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Bell Labs Innovations



WHITE PAPER

Transforming Copper to Gold

High-revenue Voice-over-DSL Services for Incumbent Carriers

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1. Executive Summary

Service providers' business models tend to view DSL exclusively as a mode of data delivery. The reasonable prices and reasonably high performance of DSL data transmission have proven attractive to residential and business customers alike. But pure "data DSL" does not optimize revenue and profit potential.

There is a compelling business case for complementing data DSL with next-generation voice-over-DSL (VoDSL) services. Many incumbent local exchange carriers (ILECs), however, believe that actively marketing VoDSL offerings may endanger their POTS revenue. This is a false presumption. VoDSL deployments from competitive local exchange carriers (CLECs) will set the price points for both existing and new customers who need voice service. CLECs are likely to have sufficient capacity to offer voice, as well as data, service, and thus the potential to cut off the POTS revenue streams of ILECs who refuse to offer VoDSL. The most likely outcome of such a strategy would be to jeopardize the ILEC's DSL revenues, without protecting POTS revenues.

ILECs can substantially enhance their financial results by delivering these voice services over the same line as data DSL. A business model developed for a medium-scale DSL service deployment using industry-available pricing and cost assumptions indicates that VoDSL can enable carriers' potential revenues—along with their market valuations and cash flows—to jump by significant multiples.

Two distinct methods of delivering DSL services are available. The first enables ILECs to leverage existing circuit Class 5 infrastructure by adding voice gateways that support the GR-303 interface. The second offers the option of introducing voice-over-packet-switching technology in new network deployments. Lucent Technologies delivers performance-proven solution sets for both of these network environments. The Lucent solutions are available today, and ILECs can begin taking advantage of revenue-generating VoDSL networks within a six-month timeframe.

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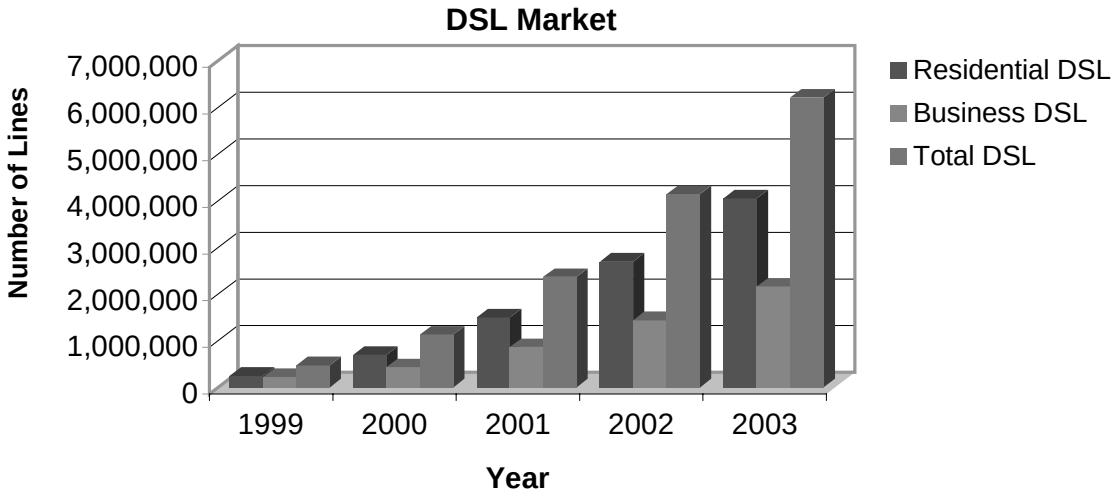
2. The Data-over-DSL Business Model

Service providers of all types are capitalizing on the popularity of the Internet by deploying new data transmission services for residential customers, small-to-medium enterprises (SME), and large corporations. It is clear emerging applications such as e-business—indeed, e-*anything*—will continue to spur demand for Internet bandwidth to the PC.

Today's carriers are in a good position to seize this opportunity with excellent network solutions becoming available to help them meet the burgeoning demand. DSL in particular is becoming popular as a fast, relatively reasonably priced route to the Internet, and the growth of DSL services is expected to be dramatic. According to the Yankee Group, the U.S. DSL market will grow from 500,000 lines today to as many as 6.2 million lines by 2003.

Perhaps the most exciting new target for DSL is the SME market. SMEs, who benefit tremendously from being wired to the Internet, number in the hundreds of thousands.

The growth of the DSL market promises a potentially lucrative revenue stream for service providers who can deploy their offerings quickly and cost-efficiently.



Source: "DSLAMs Get Smart," Yankee Group, 1999

Figure 1

2.1 Data-over-DSL Model Inputs

What kinds of returns do data DSL services provide? The following business model projects the estimated revenues and associated costs over a five-year period. It assumes that the service provider's strategy is to build market share as quickly as possible. It also assumes that this is an incremental business for the service provider; therefore it does not include the costs associated with transport (backhaul to point of presence) or backbone connectivity.

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2.1.1 Pricing

These packages and prices are based on service bundles available today:

Package	Downstream	Upstream	Installation	Monthly CPE	Monthly Price
R1: Residential DSL 384 K	384 Kbps	128 Kbps	$0	$7	$49
R2: Residential DSL 1.5 M	1.5 Mbps	384 Kbps	$0	$8	$129
B1: Business DSL 384 K	384 Kbps	128 Kbps	$50	$7	$49
B2: Business DSL 512 K	512 Kbps	256 Kbps	$55	$45	$89
B3: Business DSL 1 M	1 Mbps	384 Kbps	$105	$45	$189
B4: Business DSL 1.5 M	1.5 Mbps	512 Kbps	$155	$45	$209

2.1.2 DSL Lines

The model portrays a typical incumbent or new service provider DSL deployment. It is designed to first determine DSL line deployment for residential and business customers on a yearly basis for five years.

The model assumes that the provider will access 15 local exchanges within the first year of the DSL service offering, and that coverage will reach 80 local exchanges by the end of service-year five. The initial service areas will be in densely populated centers where large Internet usage is expected. In later years, the less-populated service areas will be added. In this case, the number of lines per local exchange is assumed at 30,000 for year one, dropping too slightly over 19,000 by year five as less dense areas are covered. In total, the number of potential lines in year one is 337,500, rising to 1.5 million by year five. Due to conditioning to support DSL service, only 75 percent of these lines are assumed to be available in year one, increasing to 95 percent by year five.

The model then projects which households and businesses would subscribe to DSL service, and the potential churn rate for each. The expected penetration for DSL with residential customers starts at one percent and rises to seven percent in year five; for SMEs, it starts at 2 percent and increases to 12 percent. This represents a conservative penetration rate that takes into account competition from other providers and technologies (such as cable modems).

(*See Appendix A: Line Assumptions)*

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Figure 2 summarizes the line-increase assumptions of the model.

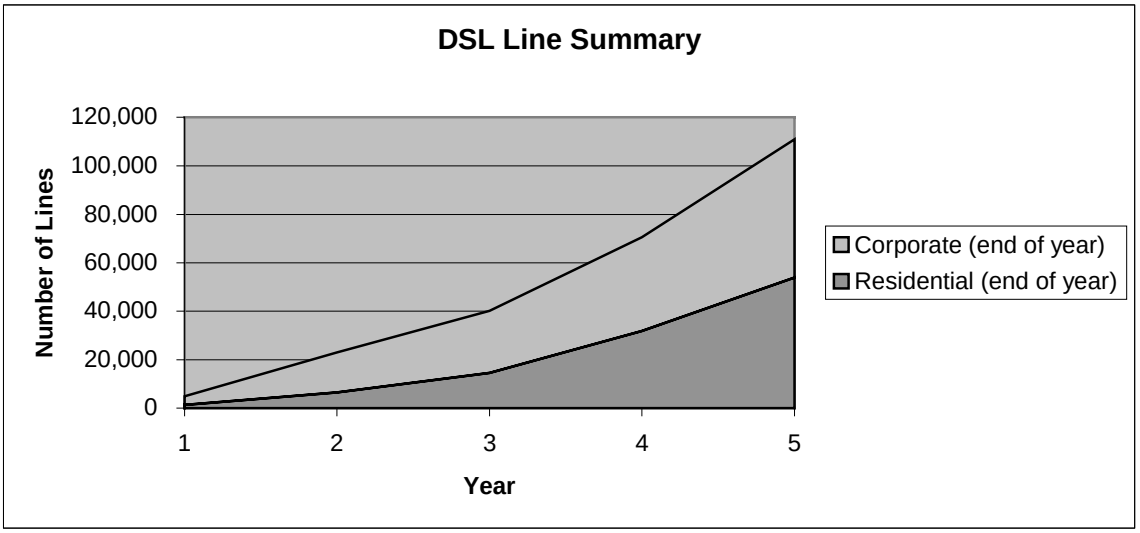

Figure 2 – Cumulative end-of-year DSL lines by segment

2.1.3 Line Distribution

Figures 2 and 3 chart the line distribution per service package. It is assumed that many residential and business customers would migrate to the 1.5 M service by service-year five.

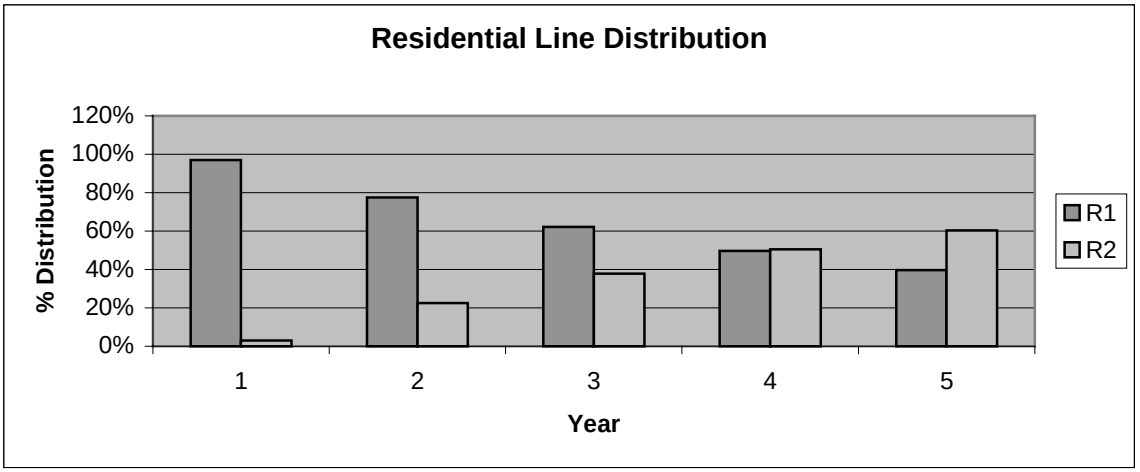

Figure 3

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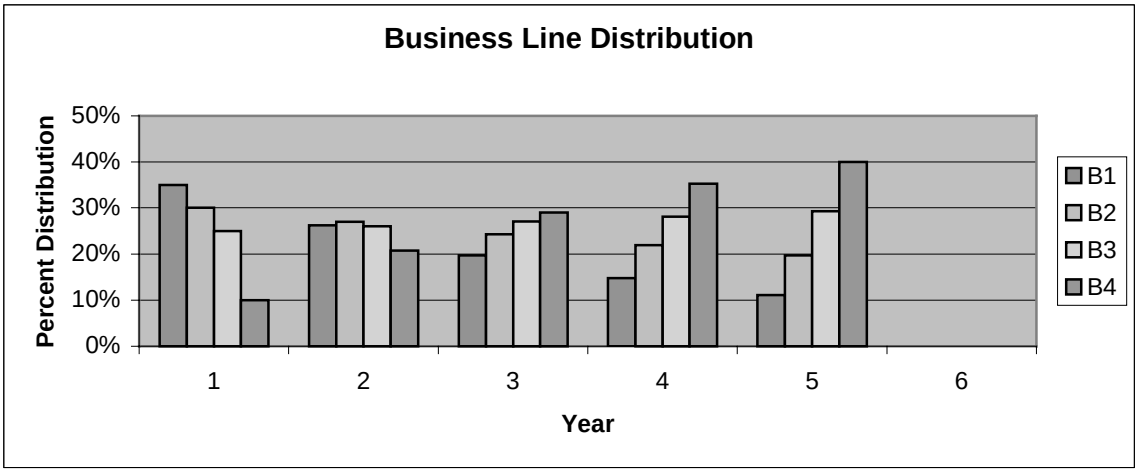

Figure 4

2.1.4 Revenue Per Segment

The line distribution assumptions of the model yield the following revenue per segment estimates:

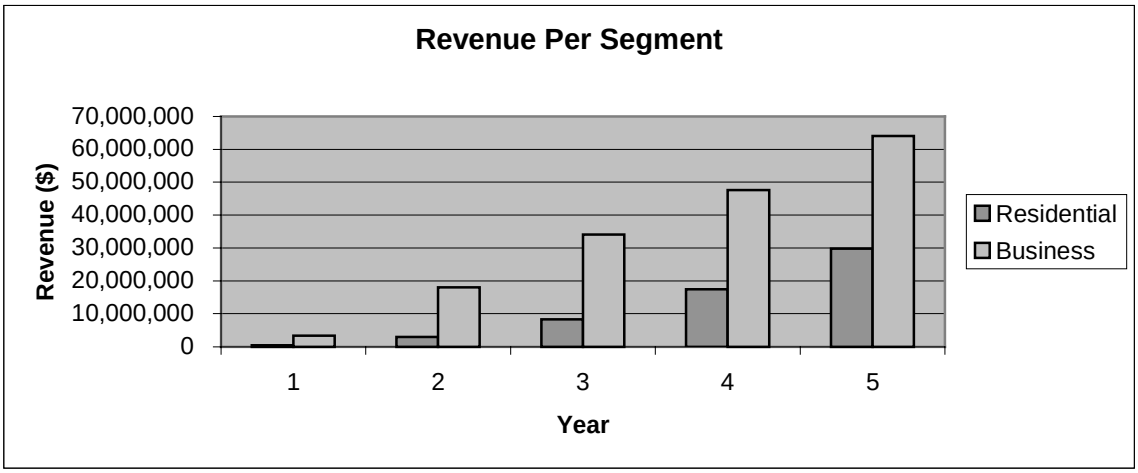

Figure 5

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2.1.5 Expenses

For copper-pair access, the DSL provider must invest in the following assets:

- DSL access multiplexer (DSLAM) equipment (empty chassis and line cards)
- Network operation center (NOC)

In addition, there are the following recurrent costs:

- Operations and maintenance (O&M) and testing costs of network assets
- Unbundled network elements (UNE)
- Co-location costs
- Customer premises equipment (CPE)
- Systems and tools
- Marketing
- Provisioning
- General overhead

Expense details are provided in *Appendix B* and summarized in Figure 6.

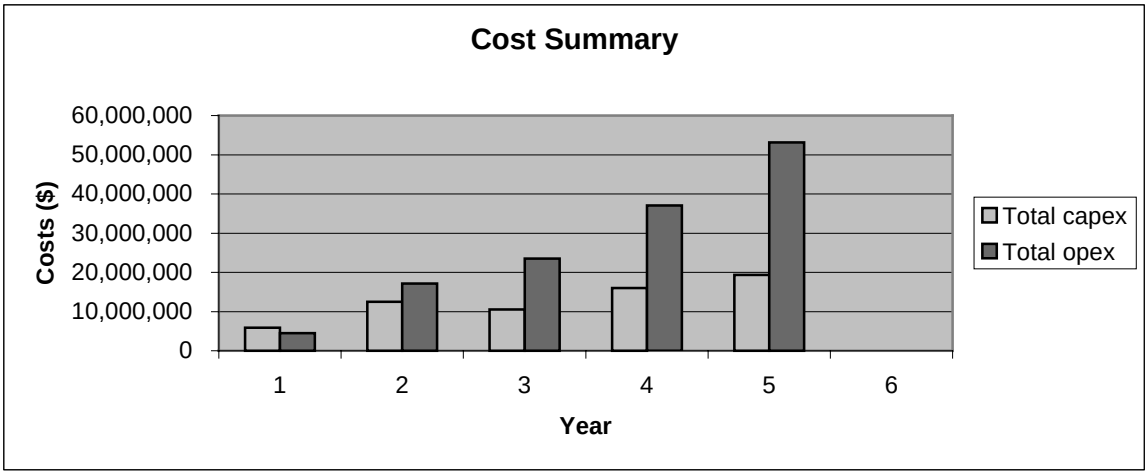

Figure 6

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2.1.6 Results

Figure 7 provides an overview of the financial results.

These projections indicate that service providers can generate positive cash flow by the end of year three. Moreover, they can anticipate revenues of some $90 million by year five, with positive cash flow of close to $20 million. The internal rate of return is an attractive 53 percent.

These results will improve as the costs for copper pair unbundling drop owing to the recent FCC ruling in favor of line sharing (FCC 99-355, November 18, 1999). Improvements would also be realized if service providers were able to deploy DSL more rapidly.

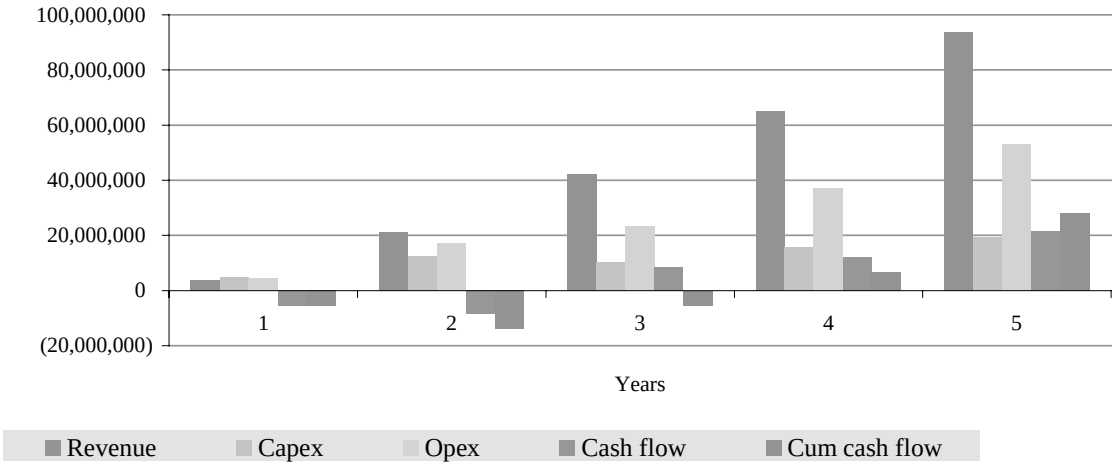

Figure 7

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3. The Business Case for Voice-over-DSL

While there are attractive financial prospects for data DSL services, an even stronger business case can be made for delivering voice services over DSL. The principal reason for this is not far to seek: The voice services market is more than 10 times larger than that for data services. If service providers can add voice to their data DSL offerings, the potential for significant revenue gains is immense.

The Voice/Multimedia Revenue Gap
($ millions)

Today's IP Market		**Today's Voice Market**	
Data Services	37,092	Switched Telephony	462,763
Internet Access	15,471	Fax	64,775
IP Telephony	1,890		
IP VPN	419		
Total	**54,872**	**Total**	**527,538**

$$\frac{\text{Today's IP Market}}{\text{Today's Voice Market}} = 9.4\%$$

Source: International Data Corp, 1998/Level 3

Figure 8 – Voice Multimedia Revenues vs. IP Revenues

Consider a business model scenario similar to that described above. Here however, instead of pure data services over DSL, the carrier offers voice services on top of the residential and business packages presented earlier. Adding these services would substantially increase the monthly rates for each package. The new pricing model would be as follows:

Package	Downstream	Upstream	Monthly Price
R1: Residential DSL 384 K with 2 voice lines	384 Kbps	128 Kbps	$89
R2: Residential DSL 1.5 M with 2 voice lines	1.5 Mbps	384 Kbps	$179
B1: Business DSL 384 K with 4 voice lines	384 Kbps	128 Kbps	$239
B2: Business DSL 512 K with 4 voice lines	512 Kbps	256 Kbps	$279
B3: Business DSL 1 M with 16 voice lines	1 Mbps	384 Kbps	$909
B4: Business DSL 1.5 M with 16 voice lines	1.5 Mbps	512 Kbps	$929

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These packages provide customers with basic DSL voice services through CPE with lifeline support. Additional voice services such as Caller ID, call waiting, or call forwarding would be made available for an additional charge. It is assumed that CPE rental and installation charges are identical to those for data DSL services.

The business impact of coupling voice and data DSL services can be assessed by applying this new pricing scheme to the business model and adding the following voice-specific costs:

Figure 9 summarizes these additional costs.

Voice Gateways	Terminate voice calls from the customer and interface with a circuit Class 5 switch. Manufacturer-quoted prices average $320 per line. A 15 percent cost factor is added to cover operations and maintenance.
Integrated Access Devices	Installed at customer premises at an average cost of $550. There would be multiple CPE versions, one for each package. CPE prices are expected to drop over five years at roughly 20 percent per year as volumes increase.
Class 5 Switch	Costs are calculated for chassis, software, line cards, and operations and maintenance. Initial cost per line is estimated at $460. This is expected to drop over five years. (Costs derived using prices from switch vendors.)

Figure 9

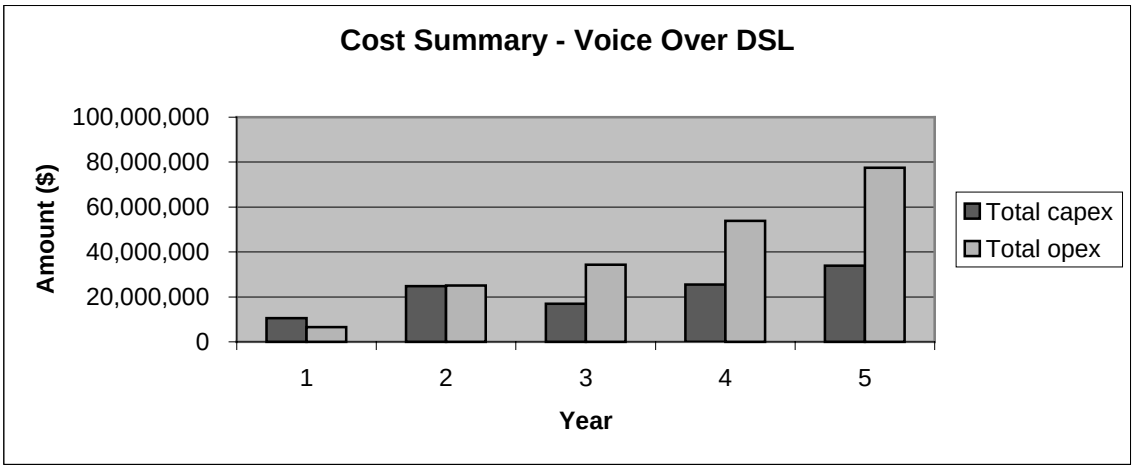

Figure 10

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These outlays are roughly 55 percent higher than those for data DSL services due to the additional equipment costs and the operational and maintenance costs associated with the voice-specific network elements. However—assuming the same business and residential line distribution patterns as with data DSL—the new revenue per segment model clearly indicates the superior financial opportunity with voice added to standard data DSL services.

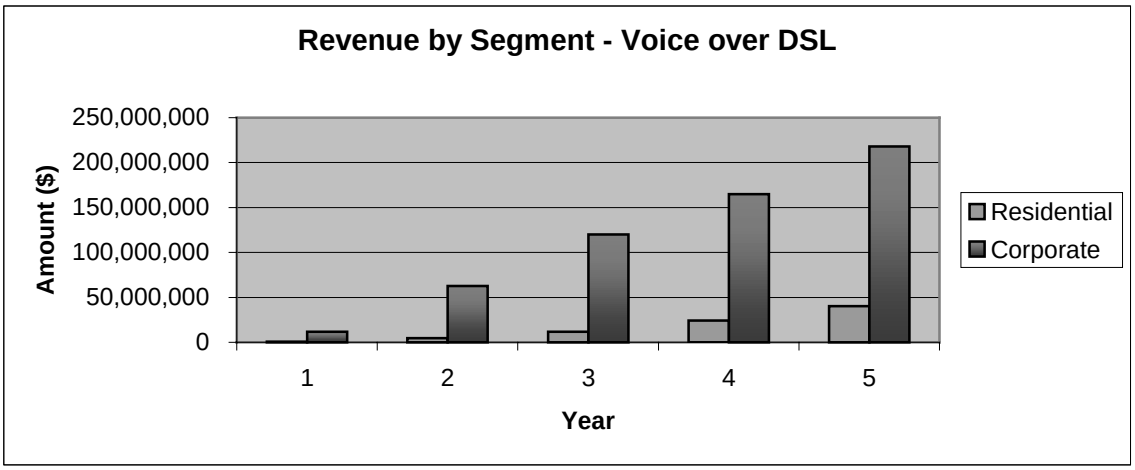

Figure 11

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The data DSL model showed year-five service revenues of approximately $30 million from the residential market segment, and just over $60 million from the business segment. Adding voice DSL services boosts these figures to almost $50 million from residential customers, and to more than $200 million from businesses.

The financial summary in Figure 12 further strengthens the business case for voice-over-DSL services.

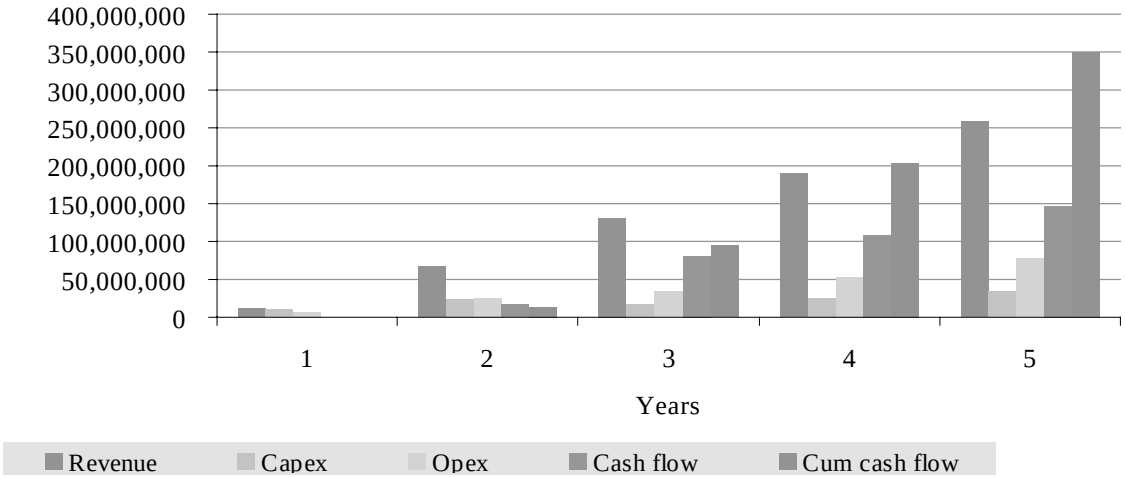

Figure 12 – Financial Summary

These results show the service provider can expect extremely positive cash flow over five years—with a cumulative cash flow of $350 million by the end of year five. This figure is more than 10 times that estimated for data-only DSL services. Similarly, the internal rate of return is projected at 694 percent, versus just 53 percent for data-only DSL.

(See *Appendix C* for the Profit and Loss Statement prepared from this business model)

The modeling tool used here is available to Lucent customers upon request.

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3.1 VoDSL: Competitive Advantages for ILECs

Incumbent local exchange carriers (ILECs) have been resistant to offering voice as an enhanced service to their DSL customers. This resistance is primarily attributable to fear of cannibalizing existing voice services, typically delivered over a depreciated voice TDM network. Moreover, there has been no strong incentive to carry VoDSL, as competitive local exchange carriers (CLECs) have not yet focused on delivering voice services to residential and enterprise customers.

Two developments have dramatically altered the status quo: 1) the recent FCC ruling that opens use of existing copper loops to CLECs at the same costs that ILECs enjoy; and 2) advances in delivering VoDSL services that make these services virtually indistinguishable from traditional voice services delivered directly from a Class 5 switch.

ILECs have assumed that VoDSL service is cross-elastic with POTS, but the reality is that once customers have chosen to explore DSL service offers from CLECs, they will naturally consider VoDSL as part of the package. If the ILEC chooses not to respond competitively to this challenge, they are likely to lose not only the DSL service revenue to the CLEC, but the POTS revenue as well.

Now that CLECs can compete for customers at effectively the same costs as ILECs, it is conceivable that enterprise and residential customers would select data DSL services from CLECs. CLECs have built their networks from scratch using the latest equipment and technology, enabling them to offer high levels of customer service. And CLECs are extremely nimble at marketing their DSL offerings to the public. Once residential and business customers have become comfortable with their data DSL services from the CLEC, they would be open to marketing initiatives for the CLEC's VoDSL services, canceling voice service from the ILEC. As this continues throughout the customer base, ILECs would soon see an erosion of voice service revenues in favor of CLECs.

ILECs have a unique opportunity to counter this threat. As the predominant data DSL vendors in many service areas, they can retain their customers by offering VoDSL services at attractive rates. Instead of losing the voice revenue to CLECs, they can compete to retain their customer base. By supporting voice-over-DSL, ILECs can retain their data DSL revenue as well, since customers would be attracted to a single voice and data service offering from a single service provider. ILECs can sell bundles of voice and data services that fit residential, SME, and large-enterprise market segments. Their experience in delivering voice services and enhanced services such as call forwarding, Caller ID, voice mail, fax services, Emergency 911, and lifeline POTS should give them a competitive edge.

The bottom line is that ILECs cannot hope to maintain an undiminished POTS revenue stream by not offering VoDSL. This strategy will only strengthen the CLEC competition, offering them an easy way to gain market share and reach economic viability by capturing ILEC customers. ILECs have to compete directly with these VoDSL offers. The alternative is to lose the customer entirely.

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4. Delivering Voice-over-DSL Services

The business case for VoDSL is compelling. But what infrastructure modifications do service providers require in order to deliver it?

There are currently two modes of VoDSL services delivery, the determining factor being the resources available within the provider's network. Carriers with existing circuit Class 5 switches can leverage them to offer VoDSL services by adding voice gateways that support the GR-303 interface. Carriers without circuit Class 5 switches can deploy these devices in combination with new, advanced-technology packet Class 5 switches.

Both of these VoDSL network configurations can be deployed today to enable service providers to realize sizable revenue gains.

4.1 Deploying VoDSL Using a Voice Gateway

Service providers have an opportunity to deliver voice-over-DSL services using an existing circuit Class 5 switch infrastructure. This offers the following benefits:

- Delivering popular CLASS features (for example, call forwarding and call waiting) while using the existing billing system, thereby reducing costs.
- Rapid time-to-market as craft-training and time-to-provisioning of voice circuits would be minimal since the interface from the Class 5 to the voice gateway is the GR-303/V5.2 interface standard and echo-cancellation is built-in on some gateways. Class 5 remote units such as a digital loop carrier (DLC) use this interface.

These benefits add up to immediate revenue opportunities, allowing the service provider to either move ahead of any competition or rapidly catch up to competitors who have launched VoDSL services.

In addition to a Class 5 switch with GR-303 interface (V5.2 for international switches), the elements of this network include:

- An integrated access device (IAD) at customer premises that supports the ATM Adaptation Layer 2 (AAL2) protocol
- ATM Adaptation Layer 2 voice gateway
- Next-generation digital subscriber loop access multiplexer (DSLAM)
- A multi-service core network that supports ATM, frame relay, and IP

4.1.1 Integrated Access Device at the Customer Premises

At the customer premises, the equipment of choice would be an integrated access device that carries both the voice and data traffic to the wide area network. The IAD combines the functions of a small key system and DSL router, making it ideal for residential and small-to-medium enterprise applications. Large-enterprise versions of the IAD supporting a primary rate interface for connections to a private branch exchange (PBX) are also becoming available.

The IAD supports a 10/100 BaseT port to connect the customer's LAN or router. It contains ports for 2 to 16 voice lines, depending on the customer requirement for connections to telephone sets, a key system, or a small PBX. The uplink to the network would be an x-DSL interface such as SDSL, HDSL 2, ADSL, or G.LITE. Future DSL standards such as G.HSDSL from the International Telecommunications Union (ITU) should be supported.

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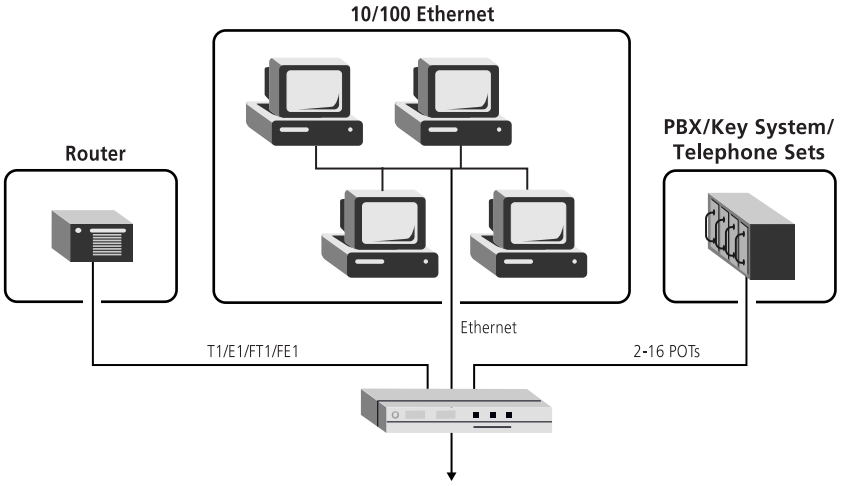
Traffic from the voice ports is carried as voice-over-ATM as prescribed in the AAL2 specification. To ensure service quality, voice service is generally sent using quality of service (QoS) such as constant bit rate (CBR). Support for AAL2 allows multiple voice channels to be multiplexed into an ATM cell. The IAD would have at least two ATM permanent virtual circuits (PVCs) to the network, with the ability to support more. The data traffic from the Ethernet port is sent to the network using the ATM Adaptation Layer 5 specification.

Signaling between the voice gateway and IAD for call setup and tear-down is specified in both the AAL2 protocol and multimedia gateway control protocol (MGCP). These call-signaling schemes also enable popular voice features commonly referred to as CLASS features to be presented to subscribers' telephone sets.

Lifeline POTS would be supported by the IAD using external battery packs. Lifeline battery support would be 8 hours for residential customers, and 24 hours for enterprise customers.



- **Integrated Access Device versions, all with lifeline support:**
  - **2-16 voice lines**
  - **10/100Base-T**
  - **Future support for FT1/FE1**

Figure 13

4.1.2 ATM Adaptation Layer 2 Voice Gateway

The AAL2 voice gateway is a crucial part of the network. As a carrier-class gateway, it converts AAL2 traffic from IADs into circuit-switched voice traffic for handoff to the Class 5 switch. This allows AAL2 voice traffic from IADs at customer locations to access voice circuits from the Class 5 switch. The voice gateway is designed to support thousands of ATM PVCs using multiple DS3, OC-3/STM-1 interfaces which connect to the digital subscriber loop access multiplexer (DSLAM).

A key benefit of this approach is that billing and CLASS features are derived from the Class 5 switch.

The AAL2 voice gateway connects to one or more Class 5 switches using multiple GR-303 or V5.2 interfaces. GR-303 specifies both the interface and the protocol to access voice circuits and CLASS features from the Class 5 switch.

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An ideal AAL2 voice gateway supports at least 1000 call sessions and has the flexibility to support any changes to the AAL2 specification, particularly aspects that pertain to signaling between devices like IADs and the voice gateway. The gateway would be highly scalable, supporting multiple GR-303/V5.2 interfaces and OC-3/STM-1 or DS-3 interfaces to the DSLAM. Interoperability with all elements of the network from the DSLAM and IAD to the Class 5 switch is required.

In addition, the gateway also manages call-control signaling with the IAD using AAL2 for call setup and tear-down.

4.1.3 Next-generation Digital Subscriber Loop Access Multiplexer (DSLAM)

A next-generation DSLAM delivers DSL services to customers over existing copper loops and supports ATM as the primary Layer 2 protocol. ATM allows for the efficient use of bandwidth and high service quality, and has become the Layer 2 protocol of choice in transporting data in service provider networks worldwide. The next-generation DSLAM effectively combines functions of an ATM switch with DSL line terminations of all types and high port densities to achieve an attractive cost per line.

The DSLAM would switch AAL2 voice traffic and AAL5 data traffic from the IAD to their termination points on the network. The AAL2 voice traffic would be switched to an AAL2 voice gateway as described, while the data traffic would be switched to an IP network provided by an Internet service provider or corporate central site. Terminating copper loops from the customer, the DSLAM provides QoS such as CBR for voice traffic and unspecified bit rate (UBR) for data.

The DSLAM should support multiple DSL standards including SDSL, HDSL2, G.HSDSL, and ADSL-DMT in one chassis, typically through different line cards. This gives the service provider the flexibility to offer multiple DSL services over the same chassis, therefore saving costs.

The DSLAM would be located in the central office point of presence (POP), delivering DSL services on copper loops to customer locations.

Figure 14 shows how these network elements create the VoDSL reference network model.

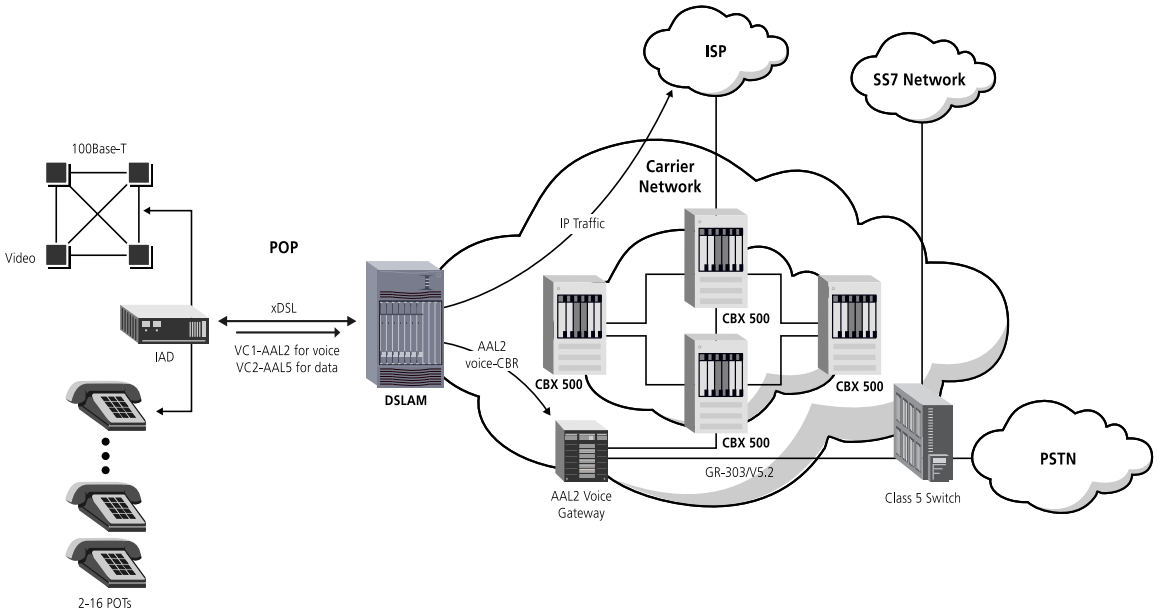

Figure 14

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IADs at the customer premises provide voice ports and an Ethernet port. The customer would use the Ethernet port to connect the local network to an Internet service provider or corporate central site. The voice ports would interface directly to telephone, fax machines, a small PBX, or key system. The voice traffic from the IAD would be transported on a specific PVC to the AAL2 voice gateway using a CBR. The data traffic from the Ethernet port would be switched to an ISP or corporate central site using AAL5 through a separate PVC. Between the IAD and the AAL2 voice gateway switch would be the next-generation DSLAM, that provides DSL services to the customer site, the ATM PVCs with appropriate quality of service, and ATM switching capabilities to deliver voice and data traffic to their termination points. The AAL2 voice gateway terminates all voice traffic from customer IADs and hands-off traffic to the Class 5 switch using GR-303 or V5.2 as the interface and protocol to access voice circuits.

4.2 Deploying VoDSL Using a Packet Class 5 Switch

Service providers can deliver voice-over-DSL using a converged network that supports both voice and data. The backbone and core would be a multi-service network that is QoS-aware, using ATM as the Layer 2 protocol. This converged multi-service network offers significant benefits:

- Lower cost to maintain and manage over separate voice and data networks
- Rapid technology improvements as packet-based products increase in performance, scalability, and functionality more rapidly than traditional circuit voice products
- Support for legacy services such as, analog voice services, and frame relay, ensuring continued revenue streams from these services as long as they are in demand
- Shorter time to provision and deploy than circuit TDM Class 5 switches, as basic configurations are simpler

These reasons are why service providers, incumbents, and new-entrants alike are building converged multi-service networks, commonly referred to as next-generation networks. As part of this next-generation network design, packet Class 5 switches perform the functions of a circuit Class 5 TDM switch, but use packet technology to carry and switch voice traffic.
These same switches enable the delivery of voice-over-DSL without the need for a GR-303 gateway.

4.2.1 VoIP Packet Class 5 Switch

Packet Class 5 switches are new voice switch designs that provide the functionality and CLASS features of traditional TDM switches, yet use IP, ATM, or IP-over-ATM to transport voice traffic.

Circuit Class 5 switches terminate copper loops, deliver voice services such as ISDN primary rate interface (PRI), basic rate interface (BRI), or analog line through these loops, and carry each “channel” in 64 Kbps circuit increments to be switched into the network. Next-generation packet Class 5 switches also terminate copper loops, but they use IP for call routing and transport, in effect replacing circuit Class 5 TDM switches.

Call routing is managed using IP route tables, and telephone number to IP address translation is supported. The packet Class 5 switch connects to the SS7 network and can switch calls as needed to the PSTN using ordinary T1/E1, PRI, or intermachine trunks (IMTs).

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The multimedia gateway control protocol (MGCP) specification has been submitted to the Internet Engineering Task Force and has become an industry favorite for controlling voice-over-IP gateways and external call control elements or call agents. The draft specification has been adopted by packet Class 5 vendors as the signaling protocol between IADs and new Class 5 switches. MGCP calls for a gateway-call agent protocol where coherent commands are sent to the packet Class 5 switch (the gateway) from the IAD (the external call agent) for call setup and call tear-down, and to establish VoIP service features to be presented to the IAD from the packet Class 5 switch. Extensions to the MGCP protocol have been implemented by vendors to extend its capabilities. For example to support the extension of CLASS features from a packet Class 5 switch to the telephones attached to the IAD.

Using packet Class 5 switches for VoDSL service delivery involves a next-generation DSLAM, plus an integrated access device at the customer premises that supports VoIP and MGCP. The packet Class 5 switch forms the core of the voice network and uses ATM to interface with the DSLAM.

Figure 15 illustrates the network configuration for VoDSL using a packet Class 5 Switch.

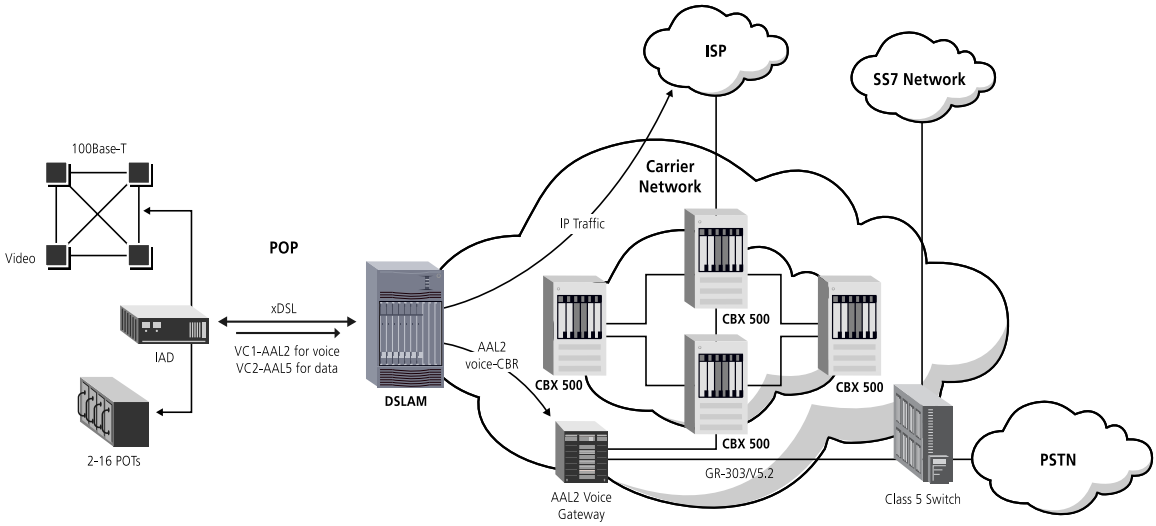

Figure 15

This network model converges voice and data into one backbone network using ATM for transport and IP at the Layer 3 protocol. Customer services for voice and data are supported by the IAD. Voice services are delivered as voice-over-IP running on an ATM PVC with a high QoS such as CBR. Data services in IP are delivered over a separate ATM PVC to an ISP or corporate central site. The packet Class 5 switch would terminate the voice traffic from the DSLAM and IAD and switch the VoIP session to the appropriate packet Class 5 switch elsewhere in the network, or convert the call into a circuit-switched session for transmission over the PSTN as necessary.

When the user at the customer location places a call, the IAD initiates a call setup sequence with the packet Class 5 switch using MGCP. Once the switch has the appropriate called number information, it initiates a route look-up within the switch to determine the appropriate packet Class 5 switch to send the call within the network. The VoIP packets are then routed to the destination packet Class 5 switch, which initiates a session with the far-end analog telephone set using MGCP to the far-end IAD, or regular voice signaling if the far-end phone is directly serviced over analog copper loops.

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Through MGCP, CLASS features such as call forwarding, call waiting, and three-way calling would be available through the new packet Class 5 switch and delivered to telephone subscribers. Telephone services would be supported in this network, providing customers with voice services they would associate with the PSTN.

5. Lucent Voice-over-DSL Solutions

Lucent Technologies offers state-of-the-art solutions for implementing both of the VoDSL network models described previously. These solutions enable service providers to rapidly take advantage of the lucrative revenue opportunities VoDSL offers.

5.1 Lucent Solution: AAL2 Voice Gateways with Class 5 Switch

Lucent offers industry-leading solutions for this network design:

- 5ESS-2000 Class 5 switch—the market leader for TDM Class 5 switches.
- CellPipe IAD integrated access device—a new IAD that supports both MGCP and AAL2 signaling, allowing it to be deployed in networks that use AAL2 voice gateways or packet Class 5 switches.
- Stinger™ next-generation DSLAM—a newly announced DSL access multiplexer that offers the capabilities of ATM switching and multi-DSL access facilities supporting ADSL-DMT, SDSL, and IDSL, with HDSL2 and G.HSDL to be available soon. Stinger is widely recognized as the leading next-generation DSLAM available today.
- CopperCom, Jetstream (Lucent OEM partner) and Tdsoft voice gateways—vendors of AAL2 voice gateways designed for incumbent and new service providers.
- Multi-service core: GX 550, CBX 500, and B-STDX 9000 multi-service suites

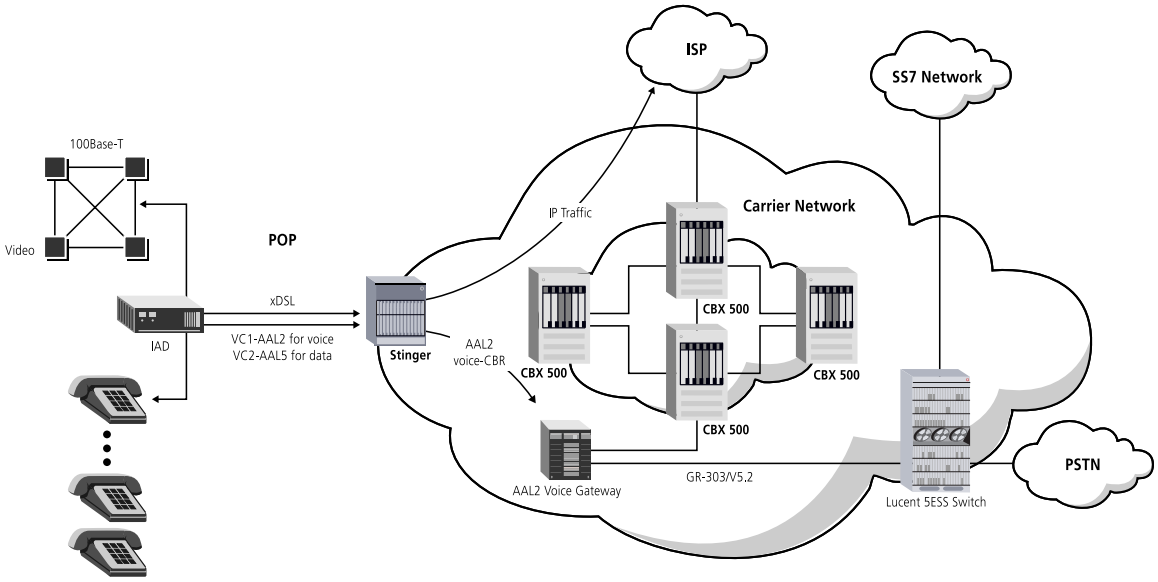

Figure 16

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Lucent provides the network equipment required to deliver a solution that scales rapidly to support up to several thousand users. This Lucent solution would be of strong interest to competitive or incumbent service providers who plan to deploy services outside of their normal service region.

If customers desire, solution elements can be provided by vendors who participate in the Lucent Wired for DSL program.

5.2 Lucent Solution: Packet Class 5 Switch

Lucent offers a unique solution set that enables service providers to quickly, and cost-effectively deploy VoDSL using a packet Class 5 switch. This includes the following network elements:

- PathStar™ Access Server—a packet Class 5 switch developed to deliver standard voice services over copper loops and use VoIP and traditional PSTN circuit interfaces. PathStar is a market-leading packet Class 5 switch for competitive carriers and incumbent greenfield networks.
- CellPipe 50 IAD.
- Stinger next-generation DSLAM.
- Multi-service core: GX 550, CBX 500, and B-STDX 9000 multi-service suites

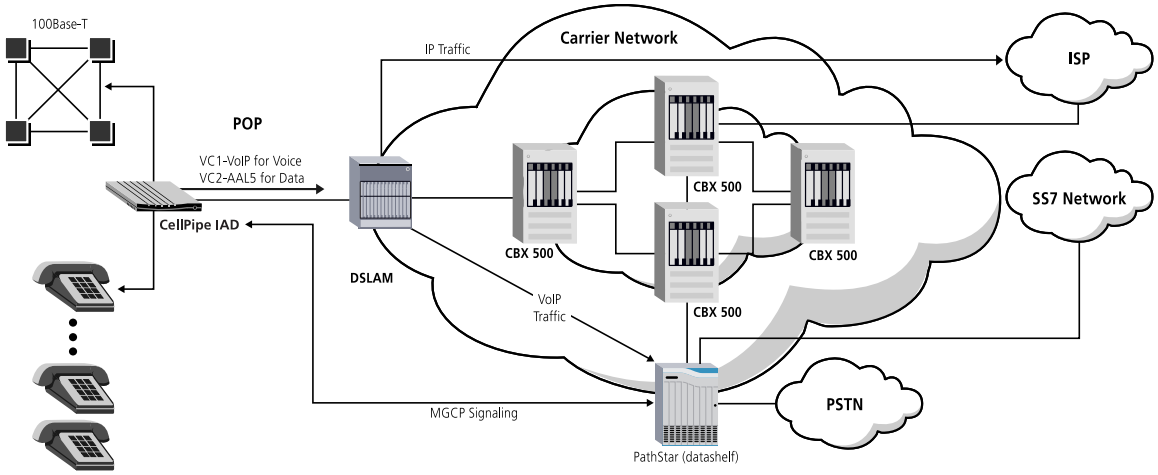

Figure 17

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This solution enables carriers to deploy a voice network using IP-over-FR/ATM as the backbone, with traditional voice loops for access. It features the PathStar Access Server, which integrates sophisticated voice gateway and Class 5 switching capabilities. PathStar provides proven Lucent CLASS features to telephone sets using MGCP to the CellPipe 50 IAD. It supports 14,000 POTs lines per system.

Calls placed outside the PathStar network would be routed to the PSTN, as PathStar supports T1/PRI interfaces and IMTs. Call detail records (CDRs) are available for billing purposes, and also compatible with BILLDADS and Kenan Arbor/BP Systems.

Service providers can deploy PathStar quickly and cost-effectively since the decision is made to implement voice-over-DSL service.

See Appendix D for further details on the Lucent VoDSL product set.

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Appendix A

Line Assumptions

Basic line assumptions	Over a five year period, the service provider will access local exchanges as follows: •Year 1: 15 •Year 5: 80 Accordingly, the model applies a 'step early' function to interpolate between first- and last-year value. This means that the operator co-locates at a faster pace in the early years to maintain a competitive advantage in key urban areas and build economies of scale, whereas it reaches other regions at a decreasing pace. The number of lines per local exchange starts at 30,000 and drops to over 19,000 by year five as the service provider deploys in less-dense service areas.
Potential DSL lines	DSL services are subject to limitations, primarily in distance to the exchange, but also with certain types of electronics. It is assumed that 75 percent of lines would be supported initially and that technology improvements at the end of the period have allowed 95 percent of the lines to be supported.
Residential lines	End-of-year (EOY) residential lines are calculated on the basis of households. DSL services are targeted at high-usage households, defined as households using the Internet for more than 10 hours a week. Customer churn rate is assumed to be 20 percent.
Corporate lines	The service provider is assumed to target SMEs only, which represent a subset of corporate lines. Their relative importance decreases slightly over time to reflect a faster increase in line usage for larger corporate customers. The number of DSL lines will depend on the proportion of SMEs online and the share of these purchasing DSL. Again, in the base case, we have used an S-curve to model service. Churn rate is 15 percent, with a typical lifetime of six years per corporate customer. Churn also decreases over time to reflect the provider's efforts to build customer loyalty through advanced packages.

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Table A.1 below illustrates the assumptions used to calculate the DSL line penetration:

Basic line assumptions	Year 1	Year 2	Year 3	Year 4	Year 5
Number of local exchange (LEX) by end-of-year	15	52	61	71	80
Lines per LEX	30,000	27,000	24,300	21,870	19,683
Total lines	450,000	1,407,857	1,492,714	1,546,521	1,574,640
Proportion of business lines	60%	58%	55%	53%	51%
Potential DSL lines (end-of-year)					
Lines supporting DSL	75%	80%	84%	89%	95%
Residential	135,000	474,560	562,336	648,118	731,155
Business	202,500	644,686	695,574	733,331	759,805
Total	337,500	1,119,246	1,257,910	1,381,449	1,490,960
Residential lines (end-of-year)					
Lines per household	1.10	1.12	1.14	1.17	1.19
Total households	163,636	532,024	583,083	621,559	648,532
DSL-capable households	122,727	422,959	491,364	555,215	614,067
Proportion of online households	20%	27%	36%	49%	66%
DSL-capable online households	24,545	114,199	179,102	273,207	407,926
Proportion of high-usage households	15%	16.3%	24.0%	34.9%	40%
High-usage DSL capable households	3,682	18,632	43,032	95,335	163,170
High-usage purchasing DSL	35%	34%	34%	33%	33%
Total DSL lines	1,289	6,426	14,624	31,927	53,846
Churn rate	20%	18%	16%	15%	13%
New lines	1,289	5,395	9,355	19,671	26,574
Residential lines (mid-year)	644	3,857	10,525	23,276	42,886
Corporate lines (end-of-year)					
Proportion of SME lines	60%	59%	59%	58%	58%
Average lines per SME	1.50	1.55	1.59	1.64	1.69
Total SMEs	108,000	311,773	305,019	291,591	273,949
DSL-capable SMEs	81,000	247,860	257,039	260,468	259,390
Proportion of online SMEs	15%	21%	29%	40%	55%
Online SMEs purchasing DSL	30%	32%	35%	37%	40%
Total DSL lines	3,645	16,585	25,575	38,537	57,066
Churn rate	15%	14%	13%	12%	11%
New lines	3,645	13,487	11,303	16,280	23,179
Corporate lines (mid-year)	1,823	10,115	21,080	32,056	47,801
Total lines	450,000	1,407,857	1,492,714	1,546,521	1,574,640
Total residential lines	180,000	596,931	667,303	725,564	772,191
Total SME lines	162,000	481,690	485,391	477,945	462,498
End-of-year residential DSL lines	1,289	6,426	14,624	31,927	53,846
End-of-year SME DSL lines	3,645	16,585	25,575	38,537	57,066
Residential DSL penetration	1%	1%	2%	4%	7%
SME DSL penetration	2%	3%	5%	8%	12%
Total penetration	1%	2%	3%	5%	7%

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Basic line assumptions	Year 1	Year 2	Year 3	Year 4	Year 5
Line summary					
Residential (end-of-year)	1,289	6,426	14,624	31,927	53,846
Corporate (end-of-year)	3,645	16,585	25,575	38,537	57,066
Total	4,934	23,011	40,199	70,463	110,912

Table A.1

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Appendix B

Cost Assumptions

CPE	•Unit cost at $500 minimum price and falls by 20 percent per year •Installation cost of $50 per CPE is assumed •Equipment from churned users can be handed over to new customers, reducing the overall capex for CPE •Each year, the DSL provider buys on average five percent CPE more than required, as a provisioning margin •Operating costs include O&M, installation, and de-installation of CPEs
DSLAM	DSLAM costs are split into two categories: •The empty chassis (which includes the processing power) •The line cards The model considers a chassis that can support up to 128 ports. Line cards (each supporting four users) can be added as demand grows. As with CPE, the model assumes a value of five percent as provisioning margin. Prices represent typical values.
Unbundled lines and co-location space	The cost of unbundled loops is driven by the number of lines (loop installation and rental) and by the number of LEX (co-location space). It is assumed that co-location costs will decrease over time, as the provider expands its service offering outside densely populated urban centers. Monthly costs at $2,000 per site. Loop costs assumed on average at $15 per pair with a one-time installation charge of $50 per pair. Actual loop costs are projected to drop more significantly due to the recent FCC ruling which levels the playing field for unbundled network elements.
Network operation center	Estimated at $1 million.
Other capital expense (capex)	Includes all systems and tools, such as billing system, IT systems, and customer care systems. The model assumes that a larger share of the cumulative capex is invested the first year, with upgrades the following year. Initial costs at $800,000 with a $190,000 upgrade.
Other operating expense (opex)	Includes marketing costs (acquisition and customer care costs), provisioning costs, and general overhead. The number of new DSL lines installed each year drives acquisition costs. Acquisition costs are assumed to be $130 per residential customer and $230 per business customer. Provisioning costs reflect the number of hours on average (one hour, in fact) required by an engineer to install the equipment to activate a line. Costs assumed at $105 per line. General overhead is assumed a constant 2 percent of gross revenue.

Cost estimates are based on published information available to Lucent Technologies.

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Table B.1 lists the total costs per year:

Total costs	Year 1	Year 2	Year 3	Year 4	Year 5
CPE	1,918,706	5,833,213	4,860,680	8,293,172	11,272,109
Unbundled line (DSLAM equipment)	3,719,459	12,848,801	15,808,134	24,695,317	33,483,792
Co-location costs	540,000	1,783,286	1,995,814	2,182,879	2,346,800
NOC	1,250,000	451,875	482,156	510,924	538,254
Systems	960,000	388,000	414,600	439,870	463,877
Marketing	1,444,377	6,125,067	7,769,580	12,423,388	18,164,110
Provisioning costs	518,032	1,944,866	2,086,507	3,559,152	4,875,816
Overhead costs	55,300	299,164	610,764	937,303	1,348,929
Total	10,405,873	29,674,273	34,028,235	53,042,005	72,493,686

Table B.1

Figures shown in US dollars.

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Appendix C

Summary of Profit and Loss Statement for Voice-over-DSL Model

Table C.1 Profit and Loss Statement

	Year 1	Year 2	Year 3	Year 4	Year 5
Revenue					
Total revenue	12,415,066	67,078,323	131,815,081	189,013,646	258,274,739
Operating Costs					
CPE installation and de-installation costs	836,583	2,980,733	2,957,485	5,543,347	8,590,704
CPE operation and maintenance (O&M)	142,459	554,627	860,697	1,236,487	1,501,133
Unbundled loops installation, rental, and termination	690,709	3,295,643	6,101,975	10,158,219	15,511,422
Co-location costs	540,000	1,783,286	1,995,814	2,182,879	2,346,800
DSLAM equipment O&M costs	378,594	1,525,414	2,548,007	4,046,644	5,787,359
DSLAM equipment testing costs	126,198	382,274	340,864	499,545	580,239
Voice gateway equipment O&M costs	193,092	691,124	937,289	1,278,001	2,100,900
Voice gateway equipment testing costs	143,148	420,048	294,631	443,043	661,893
Class 5 O&M costs	184,676	649,034	829,484	1,065,462	1,333,096
Class 5 testing costs	41,039	103,191	40,100	52,440	59,474
Network operation center costs	250,000	290,375	328,731	365,170	399,787
System costs	160,000	198,000	234,100	268,395	300,975
Customer acquisition costs	1,359,695	5,397,548	5,431,965	8,971,433	13,076,698
Customer care costs	585,409	3,102,677	6,291,610	9,504,017	13,946,323
Provisioning costs	740,045	2,775,683	2,995,480	5,140,997	7,015,204
Overhead costs	224,119	1,208,150	2,364,460	3,379,632	4,599,899
Total operating costs (opex)	**6,595,766**	**25,357,806**	**34,552,693**	**54,135,711**	**77,811,907**
EBIDTA	5,819,299	41,720,517	97,262,388	134,877,935	180,462,831
Total depreciation	2,482,363	8,525,496	12,725,425	18,270,995	24,108,472
Operating Profit (EBIT)	3,336,936	33,195,021	84,536,963	116,606,940	156,354,359
Capital expenditure	9,512,366	24,558,587	16,765,285	25,420,744	33,763,670
Cash flow	(3,693,067)	17,161,930	80,497,103	109,457,190	146,699,162
Cumulative cash flow	(3,693,067)	13,468,864	93,965,967	203,423,157	350,122,319

Table C.1

Figures shown in US dollars.

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Appendix D

Lucent VoDSL Product Set

Stinger DSL Access Concentrator

Stinger is a new carrier-class DSLAM designed for forward-looking service providers. It supports ATM and frame relay communication protocols, and all of the most common DSL access technologies.

Stinger offers all the benefits ATM brings to multi-service networks—including reduced installation, operation, and maintenance costs; efficient bandwidth management; and high availability.

Addressing the needs of carriers implementing cell-based backbone networks, Stinger features the high-capacity traffic aggregation capabilities and robust always-on performance expected of a true carrier-class product. It offers faster throughput and lower cost per port than any competing product.

PathStar Access Server

PathStar is an advanced packet Class 5 switch for converged voice and data networks. Combining voice gateway and Class 5 switching functionality, PathStar significantly reduces the complexity of deploying voice services. It also cuts cost per subscriber versus a combined voice gateway and Class 5 switch, enabling independent carriers and CLECs to provide VoDSL service more easily and cost-effectively.

PathStar integrates a digital loop carrier, a Class 5 telephony system, a voice-over-IP gateway, announcement server, and an edge router in a single system.

This revolutionary new product helps service providers maximize their return on investment with drastically lower capital and operations costs, unsurpassed support of both traditional and innovative IP-based revenue-generating voice/data services, and a future-proof open packet architecture.

CellPipe 50 IAD

The CellPipe 50 integrated access device (IAD) is an ATM-over-SDSL router/bridge that utilizes existing single-pair copper to combine data, voice, and video traffic over a single SDSL line. This next-generation IAD supports from four to 24 analog POTS lines with optional eight-hour battery backup for lifeline support and 10/100 BaseT Ethernet port.

5ESS®-2000 Switch

The Lucent 5ESS-2000 is a multi-services platform for offering subscribers a wide range of services, including wireless (both cellular and PCS), Internet and online services access, Advanced Intelligent Network (AIN) services, interactive video, multimedia services, and long distance services—all from a single switch.

The 5ESS-2000 includes multiple features recommended by the Network Reliability Council (NRC) to enhance SS7 network reliability and robustness: Message transfer part (MTP) restart, SLS expansion to 8 bits, and an improved signaling link test (SLT). In addition, ISUP message loop detection capability is provided to detect looped trunk routing errors. These capabilities, along with a continuing Lucent commitment to reliability, position the 5ESS-2000 as one of the most dependable digital central office switches.

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B-STDX 8000/9000

The B-STDX multiservice WAN switches offer carrier-class, cost-effective, and feature-rich frame relay, IP, and ATM services. Deployed for years to build core frame relay networks, the B-STDX is naturally evolving to play a leading role at the access point to the next-generation WAN. In addition to offering the broadest array of frame relay interfaces, standards support, and value add features, the B-STDX switch offers forward looking technologies such as IP Navigator MPLS, and ATM-to-frame relay interworking modules for high-speed trunking and low-speed converged access.

The B-STDX 8000/9000 in a modular platform available with either 8 or 16 I/O module slots. The B-STDX offers a low-cost point of entry for smaller network deployment that do not require the bandwidth and raw horsepower of the CBX 500 or GX 550 products.

CBX 500

The CBX 500 multiservice WAN switch is a foundation for next-generation networks that service providers can use to scale, simplify, and consolidate converged public networks of today and tomorrow. Service providers can leverage this switch's intelligence, reliability, and multi-service port density into new revenue sources while streamlining their networks. Deployed at the network core or edge, this 5 Gbps switch delivers ATM, frame relay, and IP carrier-class networking. Together the quad-plane redundant switch fabric, the output-buffering scheme, and the hardware implementation of ATM service classes ensure end-to-end quality of service (QoS).

A wide range of I/O modules let service providers deploy unmatched port densities at speeds up to 622 Mbps over fiber and copper. Module-based processing of routing and signaling enables horsepower to scale as your network grows. OSPF-based Virtual Network Navigator automatically routes switched and permanent circuits and reroutes around link and switch failures to guarantee service-reliability. With unified Navis network and service management and customer billing software, service providers get "point-click-done" provisioning while decreasing operational cost.

GX550

The GX Smart Core ATM product family offers service providers an intelligent approach to building next-generation networks. This carrier-class, multi-service platform transports multiple services over a single network infrastructure. Services such as ATM access, frame relay, and private line can all be provisioned and managed by the NavisCore and NavisXtend network and service management systems.

CopperCom, Tdsoft, Jetstream Voice Gateways

Supplied from Lucent OEM partner CopperCom, and Jetstream and wired for DSL partner Tdsoft, these innovative new products feature a sophisticated architecture supporting high-speed data delivery plus multiple voice connections. Both voice and data are delivered over a single, conventional copper telephone line in the local loop. The architecture integrates well with existing DSL, ATM, and voice switching equipment.

Sitting behind the DSLAM, these gateways convert packet voice traffic to conventional voice signals and send it on to the PSTN through a Class 5 switch. CopperCom supports both TR-008 and GR-303 interfaces while Tdsoft supports V5.2, and Jetstream supports GR-303, making the gateways appear as a digital loop carrier (DLC) would to the switch. These gateways are constantly evolving and support for additional interfaces may become available throughout 2000.

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Wired for DSL Program

Lucent's Wired for DSL partnership program is a new initiative dedicated to ensuring multivendor DSL interoperability. The primary purpose of this program is to verify the compatibility of third-party vendors' equipment and/or specific applications with Lucent's MultiDSL solutions. After the successful completion of the required internal tests, the select DSL solutions become Wired for DSL "certified." This certification assures service providers of product compatibility and reliability when deploying a multivendor DSL network.

Wired for DSL eliminates the concern of non-interoperability between Lucent's DSL solutions and our partners. Today, Wired for DSL reduces the time of deployment for new revenue-generating services by ensuring multivendor DSL interoperability.

Currently, the Wired for DSL partnership program is comprised of nearly a dozen companies. The certified solutions include leading CPE and VoDSL gateway/IAD equipment as well as DSL-specific applications.

About Lucent Technologies

Lucent Technologies develops, manufactures, sells, and services wide area networking solutions for telecommunications carriers, Internet service providers, and corporate customers worldwide.

For more information about Lucent and its products, please visit the Lucent Web site: www.Lucent.com. Or, call 1.800.621.9578 to talk with a sales representative.

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