The Growing Demand for ATM

Over the next five years, demand for Asynchronous Transfer Mode (ATM) based networks is expected to grow at a rapid rate. This growth will see ATM emerge as a LAN technology for private enterprise networks as well as a WAN technology for carrier/public network offerings. This overall demand for ATM is generating a great deal of attention in both the ATM Data Exchange Interface (ATM-DXI) and Frame-based User-to-Network Interface (FUNI) protocols for access into ATM networks. Because of their roots in frame technology, both FUNI and ATM-DXI are often compared with Frame Relay. Although ATM has received more attention in the industry press, Frame Relay currently has a much larger installed base. As a result, protocols like Frame Relay to ATM Service/Network Interworking will play a major role in allowing existing Frame Relay networks to coexist with ATM-based network environments. This paper will clarify the issues surrounding both Frame Relay and ATM technology by covering the following points:

• An explanation of FUNI and ATM-DXI
• A comparison of FUNI, ATM-DXI, and Frame Relay
• Frame Relay to ATM Service/Network Interworking technical overview
• The PVC versus SVC debate
• The Role of Frame Relay and ATM technology in the Cisco Internetwork Operating System (Cisco IOS™) software and the overall product line

This paper covers a number of technologies, focusing on providing both technical information and a market overview. In addition, the final section reveals Cisco’s direction in the Frame Relay and ATM WAN technology areas and emphasizes key differentiators in the following areas:

• Maximum WAN bandwidth network throughput through the use of compression
• Ease of configuration through Address Resolution Protocol (ARP) and Inverse ARP services
• Quality of Service (QoS) through virtual circuit (VC) prioritization
• Integrated LAN/WAN hardware support for seamless dial-up/Integrated Services Digital Network (ISDN) access, channelized T1/T3 interfaces, and ATM switching in workgroup and campus backbone environments
• Full Internet service access with integrated security/encryption functionality

These features build upon existing strengths in the Cisco IOS software and will deliver the best migration path for customers looking to integrate Frame Relay and ATM WAN technology into their networks.
FUNI and ATM-DXI Explained

FUNI and ATM-DXI are access protocols for ATM networks and are designed to preserve end users’ investments in existing low-priced, frame-based hardware; for example, the Cisco router and its serial interfaces. Instead of requiring existing routers to provide ATM cell-based interfaces, both FUNI and ATM-DXI use frames on serial interfaces and transfer the segmentation and reassembly (SAR) of user traffic into 53-byte ATM cells to another point in the network. For FUNI (see Figure 1), this point is the ATM switch while for ATM-DXI (see Figure 2), it is an ATM Channel/Data Service Unit (CSU/DSU). Because FUNI and ATM-DXI can be run on the same routers that currently use Frame Relay (or perhaps X.25), they are appealing to end users who do not want to purchase new routers with ATM cell interfaces or to upgrade interfaces on existing routers.

The similarity between FUNI and ATM-DXI occurs because the FUNI specification evolved from the ATM-DXI specification in the ATM Forum’s standards work. Although FUNI and ATM-DXI are similar frame-based protocols, it is important to note that FUNI has more functionality for large WAN ATM networks than ATM-DXI. FUNI uses the ATM Interim Local Management Interface (ILMI) to manage the link between the FUNI Data Terminal Equipment (DTE) router and the FUNI Data Communications Equipment (DCE) switch. This link can be either a WAN or LAN link, and it will be managed by the ILMI. ATM-DXI lacks ILMI support and cannot provide information about link status to the ATM-DXI router. This makes ATM-DXI more susceptible to link problems and less appropriate for WAN networks than FUNI.

FUNI also utilizes serial line bandwidth more efficiently than cell-based ATM because the variable-length frames do not add as much overhead as ATM cells with their fixed 53-byte length that includes 5 bytes of header overhead. In cases where large payload packets are being sent, FUNI adds a fixed amount of overhead and can tolerate large packets in one frame, whereas cell-based ATM service cannot. Therefore, sending FUNI over a WAN link into an ATM network is more efficient than using ATM-DXI, converting to ATM cells in an ATM CSU/DSU, and sending the resulting cells over a WAN link into an ATM network.
FUNI, ATM-DXI, and Frame Relay Technical Comparison

FUNI, ATM-DXI, and Frame Relay are quite similar in terms of frame structure. Figure 3 shows that the header structure for FUNI and ATM-DXI are identical. These two header structures are similar to the Frame Relay header in terms of bit positions, but FUNI and ATM-DXI use ATM definitions for its fields while Frame Relay uses Frame Relay definitions.

When the FUNI and ATM-DXI frames are segmented into cells, the ATM-DXI and FUNI addresses map to the ATM VPI/VCI (Virtual Path Identifier/ Virtual Connection Identifier) using identical procedures as shown in Figure 4.

This process of converting FUNI/ATM-DXI frames into ATM cells can be used as the basis for an interworking function between Frame Relay and ATM. In this mapping the following similarities exist:

- The Frame Relay DLCI address is mapped to VPI/VCI address in ATM.

- The congestion notification (CN) bit performs the same function as the Frame Relay forward explicit congestion notification (FECN) bit. The network sets this bit in frames and cells going from source to destination based upon congestion levels for traffic going in the forward direction. CN and FECN rely upon the destination user equipment upper-layer protocols to send information back to the offending user equipment via the upper-layer protocol. As interface speeds increase, the effectiveness of FECN and CN decrease, because of the round-trip delay generated in the notification process to the offending user equipment.
• The Frame Relay BECN bit does not have a similar function in ATM either for FUNI or ATM-DXI. BECN is a backward notification to a Frame Relay source indicating that the traffic it sent has experienced congestion. BECN allows the network to notify a Frame Relay source directly about congestion in the network by setting the BECN bit in frames going in the reverse direction.

• The Frame Relay discard eligible (DE) bit and the cell loss priority (CLP) bit perform the same function. CLP/DE = 1 indicates that a cell/frame has a greater probability to be discarded in the case where network congestion requires cells/frames to be discarded.

• The Frame Relay C/R bit, which is passed transparently between Frame Relay users, does not have a corresponding bit in the FUNI/ATM-DXI header.

Although this mapping between Frame Relay and ATM is convenient, it should be noted that other mappings are possible.

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**Frame Relay to ATM Service/Network Interworking Technical Overview**

Having compared Frame Relay to ATM Interworking functions in the previous section, this section will describe the two major interworking network topologies:

• Frame Relay to ATM Network Interworking, which provides an ATM transport between two Frame Relay end stations

• Frame Relay to ATM Service Interworking, which allows an ATM end station to communicate with a Frame Relay end station without either side having any knowledge about the protocol being used on the other end

The basic topology for Frame Relay/ATM Network Interworking is shown in Figure 5. It consists of Frame Relay end stations on either side going through a Frame Relay network to the Frame Relay/ATM Network Interworking Function (IWF). The IWF is connected to an ATM network, which acts as a transport medium for the Frame Relay end stations. The Network IWF transparently transports both data traffic and PVC signaling information (the Link Management Interface (LMI)) through the ATM network and effectively tunnels Frame Relay through ATM. This facilitates Multiprotocol Encapsulation (RFC 1490) and other higher-layer functionality to be transported over the network. The location of the Network IWF can either be on a Frame Relay or an ATM switch. The Network IWF can also be in a box external to either network.

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**Figure 5. Frame Relay/ATM Network Interworking Topology**

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The basic topology for Frame Relay/ATM Service Interworking is shown in Figure 6. The Frame Relay/ATM Service IWF acts as a protocol converter that allows communication between a Frame Relay end station/network on one end and an ATM end station/network on the other end. (Note that the ATM end station can use the more standard ATM User Network Interface (UNI) as well as either FUNI or ATM-DXI.) The protocol conversion or mapping function is similar to that described in the “FUNI, ATM-DXI, and Frame Relay Technical Comparison” section. Because protocol conversion is performed, the Service IWF converts Frame Relay Multiprotocol Encapsulation (RFC 1490) to ATM Multiprotocol Encapsulation (RFC 1483) to ensure interworking of upper-layer protocols. This conversion is known as the translation mode in the FRF.8 specification, and it also allows Inverse ARP to function between RFC 1293 for Frame Relay and RFC 1577 for ATM. There is also a transparent mode that does not require this conversion. When there are compatible upper-layer protocols between the terminal equipment at both ends for applications such as packetized voice, the transparent mode can be used.

For further details on either of these techniques, please refer to FRF.5 and FRF.8 published by the Frame Relay Forum.

**The PVC Versus SVC Debate**

Another important issue for both Frame Relay and ATM technology is the debate surrounding whether these services should be based upon Permanent Virtual Circuits (PVCs) or Switched Virtual Circuits (SVCs). PVCs are virtual circuit connections between two locations that remain permanently set up as shown in Figure 7. SVCs, by contrast, are virtual circuit connections between two locations that get set up and torn down (switched) based upon whether data is actually being sent as shown in Figure 8. PVCs only require a one-time initial setup between the switch and the router, but become cumbersome and costly in networks requiring any-to-any connectivity (that is, where the number of PVCs required is proportional to \( n^2 \) where \( n \) is the number of sites in the network). In contrast to this, SVCs are continually being set up or torn down based upon data traffic patterns. Although SVCs entail this overhead, the benefit is that virtual circuits are only established based upon data demand. Therefore, the number of virtual circuits is proportional to the number of actual conversations between sites rather than the number of sites. SVCs are preferred in networks that require any-to-any connectivity and dynamic VC setup, whereas PVCs are better for partially meshed networks designed to mimic leased-line topologies.

Currently, Frame Relay is PVC based in both carrier/service provider network offerings and private Frame Relay networks. During 1996, Frame Relay SVC offerings will begin to emerge in private networks requiring any-to-any connectivity as well as a few small trial implementations in service provider offerings. Despite this fact, the majority of Frame Relay networks will remain PVC based through at least 1997.
In terms of ATM, PVCs and SVCs are both used depending upon the application. For ATM-DXI, a static PVC is used for the connection from the router through the ATM DSU to the ATM edge switch as shown in Figure 9. Inside the ATM network, a PVC is also used. For FUNI, both PVCs and SVCs can be used. FUNI PVCs offer users the same benefits of Frame Relay PVCs in the WAN with the ability to have an end-to-end ATM solution with Quality of Service and seamless-service ATM switches in the LAN. FUNI SVCs offer similar capabilities with the added benefit of dynamic setup and teardown of VCs based upon data traffic. It is expected that FUNI will eventually be more common as an SVC service, although early implementations may be PVC-based.

For interworking ATM and Frame Relay, a variety of permutations possible. At present, only PVC-based ATM/Frame Relay Interworking is being specified in the ATM and Frame Relay Forums. The ATM/Frame Relay Network Interworking is PVC based, allowing a single Frame Relay PVC to be mapped to a single ATM PVC and for all Frame Relay PVCs to be mapped into a single ATM PVC. The ATM/Frame Relay Service Interworking is also PVC based and requires a one-to-one mapping between Frame Relay and ATM PVCs.

The Role of Frame Relay and ATM Technology in Cisco IOS Software and Overall Product Line

This section highlights the future directions of Frame Relay and ATM technology in the Cisco IOS software. Frame Relay/ATM Interworking technology will also be covered in this context.

In terms of Frame Relay technology, the Cisco IOS software already has a large suite of features for Frame Relay PVCs and will build upon this by providing the following:

- Compression functionality based upon the Frame Relay Forum’s FRF.9 Implementation Agreement (IA); this complements the existing Payload and TCP/IP Header Compression
- Enhanced security capabilities with Encryption over Frame Relay
- Improved Prioritization with Per-VC Queuing; this complements the existing Priority/Custom/Weighted Fair Queuing (PQ/CQ/WFQ) and provides a further degree of granularity

Cisco will also begin to offer Frame Relay SVC (DTE) functionality in the Q4 ’96 timeframe. The Frame Relay SVC features will emphasize similar functionality as the PVC effort but will be more suited to any-to-any connectivity networks.

In terms of ATM technology, Cisco already offers support for the ATM-DXI 1a standard. In the FUNI area, Cisco plans to deliver support for both FUNI DTE and DCE functionality. The major differentiators in Cisco’s offering will include:

- Integrated Internet Service access with security via encryption for both the DTE and DCE devices
- Dial-up access (ISDN) as well as leased line services for both the DTE and DCE devices
- Channelized T1 access for increased port density for DCE devices
- Point-to-multipoint support for both the DTE and DCE devices
- Integrated IP address resolution services for both the DTE and DCE devices
- Compression over low-speed FUNI WAN links for DTE devices
These features will enable Cisco to offer an industry leading FUNI implementation that is complementary to existing Cisco IOS WAN services.

In terms of Frame Relay/ATM Interworking technology, Cisco will emphasize Frame Relay/ATM Service Interworking. Major differentiators in the Service Interworking area include:

- Translation of multiprotocol Inverse ARP to permit auto-configuration of Frame Relay and ATM endpoint devices
- Interoperability of existing Frame Relay Compression (FRF.9) to allow interoperation with Frame Relay devices using compression to maximize network throughput
- Per-VC queuing to allow end-to-end QoS with ATM end users. This will be useful for mission-critical SNA environments requiring fast response times
- Integral encryption for both Frame Relay and ATM to provide seamless security

The Service Interworking functionality will initially be PVC based.

**Conclusion**

Frame Relay and ATM WAN technologies are growing at a rapid rate. New services like Frame Relay SVCs, Frame Relay/ATM Service Interworking, and FUNI are emerging to permit migration and integration of today’s PVC-based Frame Relay landscape into the SVC-based ATM fabric of tomorrow. The Cisco IOS software provides industry-leading functionality in these areas to support all common industry standards. In addition, Cisco is committed to providing its customers with value-added implementations that give superior traffic prioritization, Internet access, security, cost-optimizing data compression, and integrated LAN/WAN software support. Cisco continues to build on these defining characteristics of the Cisco IOS software as Frame Relay and ATM WAN technologies permeate into networks worldwide.
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