Voice over Digital Subscriber Line (VoDSL)

Definition

The changes in the forces that shape the communications industry have been well documented and are nearing the level of common knowledge; examples include regulation and technology. Digital subscriber line (DSL) is the technology that is employed between a customer location and the carrier's network that enables more bandwidth to be provided by using as much of the existing network infrastructure as possible. Speeds of up to 9 Mbps to the home are possible, given a number of limitations (e.g., distance and line quality). Using a greater range of frequencies over the existing copper line makes this increase in bandwidth possible. Voice over DSL (VoDSL) represents a breakthrough service by means of this technology.

Overview

This tutorial will explore the topic of VoDSL, emphasizing transport methods and standards groups. First, however, it provides a short history and explanation of DSL technology.

Topics

1. DSL Primer

A Brief History of DSL

The first practical application of high-speed data over copper wire was demonstrated in the late 1980s at the labs of Bellcore. This first harnessing of higher frequencies was offered as a one-way traffic flow, called asymmetrical. These first efforts led to the integrated services digital network (ISDN), which is historical proof that the idea of integrated voice and data is not new with DSL. As another example, data over voice (DOV) predates ISDN. Not too long afterward, high-bit-rate DSL (HDSL) was created, which is now used for most traditional tier-1 (T1) dedicated circuits in the U.S. market.

Discrete multitone (DMT) was the next major development that assisted the creation of DSL. By separating the high-frequency signal into 256 subchannels, the problems created by line noise and other types of interference were minimized. This development opened the door for more market-ready DSL development.

Two groups were originally formed to further the development of DSL. The first, the Asymmetric Digital Subscriber Line (ADSL) Forum, is a group of vendors and carriers dedicated to the continued development of that version of DSL. The second, the Universal ADSL Working Group (UAWG), proffered the G.lite standard (or ADSL lite), which does not require a splitter. G.lite was squarely aimed at the reduction in installation costs of implementing DSL out in the field.

But Just What Is DSL?

xDSL and DSL are quickly merging to become synonyms, describing the various types of DSL that exist in the marketplace. DSL enjoys a large number of enviable characteristics. For instance, DSL is a very secure service. Just like a traditional phone call, DSL is a direct link between the customer and the carrier. DSL service is referred to as always on, meaning that when asked it delivers; there are neither links to establish nor numbers to dial and answer. DSL's speed is enviable—up to 35 times faster than a standard dial-up connection. Last but not least, DSL is able to transport voice and data services over the same copper wire at the same time.

DSL, however, does have some drawbacks. As with any new service, the process for ordering, provisioning, installing, and testing DSL is still being developed within the industry. As mentioned earlier, there are some conditions that must be met in order for DSL to be effective (and therefore available) from a particular site. Depending on the version discussed, DSL has distance limitations. The site must be within so many feet of the serving central office (CO). ADSL is available up to 12,000 feet, symmetrical digital subscriber line (SDSL) up to 18,000 feet, and an ISDN–like version of DSL (IDSL) can reach out to 30,000 feet. What are the different versions of DSL? *Table 1* provides general information on these variations in the DSL family.

Table 1. Digital Subscriber Line Service Types

Type	Average Speeds (Upload/Download)	Comments
ADSL	384 kbps/128 kbps to 768 kbps/384 kbps are typical, but downstream can range from 1.5 Mbps to 9 Mbps and upstream from 64 kbps to 1.5 kbps.	This is a strong residential offering. Downstream (carrier to customer) is usually faster than upstream (customer to carrier), supporting service types typically seen at residential/small office/home office (SOHO) applications.
ADSL lite or G.lite	Lower-end speeds of ADSL (384 kbps/128 kbps) are possible.	A lower rate of ADSL is offered to extend American National Standards Institute (ANSI) T1.413. This version of DSL is splitterless.
consumer DSL (CDSL)	1.5 Mbps to 10 Mbps	This is a proprietary version of DSL from Rockwell International.
Ethernet local loop (Etherloop)	1.5 Mbps to 10 Mbps	This is a proprietary version from Nortel Networks. It uses DSL DMT techniques with burst packet efforts like Ethernet.
HDSL	Speeds of up to 1.544 Mbps (2.048 Mbps using European Telecommunications Standards Institute [ETSI] standards) are possible.	This is used as a substitute for T1/E1 transmissions. It provides a full-duplex symmetric path and uses ISDN–like technologies, developed by Ascend.
IDSL	128 kbps	
rate-adaptive DSL (RADSL)	Rates are offered in ratios between upstream and downstream.	This DSL service can adjust its rate depending on line-quality statistics. One may refer to work done by Globespan Semiconductor on a proprietary version.
SDSL	Speeds of 192 kbps up to 1.1 Mbps are possible.	This is more likely a business service offering, serving as a two-wire version of HDSL.
very-high-bit-rate DSL (VDSL)	Data rates are greater than 10 Mbps.	This is a short loop-distance version of up to 3,000 feet.

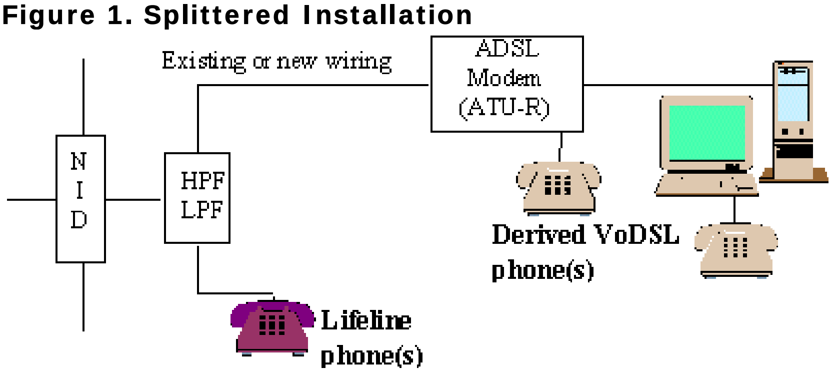
2. Interworkings of DSL

DSL is able to provide these increases in available bandwidth by using more of a frequency spectrum that can be transmitted across a copper telephone line. The traditional phone call travels in the 300-MHz to 3,200-Hz range. DSL uses this spectrum and more, employing digital encoding methods to maximize the amount of information that can be transmitted per unit of time. These transmissions can be used to transport voice and data services at the same time. There are restrictions, however. DSL technologies (DSL modems at the customer site, DSL access multiplexer [DSLAM] at the termination point of the service) must be installed across the entire service span, and that span (length of transmission cable) must be able to support these higher frequencies consistently. Items such as load coils or other objects that change the electrical characteristics of the line must be removed so that the line can support DSL services.

POTS Splitter

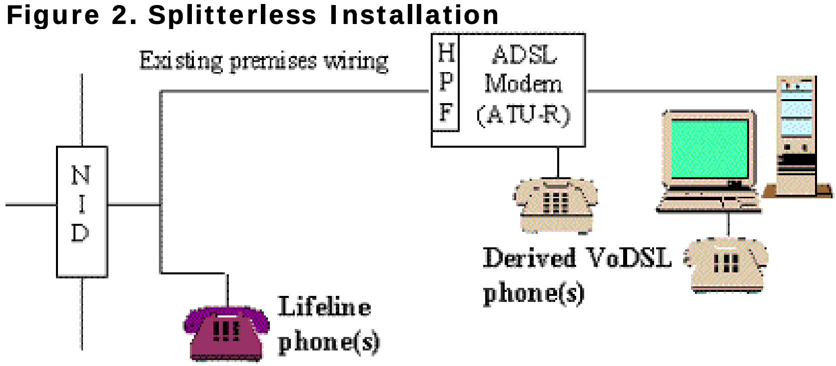
At times and with certain services, a plain old telephone service (POTS) splitter is used (see *Figure 1*).

Figure 1. Splittered Installation



At other times, however, a splitterless installation is employed (see *Figure 2*).

Figure 2. Splitterless Installation



This splitter uses a low-pass filter (which means that the filter only allows low-band frequencies to get through) to separate the voice or low-end frequencies from the data or middle- and high-end frequencies. If a splitter is not required (and some DSL services do not require such a device), then these DSL services are referred to as splitterless DSL. A DSL service that does not require a POTS splitter is easier and cheaper to provision in the network, for a carrier employee is not required to make a trip to the customer's premises to install such a device. It is preferable for splitter designs to be passive (meaning no power is needed); in the event of a power failure, the basic phone service is still available during an emergency.

Line Coding and DMT

DSL services can be provided with one of three line-coding methods: DMT, quadrate amplitude modulation (QAM), and carrierless amplitude/phase modulation (CAP). DMT is typically used for DSL services.

DMT is a method of coding information (line coding) to be transmitted over the physical phone line. The information is split into a number of channels, each having the same bandwidth requirements but packaged to be transmitted at different frequencies. This method has a number of advantages, such as channel independence. If a line gets noisy at one frequency range, others may still get through; thus, the throughput is only reduced rather than stopped.

The ANSI specification for ADSL uses 256 frequency channels for downstream transmission and 32 channels for upstream. All of these channels have a bandwidth of 4.3125 kHz, with the same number of kilohertz separating each channel from the other.

3. With All of This Variety, How Big Is the Market?

A number of consulting and research houses monitor the DSL market. Various forecasts can be purchased that suggest the amount of equipment to be sold, revenues carriers might expect from services provided, and so on. To say that the DSL market is difficult to forecast would be an understatement. Several firms were quoted in January 1999 with their own forecasts as to the number of lines of DSL that would be installed by the end of that same year. All of these forecasts were exceeded by April 1999, and the growth curve has not stopped outstripping the updated forecasts. Equipment sales are expected to reach US$2 to 3 billion by the year 2005, and service forecasts are expected to reach US$2 to 3 billion by the year 2003. Actual line deployments by the summer of 1999 were pegged at nearly 200,000. With about 180 million working copper loops in the United States alone, the market size for DSL services is very large indeed.

Once a basic understanding of DSL technologies and how they work is established, a specific kind of DSL may be discussed: ADSL. ADSL is the most common DSL variety used to support VoDSL service.

4. About ADSL

ADSL uses DMT, has a splitter and splitterless version, and can be provisioned in a rate-adaptive mode. Rate-adaptive DSL (RADSL) can provide data rates from 64 kbps all the way up to 8.192 Mbps on the downstream and from 16 kbps to 768 kbps on the upstream channel.

A pair of ADSL modems is installed—one at the customer site and one at the point of termination in the network. The chips that are being used in ADSL modems can operate in dual mode; i.e., either in a splitter or splitterless environment.

ADSL, like nearly all DSL varieties, is a good service choice for a number of data applications. Bandwidth-heavy applications such as Internet access, local-area network (LAN) access (telecommuting), broadcast video, and distance learning are all examples of how ADSL can provide the necessary bandwidth at a cost that meets the budget. There is, however, an additional application that is becoming a leading market seller for ADSL: VoDSL.

5. About VoDSL

VoDSL is means of leveraging the copper infrastructure to provide both quality voice services as well as support a wide variety of data applications over the same existing line to the customer's site. It gives data competitive local exchange carriers (CLECs) a way to increase revenue potential, incumbent local exchange carriers (ILECs) an answer to the cable modem, and interexchange carriers (IXCs) a way to gain access to the local voice loop. In short, any carrier type can increase the value of its marketed services basket.

With all the bandwidth enabled through an ADSL circuit, there are some maximums of service types that can be provided. One such example is to ask how many voice lines could an ADSL circuit provide. Depending on the type and amount of compression and the actual line speed, the answer might be surprising. See *Table 2* for some example calculations.

Table 2. DSL Dedicated to VoDSL

DSL Line Speed	Circuit Equivalents without Compression Circuit	Equivalents Using Maximum Compression
384 kbps	6	up to 40
768 kbps	12	up to 80
1.1 mbps	18	up to 110
1.5 mbps	25	up to 150

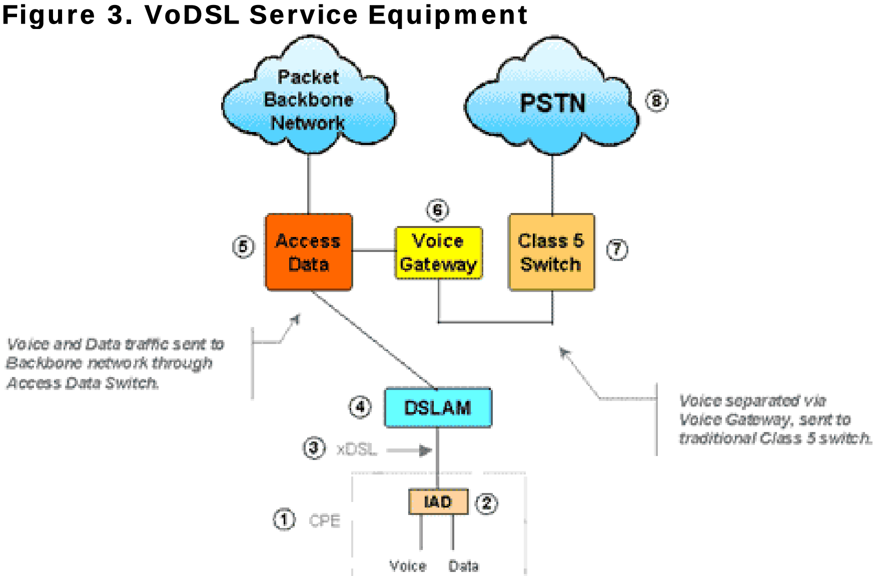
This is just one example why types of carriers are excited about the possibilities offered by VoDSL. In crowded markets, where the availability of cooper loops is at a premium, the application of this kind of technology can be a shot in the arm to the carrier's profitability.

VoDSL also generates high revenues. A number of research houses have stated that the service revenue expectation for data-based DSL services could be in the neighborhood of US$3 billion a year, while the anticipated services revenue for VoDSL is expected to be near US$13 billion.

6. How Does VoDSL Work?

VoDSL requires a platform of DSL equipment, coupled with platform adaptations or additional equipment that can handle the requirements for voice services.

Figure 3. VoDSL Service Equipment



The following are necessary to provide VoDSL:

- **customer equipment**—telephones, private branch exchange (PBX), key system, fax, modem, and so forth
- **integrated access device (IAD)**—The IAD can serve multiple functions, including those of a DSL modem. The IAD serves as the interface between the DSL network service and the customer's voice and data equipment. The packetization of voice traffic takes place on this unit utilizing standards-based technology (usually asynchronous transfer mode [ATM]). The customer premises equipment (CPE) prioritizes the voice packets over data calls to ensure toll-quality voice delivery and then sends the packets over the DSL line.
- **DSL line**—transports the data and packetized voice to the nearest carrier facility utilizing existing twisted-pair copper loops. Of course, these loops must be able to support the distance and quality requirements for DSL service to be offered.
- **DSLAM**—terminates multiple DSL lines and aggregates traffic from them
- **data switch**—receives the traffic from the DSLAM and separates the data from the voice packets; data is sent to a data network (e.g., Internet), while voice packets are sent to the voice gateway
- **voice gateway**—Voice packets are depacketized and converted to a standards-based format (GR–303, TR–08, or V5.X) for delivery to a Class-5 voice switch.
- **Class-5 voice switch**—telephony switch providing dial tone, call routing, and services; also generates records used for billing
- **public switched telephone network (PSTN)**—the public telephone network

VoDSL broadband access solutions are now hitting the market. These types of solutions are generally overlays onto the DSL network, enabling the provisioning of voice services on what started out as a data network.

Today, a VoDSL solution has two basic components: a voice gateway and an IAD. The voice gateway allows the traffic to be peeled off of the data network and handed to the PSTN for service and switching. The IAD provides the interface between the DSL network service and the customer's network equipment. Note that an IAD can be used to connect both voice- and data-literate equipment.

From a layering approach, VoDSL has several layers as well. The physical layer is actually a twisted pair of copper wires. Another is the transport layer, which can be handled by frame relay, ATM, or Internet protocol (IP). Frame-based VoDSL actually looks like voice over frame relay (VoFR); ATM–based VoDSL behaves like voice and media over ATM (VMoA); and IP transport for VoDSL is actually voice over IP (VoIP). Yet another layer is voice coding, followed by the signaling layer. The ADSL Forum is working to the idea that its standards work will concentrate on using channel associated signaling (CAS) in its first release of VoDSL work. Finally, the services layer is supported, offering services from dial tone to call waiting. The voice-capable switch in the carrier's network supports the services layer.

7. Transport Methods within VoDSL

The VoDSL market was struggling in its infancy to decide just how to transport the service. Should IP, frame relay, or ATM be used? Each method has its merits; however, all methods are moving packetized voice across packet-based networks to its ultimate destination.

IP has ubiquity going for it; frame relay has ease of implementation (if the customer site is already a frame customer); and ATM has the strongest quality-of-service (QoS) history. Much discussion has been held within the ADSL Forum to determine which course to take. The vote was overwhelmingly in favor of using ATM technologies as the basis for the first phase standard approach to VoDSL service. For those wanting to follow this standard work, refer to WT–43 from the ADSL Forum for more information.

Analysts estimate that about 90 percent of the installed DSLAM uses the ATM transport method back to the switch. Older techniques use ATM adaptation layer (AAL1), employing byte-interleaved multiplexing, which is sometimes called time-division multiplex (TDM) over ATM. The ADSL Forum is anticipated to adopt the more efficient AAL2 (with permanent virtual circuits [PVCs]), which uses packet-interleaved multiplexing. AAL2 is more efficient because it allows the network to allocate bandwidth dynamically on the DSL service between the demands of voice and data services. If no voice services are in use, then the entirety of the bandwidth can be dedicated to data services (unlike AAL1 with PVCs, which keeps the bandwidth needed for voice open in case it is needed). Use of AAL2 also allows for something called silence suppression, which can recover up to 50 percent of the bandwidth allocated for the voice traffic. Silence suppression removes the necessity of packetizing the silence in a phone conversation (where no one is talking) and instead inserts data into the packet stream. *Table 3* provides information on where more detailed standards information may be found.

Table 3. Voice over AAL2 Standards

Sponsoring Standards Body	Standard Reference
International Telecommunications Union–Telecommunications Standardization Sector (ITU–T)	I.363.2 defines AAL2
ITU–T	I.366.2 defines SSCS for voice over AAL2 voice encoding formats methods of transporting signaling
ATM Forum	AF–voice traffic over ATM (VTOA) 0113 specifies use of I.366.2 for voice trunking applications.
ATM Forum	new ATMF work item, Loop Emulation Service Uses AAL2, based on I.366.2

VoDSL can also be moved via IP, which is a method described as voice over multiservice data network (VoMSDN) by the ADSL Forum.

A MSDN can be exclusively IP–based or incorporate other packet technologies as well. A pure IP network would transport all traffic over IP, using VoIP technologies such as real-time protocol (RTP) (e.g., RFP 1889). A mixed IP and ATM network could use IP for data traffic and ATM for voice. In a VoMSDN example, all call-control protocols are provided outside of a traditional Class-5 switch. Interactions with the PSTN, as needed, are provided via a gateway that typically supports GR–303 to interconnect. Call control in this type of environment is performed by protocols such as H.323, H.248, or session initiation protocol (SIP).

8. Standards Groups Involved with VoDSL

There are a number of standards bodies involved in the creation of common methods for providing VoDSL service. Some of these include ANSI, ETSI, Digital Audio Video Council (DAVC), ATM Forum, the ITU, and the ADSL Forum.

Each of these bodies has particular DSL–related interests. For instance, physical-layer work is done in ANSI, ETSI, and the ITU–T. ATM layer work is done in ITU–T (e.g., signaling, adaptation layers) and the ATM Forum (e.g., VMOA). VoIP work is done with the Internet Engineering Task Force (IETF). Voice coding work is supported by ITU–T (e.g., codecs and echo control). The signaling and services layer work is being supported by a variety of groups as well, such as ITU–T (e.g., Q series, H.323, H.248), ANSI, and ETSI (e.g., B–QSIG), ATM Forum, and the IETF (e.g., media gateway controller [MEGACO]).

ADSL Forum

The ADSL Forum has a multifold focus: architectures and marketing information. Architecture work includes study of user requirements, service-provider requirements, and overall end-to-end architectures. The purpose of marketing information is to make the benefits of various DSL applications better known.

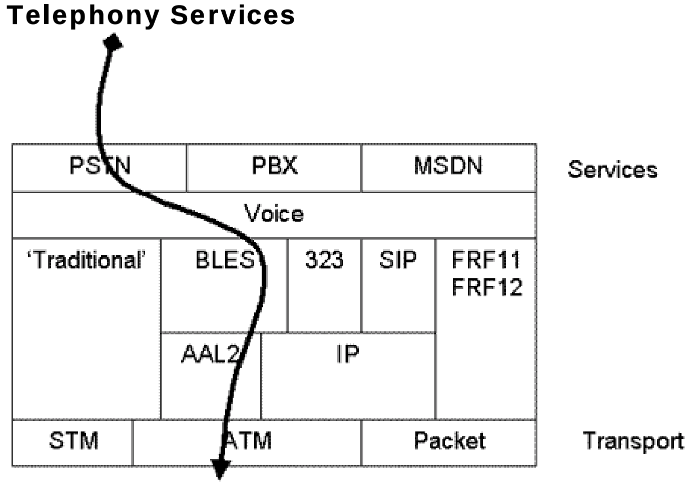
The ADSL Forum has established a number of working groups, each aimed at a function piece or purpose to furthering the acceptance and delivery of DSL technologies. One such working group is the VoDSL Group. Its purpose is to provide a set of requirements, architectures, and recommendations that provide end-to-end solutions for the delivery of interoperable derived telephony services. At all times, the ADSL Forum wishes to use existing standards. This simplifies the standards process and makes adoption that much easier.

VoDSL sub-working groups are as follows:

- broadband loop emulation service (BLES)
- voice with multiservice data networks (VMSDN)
- PBX extension (deferred)
- technical marketing (VTM)

The BLES working group charter is to establish requirements and to recommend an architecture to permit derivation of legacy local telephony services from packet-based DSL (e.g., frame or cell) by interoperable network and end-user equipment.

Figure 4. Architecture to Permit Derivation of Legacy Local Telephony Services



Source: ADSL Forum

The definition of BLES from the working group is as follows:

- use of POTS, with North American standards as the first version; future work will include an international version
- use of the GR–303 interface for connection to the Class-5 voice switch
- use of Telcordia TR–57 functionality from the telephone interface at the customer side, with Telcordia TR–909 specified voice quality
- use of a PVC dedicated for multiple voice calls between the customer premises and the network
- use of AAL2 as defined in the ITU–T recommendation I.366.2 Service Specific Convergence Sublayer for Trunking
- use of AAL2 as defined in the ATM Forum VTOA–0113.000
- use of ATM trunking with AAL2 for narrowband services, as established in January of 1999
- use of the local emulation service (LES) profile currently being defined in the ATM Forum VMoA working group

The essential goal of a BLES service is the fully functional transport of Class-5 switch subscriber line services through the broadband access network (BBN) to the end user. Examples for services that should be transported over the BLES architecture include POTS and POTS with custom local-area signaling services (CLASS). These services are to be provided so that the switch sees the end user's line as a single point of service (no sharing) and that the services provided operate in the same manner as conventional means (e.g., through a digital loop carrier [DLC]). Obviously, there are a number of ways these requirements could be deployed in the network. Using voice splitters is one way to get the voice and data traffic to the network connections needed. Using voice gateways to bridge between the voice and data networks is another. A third, upcoming option will be to use next-generation switch products that are able to switch the voice and data traffic in their native modes. Regardless of the chosen mode, POTS must provide the service to the end user in the same manner and with the same characteristics of performance.

BLES calls for each customer premises interworking function (CP–IWF) to be provisioned with at least two PVCs: one for data and one for voice. The voice PVC uses AAL2, providing a full path for voice channels and associated signaling. The AAL2 PVC operates as a variable bit rate–real time (VBR–RT) circuit. The PVC for voice is assigned a higher priority through the network than the data PVC, so as voice traffic increases, it receives the service-level attention needed to provide toll-quality voice service.

At present, the ADSL Forum has not performed work to include ISDN signaling, although the BLES model can be extended to include it. The same applies for PBX messaging, which could be added to BLES at a later time.

The management facilities defined in the ADSL Forum VoDSL standards are based on the concept of managed objects, which model the semantics of management operations. There are two general-purpose management protocols of relevance to the management of VoDSL equipment:

- the simple network management protocol (SNMP), as described in RFC 1157 [10]

- the open systems interconnection (OSI) common management information protocol (CMIP), as described in RFC 1095 [11]

SNMP or CMIP may be used to manage VoDSL equipment.

The ATM Forum's user-network interface (UNI) standard 4.0 specifies the use of interim link management interface (ILMI). This specification uses the ILMI for autoconfiguration of PVCs. It does so by defining the management information base (MIB) needed by networking equipment to be able to perform this function. Autoconfiguration is important for a mass-market appeal service such as DSL, because manually configuring each service would simply be unworkable.

9. The Future of VoDSL

There is no doubt that the market, both business and residential, is clamoring for more and faster ways to connect to the network in this Internet age. The demand for services with DSL characteristics is well documented. The ability for the carriers serving the public networking needs to fulfill this demand must certainly be tempered by the development of standards, solutions to line-quality problems, and the always-requisite interoperability standards, to name but a few. However, there is too much demand and too many capital dollars chasing solutions to believe that the DSL installation and maintenance conundrum will not be solved in the next few years.

One of the major drivers for those solutions is not just data, but traditional and new ways to offer voice services. Voice traffic pays the bills and provides the majority of the net income in the communications market. In short, the demand for high-speed services, coupled with the ability for voice to fund the development of future network architectures, paints VoDSL's future a rosy color indeed.

The beauty of DSL technologies lies in its ability to enhance the capabilities of the existing copper lines to be able to transport voice and data services simultaneously, at speeds that rival dedicated services in some instances. As the numbers of VoDSL lines grow, the network will increasingly look for solutions to handle this volume of integrated voice and data traffic.

Next-generation switching products must be able to handle this integrated voice and data traffic at the first point of switching. Additionally, more standards work must be approved to further enhance the functionality of VoDSL services.

For instance, the ADSL Forum may very well consider more signaling requirements above and beyond the existing CAS recommendation. H.248 signaling for the access side of VoDSL is a good candidate. On the trunk side, requirements for VoDSL network switching equipment to support bearer-independent call control (BICC) may become necessary.

Adaptation may very well see additional standards recommendations as well. For instance, any packetized voice service must contend with echo cancellation. The delay that is introduced from the packetization of voice information results in audible echo to the parties involved in the call. It is true that network design can overbuild to compensate for some of the introduced echo, but to be able to provide truly consistent VoDSL toll quality, some sort of echo-cancellation capability standard may need to be recommended for next-generation switches.

Self-Test

1. DSL allows the carrier to provide both voice and data services on the same pair of copper wires. What other services have done the same type of integration?

    a. ISDN and DOV

    b. CMIP and SNMP

    c. ISDN and CMIP

2. Which two types of DSL are used as T1 replacements?

    a. ADSL and HSDL

    b. HDSL and G.lite

    c. HDSL and SDSL

    d. ISDL and HDSL

3. The UAWG created the G.lite ADSL standard. Why is it called lite?

   a. It provides slower speeds than a nonlite version.

   b. It uses copper that is of a lighter gauge.

   c. It does not require a splitter.

   d. none of the above

4. DMT, CAP, and QAM are all methods of which the following?

   a. packetizing voice onto data networks

   b. line coding

   c. compression

   d. all of the above

5. RADSL is called so because it can accomplish which of the following tasks?

   a. charge different rates depending on service type offered

   b. change the rate depending on time of day

   c. modify the throughput rate depending on line quality

6. Which type of carrier would be most likely to deploy VoDSL?

   a. IXC

   b. CLEC

   c. ILEC

   d. ISP

   e. all of the above

7. What type of device is needed to interconnect the customer's premises and the DSL service?

   a. DSLAM

   b. CO switch

   c. DLC

d. IAD

8. What type of transport does the ADSL Forum recommend in the first phase of VoDSL?

   a. IP

   b. ATM

   c. frame relay

   d. Q.SIQ

9. What is the name of the ADSL Forum standard that supports VoDSL?

   a. CMIP

   b. VBR–RT

   c. BLES

   d. MDNS

10. What are the two purposes of the ADSL Forum?

   a. marketing information and architectures

   b. developing architectures and setting new standards

   c. hosting the ADSL meetings and publishing results

   d. marketing information and standards interworking

Correct Answers

1. DSL allows the carrier to provide both voice and data services on the same pair of copper wires. What other services have done the same type of integration?

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   b. CMIP and SNMP

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   See Topic 1.

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See Topic 2.

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See Topic 8.

Glossary

AAL
ATM adaptation layer

ADSL
asymmetric digital subscriber line

ANSI
American National Standards Institute

ATM
asynchronous transfer mode

BBN
broadband network

BICC
bearer-independent call control

BLES
broadband loop emulation service

CAP
carrierless amplitude/phase modulation

CAS
channel-associated signaling

CDSL
consumer DSL

CLASS
custom local-area signaling service

CLEC
competitive local exchange carriers

CMIP
common management information protocol

CO
central office

CPE
customer premises equipment

CP–IWF
customer premises interworking function

DAVIC
Digital Audio Video Council

DLC
digital loop carrier

DOV
data over voice

DMT
discrete multitone

DSL
digital subscriber line

DSLAM
DSL access multiplexer

ETSI
European Telecommunications Standards Institute

HDSL
high-bit-rate DSL

IAD
integrated access device

IDSL
ISDN–based DSL

IETF
Internet Engineering Task Force

ILEC
incumbent local exchange carriers

ILMI
interim link management interface

IP
Internet protocol

ISDN
integrated services digital network

ITU–T
International Telecommunications Union Telecommunications Standardization Sector

IWF
interworking function

IXC
interexchange carrier

LAN
local-area network

LES
LAN emulation server

MEGACO
media gateway controller

MIB
management information base

MSDN
multiservice data network

OSI
open systems interconnection

PBX
private branch exchange

POTS
plain old telephone service

PSTN
public switched telephone network

PVC
permanent virtual circuit

QAM
quadrate amplitude modulation

QoS
quality of service

RADSL
rate-adaptive DSL

RTP
real-time transport protocol

SDSL
symmetric DSL

SIP
session initiation protocol

SNMP
simple network management protocol

TDM
time division multiplexed

UAWG
Universal ADSL Working Group

UNI
user network interface

VBR–RT
variable bit rate-real time

VC
virtual circuit

VDSL
very-high-bit-rate DSL

VoDSL
voice over digital subscribe line

VoFR
voice over frame relay

VoIP
voice over IP

VOMSDN
voice over multiservice data network

VMOA
voice and media over ATM

VMSDN
voice with multiservice data networks

VTOA
voice traffic over ATM