bandwidth because of similar distances between Customer Premise Equipment (CPE) and the DSLAM.

Objective: Describe the advantages and disadvantages of utilizing NAT, local pool, RADIUS, etc. in a DSL environment to meet a customer's/network IP needs.

24. What is an advantage to using NAT in an xDSL environment?

    a) NAT is restricted to a one-to-one IP mapping.

    b) NAT supports Internet applications that use dynamic TCP ports.

    c) NAT provides increased security because private IP addresses used on the Intranet are not routable from the Internet.

    d) NAT restricts a user from using one or more computers on a local network as a host on the Internet.

Objective: Describe how permanent virtual circuit (PVC) and IP address scalability considerations impact network numbering in a DSL environment.

25. A hotel is being built that will offer xDSL services to all guests, as well as video-conferencing in the meeting rooms. The hotel's NSP operates with an ATM platform and provides IP termination services.

    Which configuration will provide guests and operations the desired data services while ensuring room for growth?

    a) SVCs and DHCP for IP addressing

    b) PVCs and static IP addresses for each room

    c) PVCs for each room and DHCP for IP addressing

    d) SVCs and routed IP subnets for service departments

    e) PVCs with a routed subnet for operations, SVCs with DHCP for guests

Objective: Describe how scalability will affect hardware requirements in an xDSL network.

26. What are two advantages of fair subtending? (Choose two.)

    a) It allows multiple DSLAMs to be set up as redundant units for fault tolerance.

    b) It provides active monitoring of xDSL networks with network management software.

    c) It lets multiple DSLAMs that service the same trunk coordinate traffic prioritization and QoS.

    d) It can provide major cost savings for providers yet still provide QoS for business applications.

Objective: Compare and contrast IP services in an xDSL environment versus dial-up connectivity (i.e.: static vs. dynamic addressing, bridge-in-routing*)? *Lucent Technologies only

27. A hotel has a videoconferencing service available in a dedicated conference room. The hotel uses a single shared xDSL connection to the Internet for all of the rooms and the conference room facility.

    What should be implemented to protect the internal network?

    a) NAT and L2TP

    b) NAT and DMZ

    c) NAT and IPsec

    d) NAT and DNS

Objective: Identify the methods for providing DSL to customers regardless of local loop limitations (deploying remote/hardened DSLAM/DSLAS solution and/or Digital Loop Cabinet).

28. You need to extend xDSL service to an area remote to the Central Office (CO). What is the recommended solution?

    a) deploy a hardened IAD

    b) deploy a hardened CPE

    c) deploy a hardened DACS

    d) deploy a hardened DSLAM

Objective: Identify the methods for providing DSL to customers regardless of local loop limitations (deploying remote/hardened DSLAM/DSLAS solution and/or Digital Loop Cabinet).

29. Why should DSLAM equipment be placed in a Remote Terminal (RT) or Digital Loop Carrier (DLC)?

    a) A DSLAM in the RT reduces the far-end CrossTalk.

    b) There is accessibility of the DSLAM for support by CLEC staff.

    c) The DSLAM is used as a single point of termination for an ILEC.

    d) ADSL, SDSL, and VDSL are only supported over contiguous copper loops.

Objective: Describe VPN and security considerations in the design of an xDSL network.

30. Two people, in the same house, work for two different companies. Both companies provide remote access via xDSL connections.

    How can both companies ensure a secure connection for their employee?

    a) provide separate workstations for both employees

    b) provide separate DSL connections using managed virtual networks

    c) provide managed IP termination services with client-server VPNs

    d) provide managed IP termination services with LAN-to-LAN VPN services

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Objective: Explain the impact of ATM switching in an xDSL network design.

31. What are three benefits of a DSLAM with internal ATM switching? (Choose three.)

    a) scalability

    b) configuration kept to a minimum

    c) the ability to provide DNS resolution

    d) simple and efficient provisioning over an ATM backbone network

    e) ability for the service provider to inject capital as the network grows

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Objective: Explain the impact of ATM switching in an xDSL network design.

32. When should ATM cell rate decoupling be used?

    a) when using PPP with SVCs

    b) when using PPP with PVCs

    c) when no live information is present

    d) when there is live information present

Objective: Explain the functions and applications of companion software in an xDSL network (NMS, AAA, PPPoE, VPN client, etc.).

33. What uses an AAA server to authenticate a connection from the Customer Premise Equipment (CPE) to the service aggregator?

    a) NAT

    b) ATM

    c) PPP

    d) MPPP

    e) PPPoA

Objective: Explain how to integrate an xDSL network into the existing network/Telco provider's services (POTS, ISDN, ATM backbone).

34. Which three must be determined prior to the design and delivery of xDSL services by an ILEC or CLEC? (Choose three.)

    a) availability of local loop to the customer

    b) availability of authentication and accounting methods

    c) existing backbone structure and deployment of ATM

    d) existing distribution of IP addresses used by customers

    e) local loop distances and location of Remote Terminals (RTs)

Objective: Describe the steps required to check bandwidth and QoS in an xDSL network.

35. Which explains the need for monitoring RSVP usage on backbone routers?

    a) RSVP negatively impacts backbone routers by reserving capacity for specific traffic.

    b) RSVP negatively impacts backbone routers by marking and prioritizing network traffic.

    c) RSVP improves backbone router performance by marking and prioritizing network traffic.

    d) RSVP improves backbone router performance by reserving capacity for specific traffic.

Objective: Given an xDSL network design, select an appropriate load/stress testing strategy.

36. When designing an IDSL network, what must you use to minimize attenuation?

    a) DSLAM

    b) repeaters

    c) load coils

    d) Customer Premise Equipment (CPE)

Objective: Given a CPE to DSLAM/DSLAS connectivity problem, analyze the situation, determine the probable cause, and recommend a solution.

37. A customer with a small business is using a single ADSL connection. The network consists of 5 workstations,1 hub, and the CPE (router). The customer is only able to connect to the Internet through one computer at a time. The customer is not having problems with the local Intranet.

    Which will resolve the problem?

    a) enable NAT

    b) replace the CPE

    c) check the local loop

    d) disable the firewall

Objective: Given a CPE to DSLAM/DSLAS connectivity problem, analyze the situation, determine the probable cause, and recommend a solution.

38. An ADSL customer consistently has an upstream speed of 608 Kbps, while the downstream is experiencing a variable rate between 2 Mbps and 244 Kbps.

    Which is the most likely cause of the problem?

    a) over-subscription of services at the NSP

    b) multiple users in the same service group

    c) multiple ISDN and T1 service lines in the same bundle

    d) distance from the Central Office (CO) is at the maximum distance allowed for service

Objective: Given a CPE to DSLAM/DSLAS connectivity problem, analyze the situation, determine the probable cause, and recommend a solution.

39. A customer wants to install IDSL with a downstream speed of 144 kbps on 24AWG wire. The distance from the customer location to the DSLAM is 24,000 feet.

    What should you recommend to solve the problem?

    a) repeater

    b) load coil

    c) bridge tap

    d) POTS splitter

Objective: Given a DSLAM/DSLAS to backbone connectivity problem, analyze the situation, determine the probable cause, and recommend a solution.

40. Which requires DSLAMs to view data packets in order to direct packets to the proper destination?

    a) ATM support

    b) voice support

    c) DHCP-relay support

    d) Frame Relay support

Objective: Identify the steps required to import and recompile MIBs after upgrading software on DSL hardware.

41. You have upgraded the software on your xDSL hardware to enable new features. The upgrade came with new MIBs and you have an existing NMS. What is the correct order for adding the new MIBs to your NMS so that you can manage the new features?

    a) copy the new MIBs into the NMS MIB directory,
    refresh the MIB browser,
    restart the NMS

    b) copy the new MIBs to the NMS MIB directory,
    compile the MIBs into the NMS,
    restart the NMS

    c) configure the new MIBs to use the correct community strings,
    compile the MIBs into the NMS,
    restart the NMS

    d) configure the new MIBs to use the correct community strings,
    copy the new MIBs into the NMS MIB directory,
    compile the MIBs into the NMS

401 Sample Exam Answers

Item	Answer:	Item	Answer:
1	C, D	22	C
2	B	23	B, D
3	A	24	C
4	D	25	E
5	C	26	C, D
6	C	27	B
7	A, E	28	D
8	B, D	29	C
9	B, C, D	30	C
10	C	31	A, D, E
11	A	32	C
12	C, E	33	E
13	A, B, E	34	A, C, E
14	A, B	35	A
15	A	36	B
16	B, C, E	37	A
17	A	38	C
18	B, C	39	A
19	D	40	C
20	A, B, G	41	B
21	A		

Appendix B
LCTE Recommended Resources

Lucent Technologies Publications:

Lucent Technologies documentation for products and solutions associated with the LCTE exams is available at www.lucentdocs.com. Additional reference material including white papers, case studies, course materials, standards and forums is available through the Lucent Technologies Public Resource Library:
http://www.lucent.com/knowledge/resourcelib/0,,,00.html

Web access to standards and forums:

IETF Home page
Internet Engineer Task Force (IETF) Home Page: Of most interest would be the Request for Comment (RFC) documents, which are indexed and openly provided by the IETF.
http://www.ietf.org

RFC Index
http://www.faqs.org/rfcs/

ETSI home page
http://www.etsi.org

IEEE Standards Page
http://standards.ieee.org/catalog/olis/

Telecommunications forums, regulators, standards bodies and test labs in countries other than the United States
http://www.tapc.org.uk/othercountries.htm

ISDN links
http://alumni.caltech.edu/~dank/isdn/

The International Engineering Consortium
http://www.iec.org/pubs/

Computer and Communications Standards
This source provides an extensive list of links to many computer and telecommunications technology standards and standards bodies, including the IETF, ANSI, IEEE, the ITU, ATM Forum and many others
http://www.cmpcmm.com/cc/standards.html

Telecommunications Information Resource
This page provides links to many resources. Be sure to check out links to Technical Information and FAQs. There are many other links that branch to useful information.
http://china.si.umich.edu/telecom/telecom-info.html

Network Professionals Resource Center
This home page provides an index of link groups to many useful study resources, including technical reports, TCP/IP resources, data communications tutorials, and more.
http://www.inetassist.com/urlidx.htm

ATM Forum
The ATM Forum is an international non-profit organization formed with the objective of accelerating the use of ATM (Asynchronous Transfer Mode) products and services through a rapid convergence of interoperability specifications. In addition, the Forum promotes industry cooperation and awareness.
http://www.atmforum.com

Frame Relay Forum
The Frame Relay Forum is an association of vendors, carriers, users and consultants committed to the education, promotion, and implementation of Frame Relay in accordance with international standards. Formed in 1991, the group and maintains chapters in North America, Europe, Australia/New Zealand and Japan.
http://www.frforum.com

The DSL Forum
http://www.dslforum.org/

The SANS Institute
The SANS (System Administration, Networking, and Security) Institute is a cooperative research and education organization through which more than 96,000 system administrators, security professionals, and network administrators share the lessons they are learning and find solutions to the challenges they face.
http://www.sans.org

Computer Security Institute
Computer Security Institute (CSI) is the world's leading membership organization specifically dedicated to serving and training the information, computer and network security professional.
http://www.gocsi.com/

Other Useful Websites
http://www.everythingdsl.com

http://www.kmj.com/radius.html

http://www.microsoft.com

http://www.novell.com

http://www.protocols.com

http://www.techweb.com

http://www.whatis.com

Online Magazines & Webzines

Network Magazine Tech Tutorials
Data Communications Magazine on line offers a section devoted to technology tutorials. This page provides a list of tightly crafted tutorials on many networking and communications technology subjects.
http://www.commweb.com/tutorials

InternetWeek Magazine Online
http://www.internetweek.com

Telecommunications Magazine Online
Select US or International versions from the home page, a great source for technology articles written by professionals in the field, product reviews etc.
http://www.commweb.com/tutorials and http://telecomflash.com

Industry White Papers & CBTs

"Differentiated Services - Moving towards Quality of Service on the Ethernet." Intel http://www.intel.com/network/connectivity/resources/doc_library/white_papers/solutions/diff_serv/diffserv.pdf (19 Oct. 2001)

"Say what? QoS in English." Network World Fusion 17 Aug. 1998. http://www.nwfusion.com/netresources/0817qos.html (19 Oct. 2001)

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National Communications System Technology & Standards Division. "Federal Standard 1037C - Glossary of Telecommunications Terms." General Services Administration, Information Technology Service (7 Aug. 1996) http://www.its.bldrdoc.gov/fs-1037/ (19 Oct. 2001)

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Suggested Industry Reference Books

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Ballew, Scott M. Managing IP Networks with Cisco Routers. Sebastopol: O'Reilly & Associates, 1997

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