3Com Technical Papers

Inverse Multiplexing over ATM (IMA)

A Breakthrough WAN Technology for Corporate Networks

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Inverse Multiplexing over ATM (IMA)

A Breakthrough WAN Technology for Corporate Networks

By Randy Brumfield

Asynchronous Transfer Mode (ATM) has compelling business benefits as a WAN technology and is on a steep growth curve both in public carrier networks and in private organizations with requirements for networking voice, video, and data traffic. As enterprises require greater WAN access in support of high-volume traffic, however, they have been faced with either paying for T3/E3 links that they often could not fully utilize, or adding more T1/E1 access lines, creating multiple parallel networks.

Inverse Multiplexing over ATM (IMA) offers a solution to this dilemma. IMA is a breakthrough standard that enables "right-sizing" and "right-pricing" of enterprise access solutions for organizations with low- to mid-range WAN traffic requirements, and offers the benefits of ATM's quality of service (QoS) and statistical bandwidth optimization capabilities. IMA divides an aggregate stream of ATM cells across multiple T1/E1 WAN links on a cell-by-cell basis—hence the name "inverse multiplexing." In combination with ATM, IMA simplifies and reduces WAN cost of ownership through traffic consolidation, while ensuring fault tolerance through traffic management and link control. The sum of these benefits lowers costs in many ways, directly impacting the corporate financial bottom line. In short, with ATM and IMA, the enterprise WAN becomes a more efficient multiservices tool for carrying voice, video, and data.

This paper is intended for the network executive who needs to secure cost-effective WAN solutions for his or her organization. It surveys the benefits of ATM in the WAN, and reviews the cost barriers prior to the implementation of IMA. It then describes how IMA brings new cost effectiveness and functionality to ATM deployment across the WAN and explains the basic workings of IMA technology. The paper outlines several criteria for selection of IMA solutions and provides an overview of 3Com products that use IMA, with application examples. Finally, the paper describes 3Com's strategy to further develop IMA solutions for enterprise networking across the WAN.

ATM Across the WAN: Changing the Nature of Networking

What are the challenges today for enterprise network managers seeking to maximize the effectiveness of their wide area networks? Among the steepest: conquering complexity and reducing cost. With a growing number of remote offices to be linked to central sites, and with the explosive growth of online services and corporate intranets, extranets, and Internet access, businesses are depending on increased bandwidth for WAN access more than ever before to carry out their daily operations. In addition, the increasing data bandwidth requirements and unforgiving delay constraints of real-time, interactive applications such as video streaming, group videoconferencing, and telephony make it imperative that WAN links be as resilient and easy to manage as possible.

Over the past several years, Asynchronous Transfer Mode (ATM) has emerged as a technology of choice for reducing the complexity of WAN communications. A proven workhorse in LAN backbones, ATM offers many important benefits that leverage to the WAN. Among them are speed, scalability, traffic management, and the ability to integrate LAN and WAN functions, binding voice, video, and data onto a single uniform protocol and design.

Inverse Multiplexing over ATM (IMA), a User-to-Network Interface (UNI) standard approved by the ATM Forum in 1997, raises ATM to an even higher level of WAN functionality and flexibility. In a nutshell, IMA specifies a transmission method in which ATM cells are fanned across several T1/E1 lines, then reassembled at the receiving end without loss of original ATM cell order. By enabling consolidated transport of the ATM protocol over cost-effective T1 and E1 lines, IMA extends ATM to all portions of the WAN, not just to locations where traffic is very high. Effectively, IMA delivers ATM to the masses.

ATM Benefits in the WAN

You could think of IMA as the previously unknown factor that adds cost effectiveness into the ATM WAN equation. And because the result equals ATM benefits for all WAN users, not just those with very high traffic loads, it's worthwhile to quickly review ATM's WAN benefits.

- *Highly scalable bandwidth.* ATM's biggest claim to fame is its speed—from ≤ 1.544 Mbps to gigabit ranges, with 1.2 Gbps (SONET OC-12) as the maximum customer premise bandwidth available. The benefit: incremental costs for incremental bandwidth, resulting in increased efficiency on high-traffic WAN links and an opportunity to "right-size" bandwidth needs even to very high user demand.
- *Network simplification through consolidation.* ATM is the answer for combining applications that traditionally required different networks because of the different transport requirements of their traffic. This in turn lets network planners stop the proliferation of complex parallel networks: for example; one carrying data, another carrying voice, and another carrying video. ATM's ability to consolidate all types of traffic onto a single WAN link greatly reduces complexity, and simplifies network management by eliminating these separately managed lines.
- *Bandwidth efficiency.* Consolidation of diverse traffic types also lets network managers with high volumes of traffic fully utilize high-speed WAN links, instead of partially filling separate links with different types of traffic.
- *Quality of service.* ATM offers bandwidth allocation based on user-defined needs and prioritization, as well as load sharing of multiple technology types for guaranteed quality of service (QoS). ATM's traffic management controls enable seamless integration of voice, video, and data while providing the separate management techniques required by each type of traffic.
- *Open connectivity.* Because ATM is not based on a specific type of physical transport, it is compatible with all currently deployed physical networks. It can be transported over twisted pair, coax, and fiber optics. And since ATM is a standard rather than a proprietary protocol, it can run on any vendor's standards-compliant products or be purchased from any carrier.
- *Excellent fault tolerance.* ATM networks can be built with very high levels of fault tolerance at relatively low cost. IMA, for example, allows for load sharing and maximum network uptime.
- *ATM infrastructure availability.* Service providers have invested heavily in the ATM infrastructure for reasons similar to those of enterprises: consolidation of traffic/backbones, better bandwidth utilization, and so on. ATM can also be deployed as a private network built from leased lines such as T1/E1, T3/E3, or OC-3/STM-1.

Taken in sum, ATM's capabilities—scalable bandwidth, network simplification, bandwidth efficiency, guaranteed QoS, open connectivity, fault tolerance, and infrastructure availability—make it invaluable for corporate WANs. ATM is also a stable WAN technology with an extensive public infrastructure. Up until now, the primary barrier to securing ATM benefits in the WAN has been the limited availability of carrier service.

Identifying the ATM WAN Barrier

Despite all the benefits provided by ATM, the biggest deterrent to its deployment across the WAN has been a narrow choice of ATM WAN transmission speeds and the gap between low- and mid-range services. This results in a cost structure that has made it difficult for the majority of businesses to "right-size" the number of WAN circuits to their network needs. Let's look at the options that were available to network planners prior to the development of IMA technology.

Option 1: T1/E1. At 1.544/2.048 Mbps, T1/E1 lines are cost effective and widely accessible. But at the edge of the network, moving out to the WAN, a significant portion of businesses need to scale beyond a single T1/E1 link—especially with higher-speed LAN technologies, soon to include Gigabit

Acronyms and Abbreviations

AAL
ATM adaptation layer

ATM
Asynchronous Transfer Mode

ICP
IMA Control Protocol

IMA
Inverse Multiplexing over ATM

MIB
management information base

QoS
quality of service

SNMP
Simple Network Management Protocol

SONET
Synchronous Optical Network

UNI
User-to-Network Interface

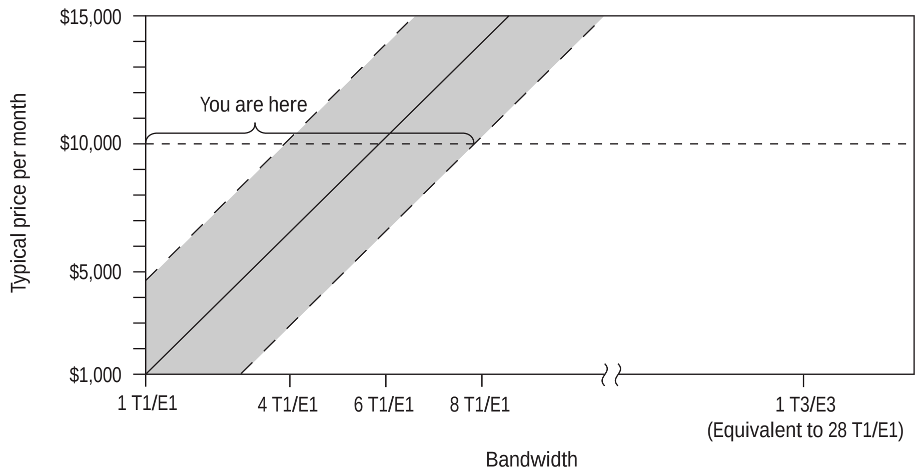

Figure 1. *T1/E1 and T3/E3 Price Point Crossover*

Ethernet, which will put increasing bandwidth pressure on WAN links.

Option 2: **T3/E3**. At 44.736/34.368 Mbps, or about 17 to 28 times the capacity of T1/E1, T3/E3 services are the next choice up. T3/E3 utilizes the high bandwidth capacity of ATM, but at a huge increase in price—with particularly high costs in Europe and Asia. In fact, in most cases the charges for T3/E3 services in these markets are prohibitive even to the main corporate office. What's more, T3/E3 services are not widely available. (The costs of OC-3 or STM-1 155 Mbps fiber services, where available, are also beyond the range of most corporate budgets.)

Option 3: Incremental T1/E1. Given the bandwidth disparity between the first two options, network planners who lack enough traffic to justify T3/E3 but whose networks have outgrown a single T1/E1 circuit must allocate WAN bandwidth in T1/E1 increments. Depending on location and carrier, multiples of T1/E1 provide a flexible, cost-effective solution for networks that require up to four or up to eight T1/E1 circuits. If an organization needs to add capacity above four or eight circuits, however, it is more cost-effective to use T3/E3 rather than purchase additional T1/E1 trunks (Figure 1). For the majority of businesses, traffic WAN bandwidth requirements lie above a single T1/E1 but below the price point crossover to T3/E3.

While this approach delivers flexible bandwidth, in terms of delivering ATM benefits to the WAN, there are severe drawbacks to using incremental T1/E1 circuits—even if the price is right. Because of the relatively small capacity of each circuit, for organizations whose traffic needs surpass a single T1/E1 line, incremental T1/E1 forfeits a defining benefit of ATM: the ability to aggregate and manage traffic across circuits. And without this traffic consolidation, circuits multiply and the benefits of ATM bandwidth efficiency and network simplification are lost. (Figure 2a on page 5).

Enter IMA: Affordable, Accessible ATM for the WAN

With the introduction of IMA, however, the option of incremental T1/E1 looks a great deal more attractive to organizations that have outgrown a single T1/E1 but are beneath the price point crossover to T3/E3. In fact, introducing IMA to the network entirely eliminates the drawbacks of incremental T1/E1, restoring the core ATM benefits of traffic consolidation, bandwidth efficiency, and network simplification. In addition, IMA introduces the additional benefit of improved fault tolerance through traffic management and link control.

What exactly does IMA do? As an example, IMA can take traffic from a relatively high-bandwidth connection, such as a campus ATM backbone running at 155 Mbps, and spread it across multiple T1/E1 WAN

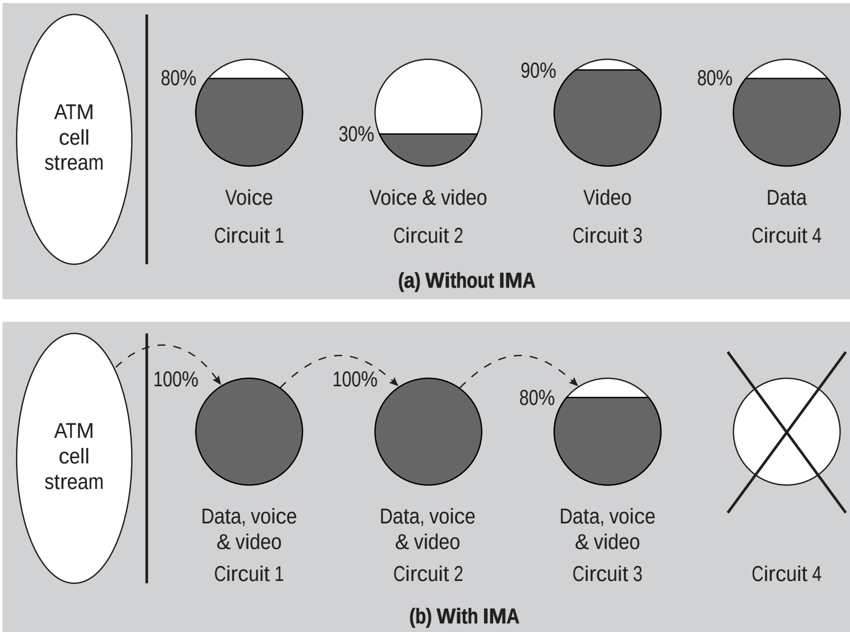

Figure 2. *Effect of IMA on Bandwidth Allocation*

circuits (Figure 2b). The aggregate bandwidth of any number of these T1/E1 lines (nxT1/E1) determines the rate of the ATM connection. IMA lets network managers utilize voice, video, and data WAN bandwidth while offering all the benefits of ATM at a more affordable T1/E1 cost. What's more, because IMA lets network planners provision bandwidth in T1/E1 increments, it is possible to increase or decrease bandwidth based on users' needs. When multiple T1/E1 circuits are multiplexed, they appear to customer equipment as one logical pipe.

How Does IMA Work?

To understand the benefits provided by IMA, it's important to understand what the standard provides and how inverse multiplexing functions. Essentially, IMA works by distributing the cells in ATM cell streams over multiple T1/E1 physical links (Figure 3 on page 6). Each link is a standard T1/E1 ATM UNI, and cells are placed on the links on a per-cell basis, using a cyclic round-robin approach. For example, the first cell is sent on the first T1/E1 circuit, the second on the second circuit, and so forth. Control information is also sent so that the status of each link and the quality of

IMA Advantages

- Transport of a single ATM cell stream at rates between T1/E1 and T3/E3, taking advantage of cost-effective bandwidth at sub-T3/E3 rates
- Provisioning of bandwidth in T1/E1 increments, which lets network planners increase or decrease bandwidth based on need
- Bandwidth consolidation across T1/E1 link groups, leading to more efficient use of circuits
- Automatic and transparent adjustment to accommodate added/restored and deleted/failed T1/E1 links, minimizing provisioning and maintenance
- Transparent transport of the ATM layer and higher layers, which preserves cell order and ATM traffic management techniques and makes IMA compatible with the existing ATM architecture

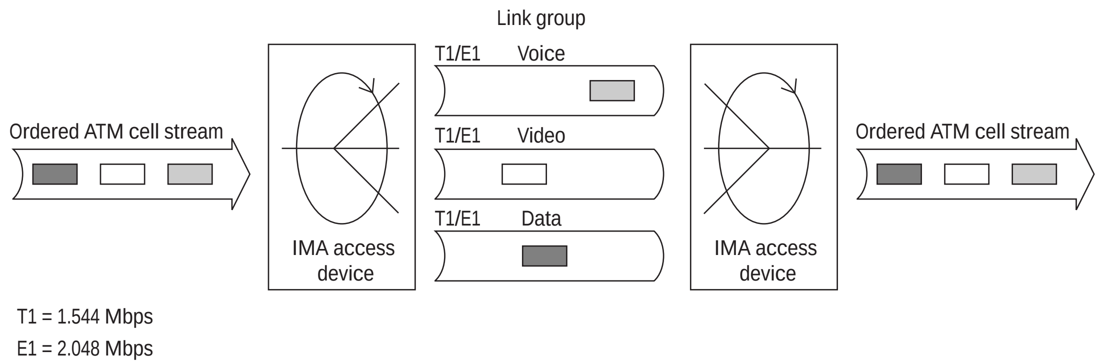

Figure 3. *Inverse Multiplexing over ATM: The Basics*

the connection can be determined and automatically corrected. Cells are then recombined by the IMA device at the receiving end of the stream.

Since the IMA access device at the receiving end requires a steady stream of cells to correctly recreate the original stream, the sending device introduces filler cells to keep the round-robin process at both ends in sync whenever there is a lull in traffic. To reduce bandwidth consumption, IMA removes idle and unassigned cells from the original stream and reinserts them at the receiving end. IMA's inverse multiplexing is transparent to the application and to the rest of the network, because cell order and format is retained and the T1/E1 delay variations within each IMA group are compensated for by software buffers in IMA equipment.

The IMA UNI is carried on top of a T1 or E1 ATM physical interface, performing inverse multiplexing using the IMA Control Protocol (ICP). The ATM Forum defines how ATM cells are mapped onto physical layer media. In the case of IMA, however, the cell-based control protocol aggregates the WAN links.

In addition to inverse multiplexing, the IMA specification includes sections on link management, connection to cell sources, cell function and cell adaptation to non-ATM data, and unit (network device) management. These components define IMA at a number of ATM protocol layers. The specification also includes a discussion of cell synchronization for IMA operation in networks containing multiple clocks.

Getting the Most Out of IMA

What are the capabilities you should expect when evaluating IMA solutions? First and foremost, look for devices that don't just implement IMA, but are engineered around the IMA standard. IMA products should be able to take advantage of ATM's sophisticated capabilities for traffic management, fault tolerance, and legacy equipment interoperability through ATM Forum standards. They should also be able to manage bandwidth to provide guaranteed delivery of voice and video, while buffering data, in a single integrated network. And finally, vendor solutions should be offered in a range of configurations to ensure proper scalability. This allows efficient utilization of WAN links, greater network flexibility, and optimal per-site return on investment.

Let's take a closer look at what's required to support ATM traffic management, and see why this requirement is so important. To be successful in the WAN, IMA devices must be able to use carrier services, plus combine diverse carriers' services in a single network to guarantee route diversity. To do this, the IMA vendor's products must support ATM traffic shaping and class of service to match the carrier service contract. Traffic shaping is the ability to meter bandwidth onto each WAN circuit so that it never exceeds the bandwidth purchased from the service provider.

In addition, since IMA devices must operate across multiple networks, they must also operate under multiple network clocks, where non-synchronous circuits are routed through different paths and more than one timing domain. Each IMA receiving device must be able to implement controlled frame slippage to compensate for the timing differences between circuits and master clocks, and work in a hybrid (mixed public/private) network.

The vendor's products should also support the capabilities of IMA fault tolerance and provide robust WAN availability features. The product should be able to monitor IMA T1/E1 links for performance and take automatic action to "heal" the network when a link is broken. For advanced fault tolerance, each T1/E1 link should deliver data into its own buffer, which needs to be sufficient to tolerate its potential component of T1/E1 link differential delay variation (the greatest difference in delay between any two links in the IMA bundle). If T1/E1 errors or excessive IMA link delay variation occurs, the IMA device should be able to identify and automatically remove the bad link from the group. The rest of the links should survive this failure and continue to pass network traffic. Insist on IMA solutions that demonstrate this level of fault tolerance.

IMA products must also interoperate with legacy technologies. ATM access products with IMA should be able to interface to data, voice, and video networks without expensive upgrades to existing equipment, and without compromising the services those networks provide to end users. Within the IMA specification, legacy interoperability is provided via internetworking standards such as those called out by the various standards bodies (ATM Forum, ITU-T, Frame Relay, etc.). Legacy sources such as Ethernet, Frame Relay, serial applications, circuit switched, and others should be supported. For example, an Ethernet or Frame Relay interconnection lets an existing router or routed application with no ATM interface connect to an ATM access device, where its data traffic may be combined with voice and video and then sent on to the WAN using IMA.

And finally, an important caution: as you evaluate IMA products, be wary of vendors who offer a narrow range of products or a single product that promises to accomplish everything. Instead, select a product lineup that is designed for flexibility of solutions; one that offers a wide set of product options and an opportunity for cost savings. Many vendors with a single solution oblige their customers to overpurchase, which actually forfeits the scalability and flexibility at the core of the IMA standard. Big switches for small jobs, for example, are cost-excessive up front as well as over the long term due to the price of maintenance, upgrades, and administration, and are likely to waste bandwidth by using expensive, high-capacity switch slots for low line rates such as T1/E1.

3Com Provides Robust, Standards-Based IMA Products

3Com's product offerings meet all the criteria for successful IMA implementation. In fact, 3Com is an active participant in the ATM Forum's development of the IMA standard, as well as the first vendor to bring to market products that adhere to the IMA specification. As a result, 3Com networking solutions make the best use of IMA and exceed ATM technology's specifications on traffic shaping for optimal control of bandwidth allocation.

What's more, 3Com is the first vendor to deliver enhanced ATM traffic shaping that smoothes traffic to wide-area services, using both cell transfer/queuing and bulk rate trunk shaping. 3Com's traffic shaping alleviates

Characteristics of a Successful IMA Solution

- Engineered around the IMA standard
- Full implementation of ATM capabilities for traffic management
- Complete fault tolerance capabilities, including self-monitoring and self-healing links
- Connectivity with legacy technologies
- A range of product offerings for locations of all sizes

congestion for peak and bursty traffic, especially when input speeds exceed WAN access speeds.

3Com IMA products also provide a high rate of tolerance for link delay variation. Here 3Com not only meets but exceeds the IMA specification for acceptable differential delay. The PathBuilder™ S600 T1/E1 UNI with the Integrated IMA module allows up to 70 milliseconds (msecs) of link delay variation, whereas the ATM specification calls for only 25 msecs. This protects users from the delay that can occur under real-world conditions, such as T1/E1 backhauls and synchronization issues resulting from service by a variety of carriers.

In addition, IMA access products from 3Com provide superior resilience across the network, with an automatic mechanism for removing failed lines from an IMA bundle. Under such failure conditions, 3Com products keep good links in operation using adjusted bandwidth (Figure 4). This "self-healing" capability provides a great tool for ensuring overall network resilience (Figure 5).

In addition to fault tolerance and network resilience, 3Com delivers on another IMA selection criterion: support for legacy interfaces. In fact, 3Com, has the widest range of legacy interfaces in the industry. Ethernet, Frame Relay, serial, and circuit switched are among the legacy interfaces installed and in operation on 3Com platforms.

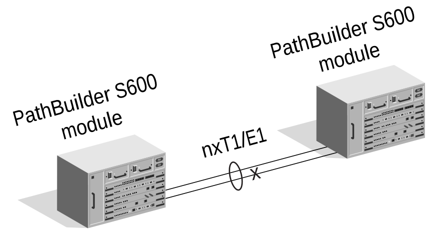

Figure 4. *Fault Tolerance in 3Com IMA Products*

Most important, though, the architecture of 3Com's IMA products allows for growth without forklift upgrades, delivering both cost savings and flexibility. The products range from a platform for a single T1/E1 link that is software upgradeable for IMA, to a platform for mid-sized branch offices, to a chassis-based platform.

The Benefits of 3Com's PathBuilder WAN Switch Family

For the central site, the powerful PathBuilder S600 WAN access switch provides high performance, flexibility, and scalability in a compact, six-slot chassis, configurable with a mix of trunk and application modules.

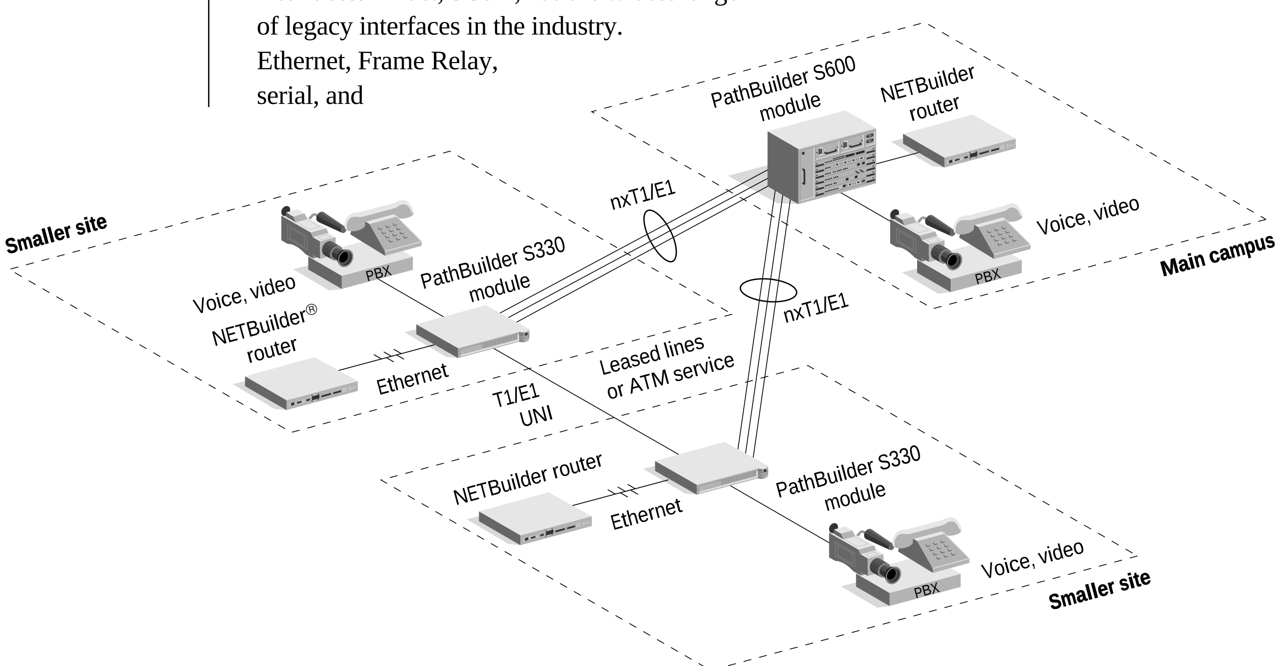

Figure 5. *Self-Healing T1 IMA Loop with Fail-Safe IMA*

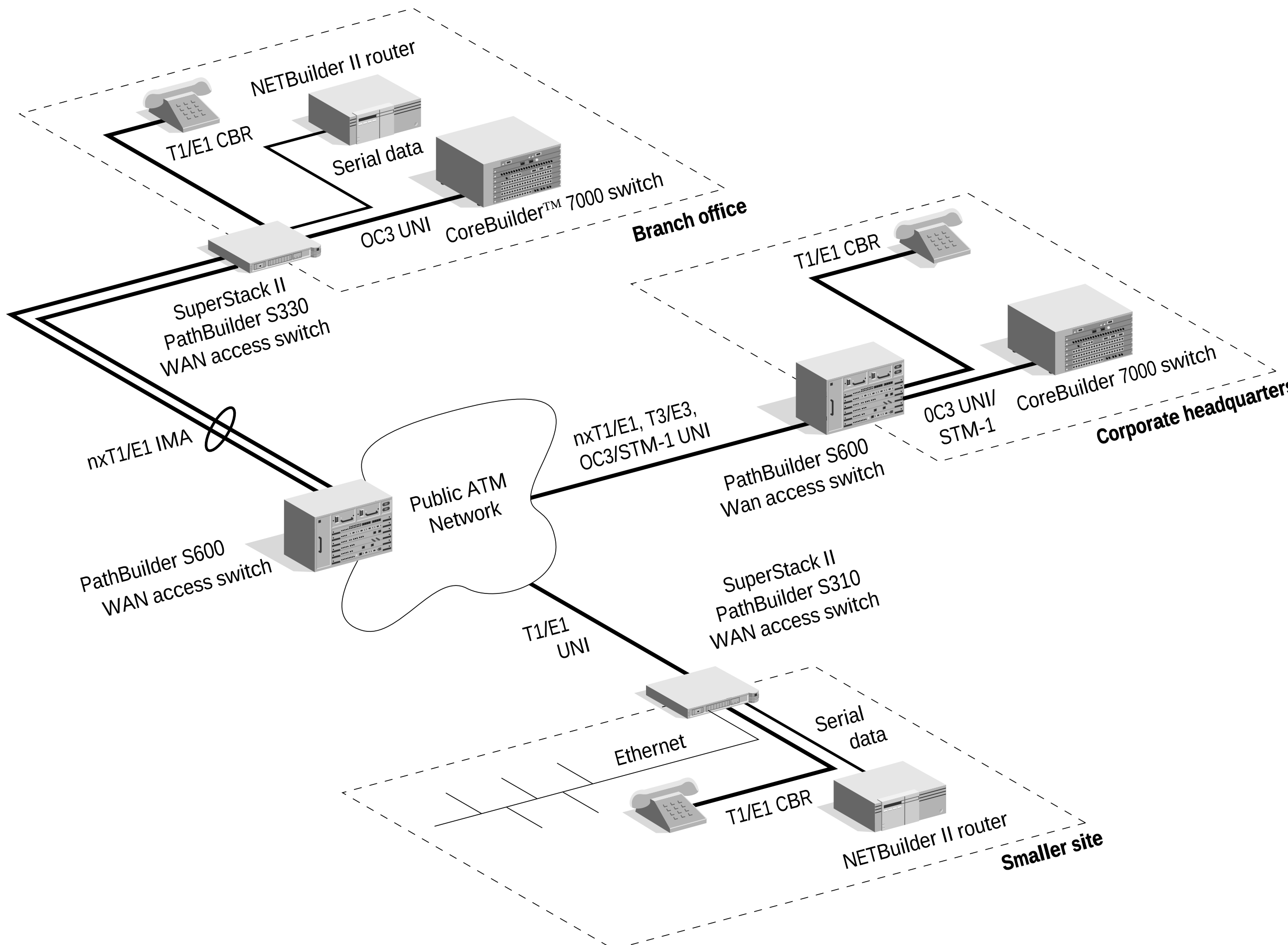

Figure 6. *A Complete Solution for Public ATM Network Access*

The PathBuilder S600 T1/E1 UNI with the Integrated IMA module provides up to eight T1 or E1 ATM ports that can be used individually or in IMA bundles of two, four, or eight circuits to offer an ATM connection of up to 12 Mbps (T1) or 16 Mbps (E1). The module's versatility makes it ideal for extending public or enterprise ATM networks to small sites without expensive T3/E3 or OC-3c/STM-1 access (Figure 6).

For deployment of ATM applications across the enterprise to branch offices, the SuperStack® II PathBuilder S300 WAN access switch, also shown in Figure 6, combines the high-performance features of the PathBuilder S600 switch with the versatility and scalability of the SuperStack II system architecture. The SuperStack II PathBuilder S330 switch offers nxT1/E1 IMA access with up to four interfaces for an aggregate bandwidth of 6 Mbps.

For sites requiring only a single T1 link today, the "IMA-ready" SuperStack II PathBuilder S310 switch is a cost-effective entry point. As bandwidth requirements increase over time, a simple software download upgrades the device to a SuperStack II PathBuilder S330 switch with full IMA capability.

Because 3Com's IMA products are designed from the ground up to support the IMA specification, they make efficient use of IMA carrier services. For example, 3Com's SuperStack II PathBuilder S330 switch lets users upgrade from a single T1/E1 to a group of IMA T1/E1s without additional hardware or interfaces. This type of scalability allows seamless network growth. And 3Com's chassis-based central site solution, the PathBuilder S600 switch, supports eight T1/E1 UNIs per card for connections to remote sites.

How 3Com Delivers a Successful IMA Solution

- As an active member of the ATM Forum and an active participant in development of IMA technology, 3Com engineers its products around the IMA standard.
- 3Com IMA products fully support ATM traffic shaping capabilities, exceeding the IMA specification for differential delay.
- 3Com IMA products automatically detect and remove failed lines from an IMA bundle.
- 3Com offers the widest ranges of legacy-to-ATM interfaces in the industry.
- 3Com's wide range of ATM access products deliver cost savings and flexibility and avoid forklift upgrades.

All PathBuilder products, as well as the broad array of other 3Com networking solutions, can be managed under the Transcend® network management platform. The PathBuilder S600 module offers extensive manageability and diagnostic capabilities with a full SNMP MIB, and can be managed from local or remote sites.

Conclusion

ATM has emerged as a technology of choice for reducing the complexity of WAN communications and offers many compelling business benefits. IMA, a recently approved UNI standard, removes the cost barriers to ATM on the WAN. It enables "right-sized" and "right-priced" ATM solutions for organizations with mid- to low-range WAN traffic requirements. Combined with ATM, IMA simplifies and reduces WAN cost of ownership through network consolidation, and at the same time ensures fault tolerance. Using ATM and IMA access products from 3Com, an organization's enterprise WAN becomes a more efficient multiservices tool for carrying voice, video, and data.

3Com will continue to support IMA and expand the capabilities of its existing product offerings. As IMA enhancements become available and are made standard, 3Com will be among the first to integrate these improvements into its product offerings. ❑

Voice and Video Networking over ATM

In addition to carrying data, 3Com's PathBuilder products ensure fail-safe transport of delay-sensitive voice and video applications across the WAN, using IMA self-healing loops. In addition, because 3Com's IMA solutions adhere to the IMA standard, the PathBuilder family of products delivers excellent voice and video quality through IMA integration with the ATM adaptation layer 1 (AAL 1), a circuit emulation mode that handles constant bit rate traffic. Support for AAL 5 variable bit rate voice and video is planned for release in the near term. Unlike other vendors that use proprietary methods to carry voice traffic, 3Com's adherence to standards ensures quality of service and carrier interoperability, future-proofing the buying decision.

Through 3Com's support of ATM structured circuit emulation, ATM connections are built at the low level of 64 Kbps DS-0 channels, maximizing the use of ATM WAN circuits. In addition, dynamic bandwidth allocation is supported in all PathBuilder products, which can sense each channel's active and inactive status and apply bandwidth accordingly. If a DS-0 is inactive, bandwidth is dynamically freed up to support other traffic, such as data. That's a real advantage in WAN throughput and efficiency, especially when traffic is carried on slower T1/E1 and nxT1/E1 links.

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