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CRASHING THE BANDWIDTH BOTTLENECK

BRINGING BROADBAND OVER THE LAST MILE

Implementation Issues for ADSL

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Introduction

This paper covers some business and technical implementation issues of extending the broadband network to the end user, using Asymmetrical Digital Subscriber Line (ADSL) to send multi-megabit data over ordinary subscriber loops, the "last mile" of the installed copper plant, to end-users.

In order for a mass-market, broadband-access network to develop, it requires low costs and flexible services for market segments. Key issues of ADSL service are how to configure and manage concurrent connections from end-users to their multiple service destinations, end-to-end. 3Com sees three implications:

- ATM is the key back-end infrastructure needed to build a broadband-access network over the last mile, because it best accommodates end-to-end connections. For the ADSL end user, who is a telecommuter, Internet enthusiast, or small office, ATM does wonderful things. But the carriers must hide the complexity of ATM from the end user; this is a lesson learned from ISDN experience worldwide.

- Renovation of the Element Management System and the configuration process are key to making the business case for mass deployment. Management systems will have to learn to look end-to-end, not just at a collection of elements.

- Open standards are the key to lowering costs, protecting customers' investments, and achieving interoperability. ADSL equipment vendors and customers that are slow to adopt open standards endanger their ADSL business.

Why ADSL?

The value proposition of ADSL service is compelling for the end user: for most applications it provides near-Ethernet performance for small or home offices. Multiple megabit-per-second bandwidth to the home or small office enables new applications in commerce, entertainment, education, and science. The service cost in the typical carrier's business case is roughly comparable to basic ISDN service.

How does ADSL operate? The secret is to take advantage of the wire's ability in the subscriber loop to transmit signals at a much higher frequency than voice-band transmission. While higher frequency transmission on subscriber loops is noisy, digital signal processors (DSPs) can remove the noise. DSP chips are fast and cheap, and are getting faster and cheaper every day. Many companies are building ADSL chips that incorporate dedicated DSPs. Some, like 3Com, are moving to general purpose, reprogrammable DSPs. Currently, 3Com is developing – with a 1600 MIPS (million of instructions per second) DSP chip from Texas Instruments – enough horsepower to run any of the protocols required, allow for software updates, and even process multiple ADSL channels per chip.

ADSL, or Asymmetrical Digital Subscriber Line, gets its name from the asymmetry of how data is sent and received. The user sends data at one rate but receives data up to 10 times the send rate. This send/receive rate asymmetry is effective for many typical applications where more data downloads than uploads. Such applications include WWW access, database queries, file transfers, and broadcast video.

ADSL Equipment and Architecture Overview

ADSL service requires an ADSL modem on either side of the DSL, or digital subscriber line.

End Users Products are available for the single user, or with integrated routers to support multiple users on a small-office LAN. Today, most single-user modems are standalone and attach to a PC via Ethernet. Another approach that lowers cost is to build an internal-PC card modem for an ISA or PCI slot in the PC, and which can rely on host processing from the PC and Microsoft's NDIS standard for routing. 3Com's new COBRA-DSL™ is an example of this approach.

End-User Modem GUI ADSL services currently require a manual setup for the user modem; users must enter IP addresses and other configuration information. The necessary configuration information is supplied out-of-band—through a fax, letter or, most likely, an installation technician. The information must be entered via a GUI application for the modem. Later in this paper, we'll look at the how to evolve this process and eliminate manual data entry.

Since PCs are so often managed over a LAN, one option for improving the manual data entry procedure is to have the software application and GUI for multi-user modems be implemented as HTML code using a standard browser application. This is how 3Com implemented the GUI for VIPER-DSL™, so it can be administered from anywhere on the LAN. Internal modems should take advantage of Microsoft's Plug and Play installation facility, as does COBRA-DSL.

Carrier Equipment To multiplex the ADSL lines and translate data to ATM or other links, carriers have two approaches. First, rack-mount modems called DSL Access Multiplexers (DSLAM) have multi-port ADSL cards and multiplex the signals to a fatter ATM or Frame Relay pipe. The other approach for is to use ADSL line cards in Digital Loop Carriers (DLC) or Remote Terminals (RT). Carriers increasingly use DLCs to act as a first stage of subscriber-line concentration. New-generation DLCs such as those from Advanced Fibre Communications have extremely high bandwidth and mix-and-match capabilities for offering various data services.

Splitters Enabling Voice Service ADSL service was designed to get maximum use of the installed copper subscriber loops, and this includes the capability to use voice on the same line as data, unlike analog dial-up access. ADSL signals can't go through a switch because the signal contains high frequencies. This is unlike analog modem signals commonly used by the dial-up ISP, where the signal can proceed from the user's modem, over the line to the switch, and over another line to the ISP's modem bank. For ADSL, the carrier must install the DSLAM in the signal path before the switch. To support both voice and data, both carrier and customer install a frequency filter in a Y configuration called a POTS splitter. The splitter sends voice signals to the voice switch and sends data signals to the DSLAM.

Trunk Side Interface Regarding the trunk side, some integrated carriers/service destinations favor Frame Relay, especially smaller central offices with only T1 connections. Carriers are increasingly investing in ATM backbone networks that connect to the DSLAM because:

- Aggregate bandwidth requirements are beyond Frame Relay capabilities, and need DS-3, OC-3 or higher bandwidth.
- Customers want - and will pay for - a guaranteed bandwidth capacity. ATM lets the carrier implement better Quality of Service (QoS) guarantees.
- Customers need concurrent access to multiple carriers and multiple service destinations. These capabilities are much better supported with ATM.

ADSL Service Issues

Basic service issues include the choice of equipment, cost of provisioning, as well as how carriers can price their services and compete for customers. Six critical issues will be examined in this section, including:

- Competitive Services and Impact on Existing Services

- Equipment Standards, Availability and Affordability
- Data Rates
- Concurrent Connections to Service Destinations
- Configuring the User Modem
- Open Standards and Protocol Maturity

Competitive Services and Impact on Existing Services

External Competition Carriers face emerging competition from cable and wireless operators. 3Com anticipates affordable, mass-market, high-bandwidth wireless services achieving data rates of up to 256 kilobits per second (Kbps) within the planning horizon. This capability uses on-channel bonding, which simultaneously uses multiple channels per connection. This is occurring rapidly in both the CDMA and GSM communities. 3Com also sees the cable industry as aggressively pursuing the broadband data business. Carriers that don't establish an early lead in last-mile broadband could easily find themselves at a considerable competitive disadvantage.

Internal Competition Most carriers see ADSL opportunities as positioned above their ISDN business and encroaching on their high-margin and fast-growing T1 business.

Carriers' Approach Carriers want to rely on service tiers to position ADSL to avoid cannibalizing other businesses. Service tiers involve such variables as a service's speed, quality, and up-time guarantees. ADSL with ATM is enormously configurable, allowing carriers to fine tune their service offerings.

Equipment Standards, Availability and Affordability

Equipment Cost ADSL equipment costs are decreasing to the range of ISDN or even analog modems. For example, 3Com has just introduced an end-user ADSL modem for below $300 US, and when combined with the 3Com DSL access multiplexer (DSLAM), the U.S. list price is below $900 per subscriber line. And prices will continue to fall. Large companies that manufacture millions of modems a year, like 3Com, Cisco, and Ascend, will bring manufacturing clout to the market, through economies of scale.

Data Rates

What factors affect the data rates that carriers want to offer? We've mentioned business impact on the carriers' existing service. Interference is another.

Interference First, loops come into switch facilities in bundles. Interference problems can occur as adjacent lines. Interference is complicated by who owns the line versus who leases the line. In the U.S., alternative phone companies can lease lines from phone carriers and run their own DSL service. There are strict limits to interference that alternative telephone companies can put on carriers' lines.

How severe is the interference issue with ADSL? Technically, no worse than it is for HDSL [High bit rate Digital Subscriber Line], a more-established market for high-speed interconnection of campuses. HDSL must be managed "by hand," line by line, which is acceptable because HDSL is more limited in deployment than ADSL. ADSL will be deployed on a mass scale, and carriers are seeking ways to eliminate and prevent the issue en masse.

Interference Workarounds Lowering transmission speed also reduces the energy placed on the line. Some carriers are moving to a service that's positioned between their ISDN service and their T1 service. This "ADSL
offer 56 Kbps to 1 Mbps or better service, and reduces or eliminates interference issues.

There are different modulation schemes for ADSL; they have different interference profiles. This means that ADSL products from different vendors are incompatible, a situation 3Com is determined to correct. Carriers are in trials to investigate their interference profiles versus vendor claims. Not withstanding the ADSL Forum's efforts to date, the market hasn't endorsed modulation standards yet. Like analog modems, 3Com's strategy is ultimately to provide multiple modulation schemes in software so customers don't have to worry about the vagaries of standards adoption. To the customer, it has to appear as "just another modem" before the market will establish itself. To do this, 3Com is developing general-purpose DSP chips. In fact, 3Com is building a hybrid modem that also provides 3Com's x2™ 56 Kbps analog modem, so the user can be assured that his investment is protected.

Concurrent Connections to Service Destinations

A stringent end-user requirement for ADSL services is concurrent access to multiple service destinations. The customer needs to connect to one or more corporate networks, as well as to one or more ISPs based on their differentiated service offerings. Carriers can charge for incremental connections. In the near future, we see people connecting to networks of other communities of interest like church and school.

Multiple Connections with PVC This is the earliest and simplest method: the carrier configures Permanent Virtual Circuits (PVCs) between the user and service destination. PVCs are always hooked up to a particular destination. The ATM equivalent of this is an end-to-end connection along a fixed path. The advantage of this is it uses off-the-shelf protocols, products are available now, and it's deployable. The disadvantage is that it takes more hands-on work, it wastes trunk-side bandwidth, and it's difficult to manage.

To Configure the Network The carrier has to preconfigure PVCs to various service destinations using an Element Management System (EMS). The carrier configures PVCs on the EMS workstation, accessing each user's port on the DSLAM, as well as the corresponding ATM User-Network Interface on the edge switch or router for each service destination that each user signs up for. This is where class of service, bit rate limits and guarantees are defined.

How? In a manual operation, a user sits at an EMS station with a printout and enters numbers. This high-tech clerical work is error prone and costly. The carriers are trying to automate this process. If automated, the telco sales person who takes the order enters basic information into the order entry system and it automatically sends messages to the management system. This takes time the for the phone companies to build. ADSL as a low cost-service will need millions of customers to become profitable, so this must become an automated process.

Configuring the User Modem

Multiple IP Addresses. Having multiple service destinations means having multiple user addresses, since each service destination wants to assign user addresses and can't reconcile a user's address with the others. For example, it's important for a secure corporate LAN to assign appropriate addresses that logically put remote users "behind" a security firewall. Therefore, it's a critical requirement that the ADSL architecture accommodate this.

Two main approaches are available to implement it, as illustrated by two different 3Com modems targeted to different market segments and price points.

VIPER-DSL™ (multi-user, standalone, integrated router) supports routing protocols and multiple address translation. Therefore, VIPER-DSL allows users to have multiple IP addresses, each one provided by a different service destination. If VIPER-DSL receives data from AOL, the user appears to have one address, and if VIPER-DSL receives data from a corporate LAN, the user appears to have another address. In other words, VIPER-DSL allows concurrent use of two addresses.

COBRA-DSL™ (Internal PC card modem, single user, uses some host processing on the PC, ultra low-cost) uses a call-management selection in its GUI which binds the protocol stack to a particular ATM virtual circuit (VC). The user chooses one and then the other, with the modem's software package.

Regardless of software efficiency, it's bad policy to require the user to be concerned about IP addresses and other technical specifications. Therefore, most carriers initially plan to have service people do the installation through on-site visits. This is expensive, error prone, and limits the kind of ease-of-use that creates "out-of-the-box delight" that builds a mass market. This heavy manual workload is one reason why trials have been slow to progress into real ADSL services. The solution is to teach the modems to configure themselves based on information in the DSLAM or DLC to which they attach upon power-up, and based on information that comes from the carrier's Element Management System.

Evolution to SVC The PVC scheme works fine at the access network (the last mile) level, but is inefficient on the trunk side. Service destinations with T1 and DS-3 connections will quickly exhaust bandwidth because PVC connections require a lot of router table information, which is costly for carriers as well as service destinations. Therefore, the architecture will evolve to SVC, or Switched Virtual Circuit, which operates analogously to ordinary phone calls that are dynamically established by dialing, and dynamically disconnected by hanging up. In this evolution, Switched Virtual Circuits will at first be used between the carrier's edge switch to the service destination, triggered when the user powers up the modem. The benefits: efficient use of trunk space and saved router table space on their router or edge switch for both carriers and service destinations.

Down the road, a more advanced method is to establish SVCs end to end, so that modems request a connection to particular addresses on the fly. The overwhelming benefit to the carrier is that it doesn't have to configure a PVC for each end user.

But the user still has to have the address of any particular service destination. How does this happen? It's again analogous to dialing a phone call: the end-user has to get a "phone number" from the service destination. The modem vendors will provide end-user software applications, relying on ILMI or other techniques that give the user a directory from which the user chooses service destinations. Why isn't this available now? This scheme must support SVCs in user modems and network. ATM switches are just now coming to support SVC.

Open Standards and Protocol Maturity

3Com believes that ADSL communication protocols must be solid, available, robust, deployable and above all, open, like other technology areas that begin with proprietary products and are moved by market forces to adopt open standards.

Like mainframes vs. client/server, UNIX, and even NT, open-market players tend to become the market share leaders, and the other vendors disappear. Open standards make equipment interoperate between vendors, lower costs, and protect investments. This makes for a better business case for carriers and service destinations, and a better value proposition for end users. We need open standards and a renovation of system management tools that reduce operations, administration, and management burdens for carriers, and are working within the ADSL Forum, ITU Study Group 15, Question 4 and various ad-hoc consortia. Therefore, 3Com supports the following open standards:

Line Coding After all the debate about modulation standards, our position is: may the best standard win. Our product strategy is to support whatever the market wants, which is likely to be determined because of interference reasons we'll cover later. That's why 3Com is building its code in software reprogrammable DSPs; to protect the user's investment.

IP Encapsulation over ATM 3Com chose RFC-1483 as an initial method to encapsulate IP packets over ATM to meet these requirements. It's stable and well supported in the edge routers owned by service destinations. Its limitation is that it doesn't let the user modem poll the carrier to get IP addresses; either the customer or an installer must do that. Even with great user software to help with this, the lesson from ISDN is that requiring the end user to supply this configuration information is a barrier.

The next step is to add additional supports for PPP (the Point-to-Point Protocol) because it provides a more thorough level of auto-configuration. The user's modem can simply poll for the addresses that have been assigned by the service destination. This implementation is new, but backed by Microsoft, Cisco, 3Com, and other large players. So 3Com feels confident in it. This is where our products are now.

3Com rejected both Multi-protocol Over ATM (MPOA) and Layer 2 Tunneling Protocol (L2TP) because of immaturity and because they both require the carrier to do too much hands-on connections work.

Support for Management Clearly, management systems will have to do more and reach farther than they do today. They'll have to reach across copper subscriber loops, and they'll have to reach across the country or world to service destinations. To facilitate this, 3Com has endorsed an ATM Forum standard called ILMI at the ATM layer.

Automatic CPE Configuration ILMI (Integrated Local Management Interface) is an auto-configuration approach for user modems that's receiving attention and endorsements, including 3Com's because it promises to relieve this service bottleneck. ILMI is a ATM Forum standard and method to manage a UNI (or ATM terminal device). It is being extended for ADSL, but it's well defined, and goes back to older versions of UNI. It runs on the user modem and requests information from the DSLAM and the management system.

Once ILMI is broadly accepted, the user modem can query the network for the configuration information, avoiding manual intervention and costs.

Embedded Operations Channel At the ADSL layer, we need standards for an operations channel that's independent of ADSL line coding, a way to support an OAM application over ADSL. We believe that the T1 413 EOC standard is inadequate.

These are the focus of our recent work with the ATM Forum and other standards body work and invite your participation in the open standards efforts.

Why are theses choices so important? Because they provide (1) a foundation for interoperability between equipment vendors, and (2) a foundation for the development of new management tools that look end-to-end over a connection, not just at a collection of elements. ADSL market development hinges on both.

Billing Systems Must Evolve. Finally, billing systems must evolve to support the flexibility and variety of service offerings that ADSL affords. Element Management Systems will need to capture and forward user account activity to the appropriate destination for billing purposes. It must be flexible to accommodate different QoS levels, as well as flat and per diem billing rates.

Conclusions

- A successful mass market using ADSL will require enormous service flexibility. ATM is necessary to deliver this flexibility.

- ILMI and integrated Element Management Systems are critical to relieving the labor required so that a carrier technician isn't required to manually install user modems. This is critical to the cost structure to enable ADSL to become a mass market.

- Although many carriers will also be Internet Service Destinations, the carrier and service destination aren't always one and the same, so it must be easy for the customer to access multiple service destinations independently.

- ADSL changes the way service destinations connect to their users—through big ATM pipes rather than modem pools. The modem pools shift to the carriers. This will change the cost structure and, therefore, the economic model and service offerings of all players.

- Small office/home office users who get their hands on ADSL at home don't want to give it up. There is enormous pent-up demand for ADSL. Broadband in the last mile has important social implications for how people commute, travel, work, and play.

- 3Com's approach is to drive a completely open standards marketplace, in order to lower costs, create interoperability, and protect customers' investments. Public-domain standards and open systems is the key to market development. We invite you to join 3Com in these efforts and look forward to your active participation with us within the ITU, ADSL Forum, ATM Forum, and other industry groups. 3Com challenges you not to give in to proprietary implementations which we feel will hamper market development. Since the standards need to support the vendors of end-user equipment, carrier equipment, and service destination equipment, all supported by a renovation of management systems, the standards have to work for everybody, or they won't work for anybody.