Cisco Any Transport over MPLS

Challenge

Recently there has been an increasing market demand to provide metropolitan and longer-reach Ethernet connectivity. According to a Yankee Group estimate, in 2001 the market for virtual private network (VPN) services over traditional (ATM and Frame Relay) transports was three times larger than IP VPN services in 2000, although the IP (including Multiprotocol Label Switching [MPLS]) segment is growing much faster and could eclipse traditional services before 2005.

This growth, combined with the increasing need to protect existing infrastructure and provide traditional point-to-point connections of different types, has pushed service providers to look for solutions that allow them to carry Layer 2 and Layer 3 traffic across a common, converged, single infrastructure without changing the existing service models. Thus Cisco has an opportunity to deliver its Layer 2 tunneling solutions to address this market requirement. Cisco Any Transport over MPLS (AToM) is one such solution that addresses the needs of providers who would like to deploy MPLS and offer services such as Layer 2 aggregation and virtual leased lines using MPLS traffic engineering and quality of service (QoS) along with Cisco AToM.

Cisco AToM benefits service providers that offer Layer 2 connectivity to customers with traditional offerings such as ATM, Frame Relay, and serial/Point-to-Point Protocol (PPP) services. Additionally, it serves providers specializing in Ethernet connectivity in metropolitan areas. Services for Layer 2 VPNs also appeal to service providers' enterprise customers who may already run many of these networks and want just point-to-point connectivity.

The Cisco Solution

Any Transport over MPLS (AToM) is Cisco's solution for transporting Layer 2 packets over an IP/MPLS backbone. AToM is provided as part of the Unified VPN portfolio of leading-edge VPN technologies available over the widest breadth of Cisco routers. Cisco support for AToM enables service providers to provide connectivity between customer sites with existing data link layer (Layer 2) networks, by using a single, integrated, packet-based network infrastructure—a Cisco MPLS network. Instead of separate networks with network management environments, service providers can deliver both traditional ATM and Frame Relay connections and Ethernet connections over an IP/MPLS backbone.

The AToM product set accommodates many types of Layer 2 packets, including ATM, Ethernet, Frame Relay, PPP, or High-Level Data Link Control (HDLC)-based networks across multiple Cisco router platforms.

With Cisco AToM technology, provisioning and connecting is straightforward. A customer using Ethernet within a building

or campus in one location can connect via a service provider offering Ethernet over MPLS to the customer's Ethernet networks in distant locations. A service provider offering Cisco AToM-based services enables Layer 2 networks such as ATM or Frame Relay networks to make new point-to-point connections much more easily.

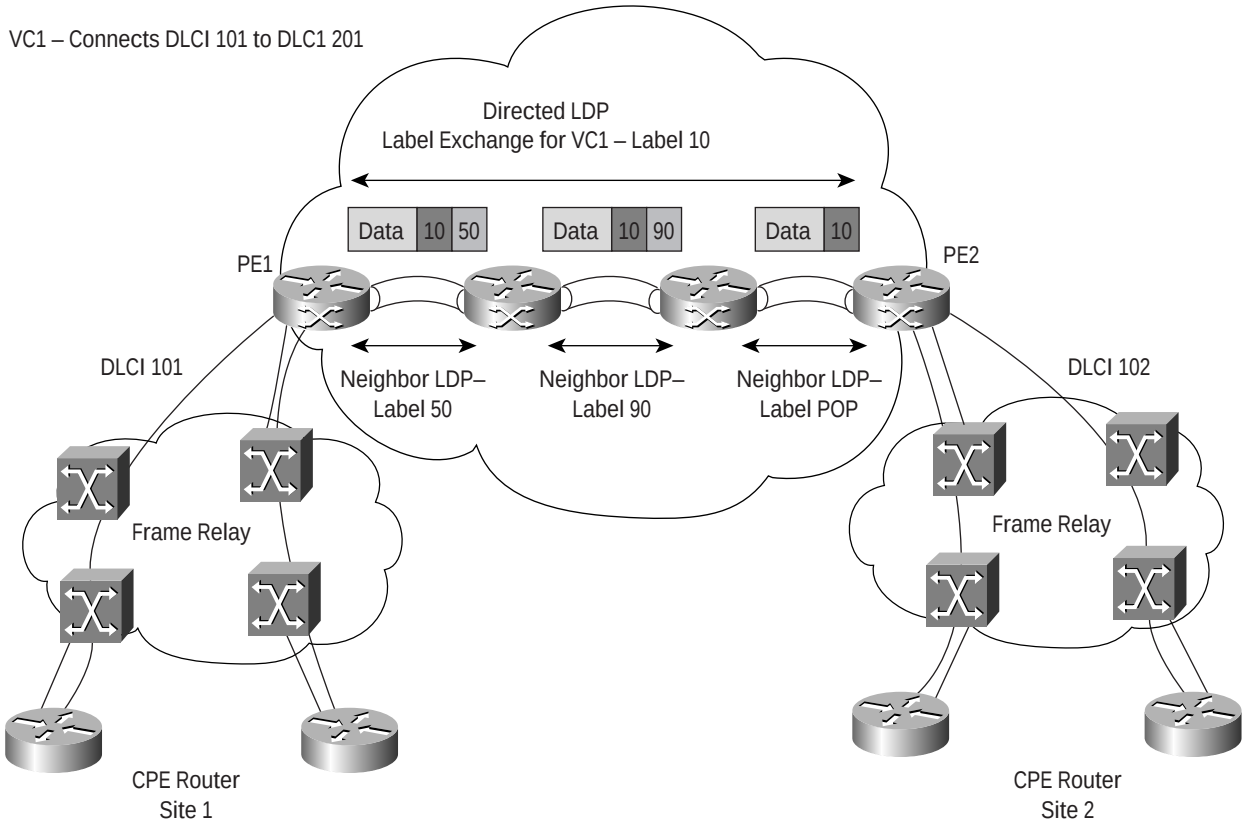
With point-to-point virtual circuits built with Cisco AToM, the Layer 2 connections retain their character as VPNs. The customer controls traffic routing within the network, and the routing information resides on the customer's routing equipment. The service provider's packet network equipment supplies point-to-point connections or an emulated pseudo-wire required by the customer.

Cisco AToM provides a common framework to encapsulate and transparently transport any traffic type over an MPLS network core. Service providers can use a single IP/MPLS network infrastructure and network management environment to offer customers connectivity for ATM, Frame Relay, Ethernet, PPP, and High-Level Data Link Control (HDLC) traffic, as well as carry customers' IP traffic in Layer 3 VPNs. Importantly, service providers can use Cisco superior capabilities in QoS to assure appropriate levels of service for different types of traffic. Cisco AToM saves money for service providers, and Cisco QoS provides ways to gain incremental revenue for premium classes of service.

How Any Transport over MPLS Works

Figure 1 shows how a Layer 2 packet travels from Site 1 to Site 2 in VPN A, using the IP/MPLS backbone.

Figure 1



The following process shows a Layer 2 packet traveling from Customer Edge 1 (CE1) on VPN A (Site 1) across the service-provider network, to CE 2 on VPN A (Site 2).

1. CE1 connects to the Provider Edge 1 (PE1) on the service-provider network through a traditional Layer 2 virtual circuit, such as a Frame Relay, data link connection identifier (DLCI 101), virtual circuit. The packet travels from CE1 to PE1 through that circuit.
2. In the service provider network, an operator configures a label switched path (LSP) from PE1 to PE2
3. For AToM, the operator configures
   - (At PE1, a cross-connect between Attachment VC 101 and Emulated VC1, and the destination PE to be PE2
   - (b) At PE2, a cross-connect between Emulated VC1 and Attachment VC 201, and the source PE to be PE1
   - Note: No AToM configuration is required on the P routers.
4. At PE1, the following events take place on the ingress interface of the router:
   - An incoming packet on the ingress line card of the provider-edge router is stripped of the Layer 2 header.
   - A control word and virtual-circuit label [10] are pushed on the packet.
   - An appropriate network-facing interface is selected.
   - A tunnel label is pushed (for normal MPLS routing through the cloud).

   The control word and the virtual-circuit label are pertinent only to the ingress and egress provider-edge routers. The routers within the MPLS backbone (the P routers) do not use the control word or the virtual-circuit label. Instead, the P routers use the tunnel label [50 & 90] to move the packet through the MPLS backbone. A P router does not distinguish AToM traffic from other types of traffic. The packet is handled just like other packets in the MPLS backbone.
5. The packet is sent through the service-provider network to PE2.
6. The following events take place on the egress router PE2:
   - The virtual-circuit label [10] is stripped.
   - The control word is processed and stripped.
   - The header is reconstructed.
   - The packet is sent out the appropriate customer-facing interface.

   No tunnel label is present in the network-facing side of the router because that label was popped by the penultimate router.
7. PE2 connects to CE2 through a traditional Layer 2 virtual circuit, such as Frame Relay (DLCI 102) virtual circuit.

How MPLS Improves Scalability in Circuit-Based Networks

Most service providers have implemented connection-oriented ATM networks in the core. ATM provides performance, bandwidth, and the ability to perform traffic engineering. However, an ATM network does not scale well, because it relies on virtual circuit state information in the core.

In contrast MPLS AToM scales well and does not require VC state information to be maintained by core MPLS devices. This is accomplished by label stacking to direct multiple connections bound for the same destination onto a single. Using MPLS, the provider must configure only the edge device (provider edge) router, as opposed to all the P routers in the network.

How AToM Helps Transition to IP/MPLS Networks

As service providers migrate to IP/MPLS networks, they need to be able to support existing services, such as the ability to transport Layer 2 packets. Using AToM, the service provider can transport Layer 2 packets over the IP/MPLS backbone. AToM is the architectural framework of transporting different Layer 2 packets, such as ATM, Frame Relay, Ethernet, PPP, and HDLC, over an MPLS backbone. In a nutshell, AToM encapsulates the packets at the provider-edge router and then transports them over the backbone. When the packets reach the provider-edge router on the other side of the backbone, they are unencapsulated and sent to their destination.

The upgrade to AToM is transparent to the customers, because the service provider's backbone network is separate from the customer's network. The service provider does not participate in the customer's Layer 3 routing. The service provider provides Layer 2 connectivity only.

AToM and QoS Support

QoS sorts and classifies packet requests into different traffic classes and allocates the proper resources to direct traffic based on various criteria, including application type, user or application ID, source or destination IP address, and other variables.

The bits in the packet translate to the priority of the packet. For MPLS packets, the MPLS experimental bits, also known as the EXP bits, allow you to specify the QoS for an MPLS packet. For an IP packet, the IP Precedence/differentiated services code point (DSCP) bits allow you to specify the QoS for an IP packet.

When an IP packet travels from one site to another, the IP Precedence field (the first three bits of the DSCP field in the header of an IP packet) specifies the QoS. Based on the IP Precedence marking, the packet is given the desired treatment such as the latency or the percent of bandwidth allowed for that class of service. If the service-provider network is an MPLS network, then the IP Precedence bits are copied into the MPLS EXP field at the edge of the network.

When an Ethernet frame travels from one site to another, the 802.1P field (three bits in the Ethernet header) specifies the QoS. Similarly for Frame Relay, the discard-eligible bit specifies the discard eligibility of the Frame Relay frame and for ATM, the cell loss priority (CLP) field specifies the cell loss priority of the cell being carried. This marking can be translated to the MPLS EXP field for preservation and transportation of QoS across the provider network.

If the service provider wants to set the QoS of an MPLS packet to a different value than that of the IP Precedence bits or the Layer 2 frame bits, the service provider can set the MPLS EXP field instead of overwriting the value in the customer's IP Precedence field or the Layer 2 header. The IP header or the Layer 2 frame remains available for the customer's use and is not changed as the packet travels through the MPLS network.

Service providers can classify MPLS packets according to their type, input interface, and other factors by setting (marking) each packet within the MPLS EXP field without changing the IP Precedence/DSCP/Layer 2 field. For example, service providers can classify packets with or without considering the rate of the packets that PE1 receives. If the rate is a consideration, the service provider marks in-rate packets differently from out-of-rate packets.

This setup allows service providers to offer different grades of service for the same transport type to different customers.

Features and Benefits

Table 1 Features and Benefits of Cisco AToM

Features	Benefits
Cisco AToM: Ethernet over MPLS	With Cisco AToM for Ethernet, service providers can offer customers ways to economically create an Ethernet virtual LAN (VLAN) among geographically separated sites. Sites in different cities can operate together transparently over an MPLS network as though they are on a common Ethernet network. Ethernet over MPLS allows for transport of Ethernet traffic (unicast, broadcast, and multicast) from a source 802.1Q VLAN to a destination 802.1Q VLAN over a core MPLS network, by mapping these VLANs to MPLS LSPs. Ethernet over MPLS uses the Label Distribution Protocol (LDP) to dynamically set up and tear down LSPs over the core MPLS network for dynamic service provisioning.
Cisco AToM: ATM over MPLS	With Cisco AToM for ATM, Cisco supports ATM adaptation layer 5 (AAL5) transport over MPLS now and will support cell relay over MPLS in the near future. ATM traffic conforming to AAL5 packet format can be transported over an MPLS backbone network consisting of Cisco 12000, Cisco 7200, and Cisco 7500 Series routers with Packet over SONET (POS) links. ATM traffic conforming to AAL5 packet format can be transported over an MPLS backbone network consisting of Cisco 12000 Series routers with POS links. With Cisco AToM, service providers can quickly add new sites with less effort than typical ATM provisioning.
Cisco AToM: Frame Relay over MPLS	With Cisco AToM for Frame Relay, customers' Frame Relay traffic can be encapsulated in MPLS packets and forwarded to destinations required by the customer. With Cisco AToM, service providers can quickly add new sites with less effort than typical Frame Relay provisioning
Cisco AToM: ATM Cell Relay over MPLS	With ATM cell relay functionality, ATM cells can be transported across MPLS networks transparently. This setup allows transportation of ATM signaling and Operations, Administration, and Maintenance (OAM) cells across a packet network, making a packet network invisible to the ATM network. This feature offers tremendous advantage to service providers because they can continue to use the same tools for provisioning and aggregate the existing frame and ATM installations to a high-speed packet core based on IP/MPLS.
Cisco AToM: PPP over MPLS	With Cisco PPP over MPLS, customers' PPP frames are encapsulated across the MPLS packet core using Cisco AToM. This setup allows service providers to emulate a point-to-point PPP link across any layer transport. Using PPP over MPLS on POS links allows service providers to create a "multiplexed" subinterface that can then be used to individually peer with other providers. PPP over MPLS allows service providers to provide a transparent PPP pass-through where the customer-edge routers can exchange the traffic via an end-to-end PPP session. Service providers can offer a virtual leased-line solution, and use the PPP subinterface capability to peer with multiple providers via a single POS connection.
Cisco AToM: Cisco HDLC over MPLS	With Cisco HDLC over MPLS, a HDLC connection is emulated from a customer router to another customer router across the packet backbone. Like PPP, this technology also allows transportation of Cisco HDLC frames across the packet networks.

Standards and Drafts upon Which AToM Is Based

The AToM technology is based on the following Internet Engineering Task Force (IETF) draft documents:

- *Transport of Layer 2 Frames over MPLS*, draft-martini-l2circuit-trans-mpls-07.txt; this document can be accessed at the following URL: http://www.ietf.org/internet-drafts/draft-martini-l2circuit-trans-mpls-07.txt
- *Encapsulation Methods for Transport of Layer 2 Frames over MPLS*, draft-martini-l2circuit-encap-mpls-03.txt; this document can be accessed at the following URL: http://www.ietf.org/internet-drafts/draft-martini-l2circuit-encap-mpls-03.txt/

Benefits of Using AToM as Part of the IP/MPLS Network

The following list explains some of the benefits of implementing AToM in the IP/MPLS network:

- The AToM product set accommodates many types of Layer 2 packets, including Ethernet, Frame Relay, ATM, PPP, and HDLC across multiple platforms. This setup enables the service provider to transport all types of traffic over the backbone and accommodate all types of customers.
- AToM adheres to the standards developed for transporting Layer 2 packets over MPLS. (See "Standards and Drafts upon Which AToM Is Based" for the specific standards that AToM follows.) This setup benefits the service provider who wants to incorporate industry-standard methodologies in the network. Other Layer 2 solutions are proprietary, limiting the service provider's ability to expand the network and forcing the service provider to use only one vendor's equipment.
- Upgrading to AToM is transparent to the customer. Because the service-provider network is separate from the customer network, the service provider can upgrade to AToM without disruption of service to the customer. The customers assume that they are using a traditional Layer 2 backbone.
- AToM is a scalable solution. The amount of forwarding information that the core routers have to store is minimal, because of the nature of the MPLS. The core routers do not store any VPN or virtual-circuit information. The provider-edge routers store only the AToM virtual-circuit information to which the customer edges connect. So, the number of virtual circuits/VPNs they service does not affect the service-provider core network.
- Another scalability benefit of AToM is that it allows for unlimited virtual circuits to be created. The IETF draft *Transport of Layer 2 Frames over MPLS* states: "This technique allows an unbounded number of Layer 2 "VCs" to be carried together in a single 'tunnel.' Thus it scales quite well in the network backbone." Because AToM adheres to this IETF draft, it benefits from the scalability aspects of the design. Other Layer 2 solutions that do not adhere to the IETF draft are limited in scalability.
- When you combine AToM with MPLS QoS and traffic engineering, you can offer such services as virtual leased lines (VLL). The white paper *Virtual Leased Line Services Using Cisco MPLS DiffServ-Aware Traffic Engineering* provides more information on providing leased-line services that guarantee bandwidth.

The white paper is available at the following URL:

http://www.cisco.com/warp/public/cc/pd/iosw/prodlit/msdvl_wp.htm.

Related Documentation

- *Cisco IOS® Software and Multiprotocol Label Switching*
  http://www.cisco.com/warp/public/cc/pd/iosw/ioft/iofwft/prodlit/iosmp_ai.pdf

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