Internet Protocol (IP) Internetworking Transport

Definition

Internet protocol (IP) internetworking transport is the process by which IP traffic is transported across a wide-area network (WAN) providing connectivity for geographically distributed hosts or local-area networks (LANs).

Overview

One of the biggest opportunities for service providers today is to provide IP–based internetworking services to meet the exponential growth in demand from both business and residential customers. With this opportunity comes a number of issues that must be resolved in order to meet capacity requirements and deliver services in a cost-effective and revenue-generating manner. Two of the most frequently considered options for providing IP transport include IP over point-to-point protocol (PPP) over synchronous optical network/synchronous digital hierarchy (SONET/SDH) (sometimes referred to as packet over SONET/SDH [PoS]) and IP over asynchronous transfer mode (ATM) over SONET/SDH (IP over ATM). This tutorial examines these alternatives and presents the benefits of each. With this knowledge, service providers can make better-informed decisions about which technology best suits their requirements and where it is most appropriate to deploy each solution.

Topics

1. Executive Summary

Service providers are searching for ways to expand the capacity of their networks to meet the growing demand for IP–based services. The primary alternatives for IP transport include IP over PPP over SONET/SDH networks (sometimes referred to as PoS), and IP over ATM over SONET/SDH (IP over ATM).

PoS is a high-speed method of transporting IP traffic between two points. IP over ATM offers a feature-rich environment for the provision of value-added IP–based services such as IP–based virtual private networks (VPNs), including definable classes of service (CoS) and support for deterministic service-level agreements (SLAs).

Service providers that wish to sell IP–backbone services to customers with similar service needs (that is, those in the public arena that do not want to offer service guarantees) may benefit from using PoS. Those that wish to sell differentiated services to gain a competitive edge in an overcrowded IP–transport market will want to consider the superior bandwidth management and quality of service (QoS) guarantees available using IP over ATM.

In the majority of cases, each service provider will use a mix of these technologies to provide the best solution for the variety of markets that are part of its service base.

2. End-User Requirements

To understand the changing demands on the service provider's network, it is first necessary to understand the enterprise and residential drivers for IP–based services.

The issues and challenges facing the enterprise include the following:

- need to offer IP–based networks such as intranets and extranets in a cost-effective and secure manner
- need to do more with less—demand is increasing but IT budgets are staying relatively constant

- need to reduce WAN capital and operating costs
- need for new private network alternatives that use the public Internet infrastructure but are secure and reliable; the industry term for this is *virtual private networks (VPNs)*
- want flexible billing options in customizable bandwidth increments
- need for deterministic SLAs so enterprise customers can be assured that services based on the provider's network will be available when required

On the residential side, end users want the following:

- faster access to the Web for personal use
- faster access to the corporate network for work use
- low-cost access (primarily a personal issue)
- new multimedia-application services (corporate and personal)

3. Service Provider Requirements

To respond to these customer demands and manage exponential growth within their networks, service providers must be able to do the following:

- provide more bandwidth at both the network edge and the core
- integrate with legacy operating support systems (OSSs) for optimized operations, administration, and maintenance (OAM)
- off-load analog data traffic from voice networks
- sell bandwidth in varying increments at a market-driven price
- engineer networks to allow for QoS and CoS for IP traffic
- create a network infrastructure that is shared among all customers and can still provide service guarantees and customer isolation
- make decisions on how to rationalize current voice and data network infrastructures
- scale the network in a manageable way

- quickly bring on new services
- manage customers not boxes
- make the right technology decisions for the future
- work with today's equipment
- roll out services in a profitable manner
- provide customers with customer-network-management features

As mentioned earlier, the two primary choices for upgrading the service provider's network are to expand the capacity of the router network by adding higher-capacity routers with fixed bandwidth backbone facilities or to add IP internetworking as a service on an existing or new ATM infrastructure. The service provider must examine each of these choices with a view to satisfying the above requirements within their existing and future network infrastructures. The following modules examine each of these technologies and their benefits.

4. What Is ATM?

ATM is a standards-based multiplexing and switching technology used to deliver multimedia services over broadband networks. It uses fixed-length cells and virtual circuits (VCs) to transport data, voice, and video traffic in a rapid manner while providing deterministic behavior between end points in the network.

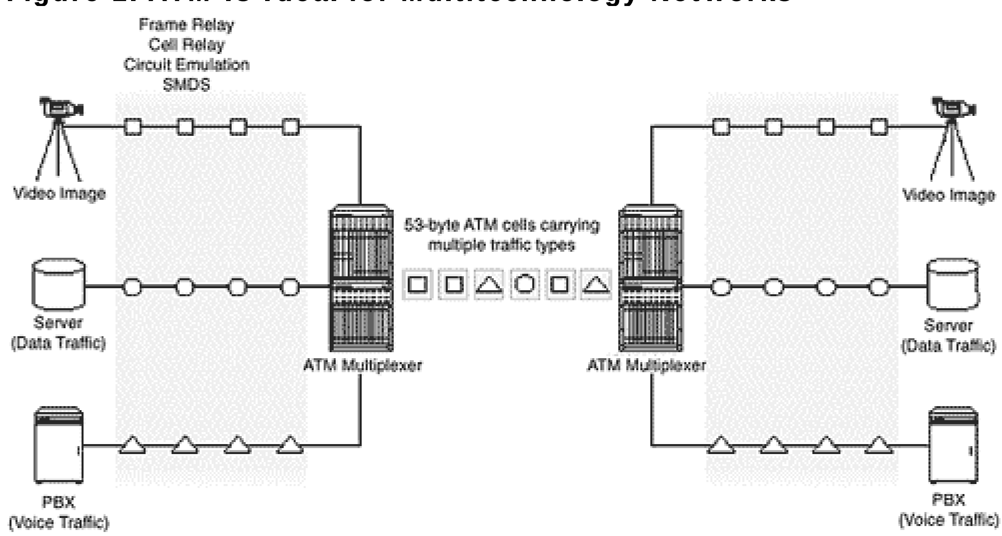
The key ATM features include the following:

- set up of end-to-end data paths using standardized signaling and load-and–QoS–sensitive ATM routing
- segmentation of packets into cells and reassembly at the destination
- statistical multiplexing and switching of cells
- network-wide congestion control
- advanced traffic-management functions including the following:
    - negotiation of a "traffic contract" to determine the parameters that affect the end-to-end delivery of packets
    - traffic shaping to maintain the traffic contract
    - traffic policing to enforce the traffic contract

- connection admission control to ensure that traffic contracts of new customers do not adversely affect existing customers

There are several advantages to using ATM for providing multimedia-transport services. It uses VCs to set up an end-to-end data path for which a QoS can be guaranteed in a deterministic fashion. Also, ATM switches interpret cell headers on the fly, using embedded information to route traffic efficiently through the switching fabric. This dynamic method of path determination provides enormous scalability and network adaptability. It also allows the ATM network to provide excellent traffic-management capabilities. Finally, ATM is the first worldwide standard to be embraced by the computer, communications, and entertainment industries as a means of supporting multimedia traffic, including video, audio, voice, and data. North American and European telcos and post telephone and telegraph associations (PTTs) have been instrumental in the development of these standards over the past several years in the International Telecommunications Union (ITU), American National Standards Institute (ANSI), and ATM Forum.

Figure 1. ATM Is Ideal for Multitechnology Networks



5. What Is SONET/SDH?

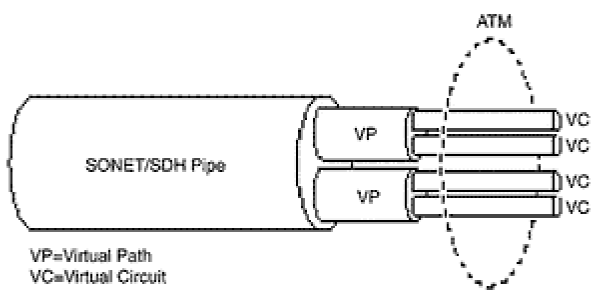
SONET, used in North America, and SDH, used in Europe, are almost identical standards for the transport of data over optical media between two fixed points. They use 810-byte frames as a container for the transport of data at speeds of up to OC–192 (9.6 Gbps).

SONET/SDH is used as the bearer layer for higher-layer protocols such as ATM or IP/PPP, employed on devices that switch or route traffic to a particular end point. The functions of SONET/SDH in the broadband arena are roughly analogous to those of T1/E1 in the narrowband world. The SONET/SDH standards define the packaging of data within SONET/SDH frames, the encoding of signals on a fiber-optic cable, and the management of the SONET/SDH link.

The advantages of SONET/SDH include the following:

- rapid point-to-point transport of data with little overhead
- standards-based multiplexing of SONET/SDH datastreams
- transport independent from the services and applications that it supports
- self-healing ring structure to reroute traffic around faults within a particular link
- widely deployed transmission infrastructure within carrier networks
- TDM grooming and aggregation from the DS0 level

Figure 2. A SONET/SDH Pipe Carrying ATM



6. Transporting IP over ATM

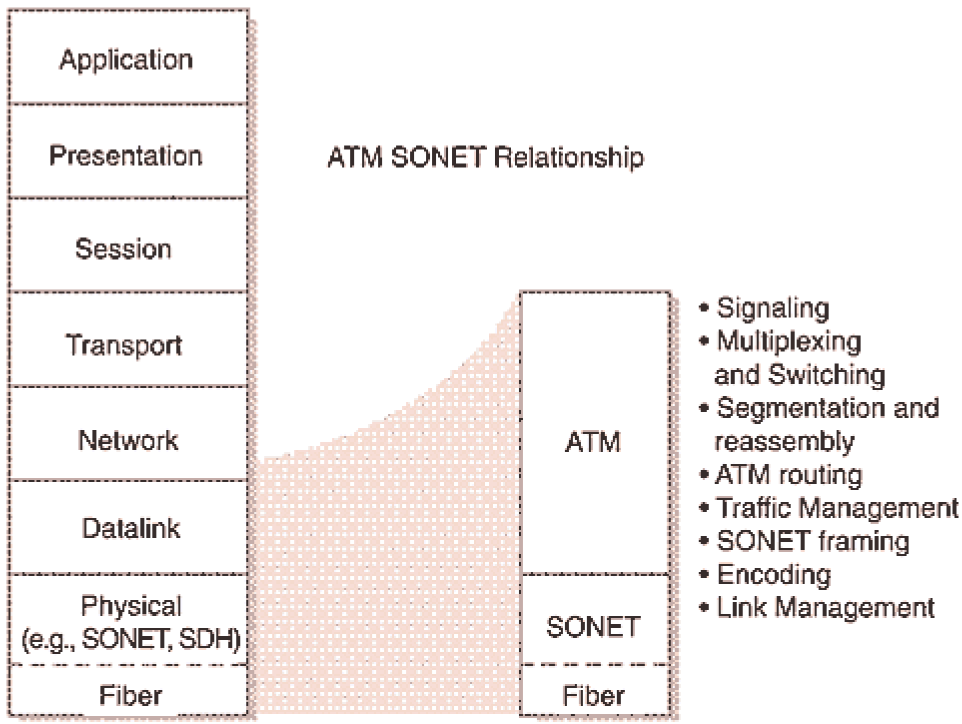
There are a number of mechanisms, existing or proposed, capable of transporting IP effectively over ATM. The key functions of these mechanisms are to manage the set of virtual circuits used to transport IP over the ATM infrastructure; aggregate the appropriate sets of IP packets onto the correct VCs; and provide the mechanisms to interoperate with existing routers.

To interoperate with existing routers, the IP/ATM infrastructure must implement standard routing protocols such as routing information protocol (RIP), open shortest path first (OSPF), border gateway protocol (BGP), distance vector multicast routing protocol (DVMRP) and protocol independent multicast (PIM), as well as the standard non–ATM interfaces. This permits the infrastructure to accept and deliver both user data and control information to and from existing routers.

Internally, the IP/ATM infrastructure must construct the set of VCs (either permanent or switched) required to provide connectivity across the infrastructure. The VCs may be established in response to demand (and torn down when the demand no longer exists) or by administrative control or some combination of both options. The IP/ATM infrastructure must also ensure that each virtual channel connection (VCC) has the appropriate traffic descriptors to achieve the required CoS.

Given that a set of VCs is, or can be, established, the IP/ATM infrastructure must ensure the appropriate packets are aggregated onto the correct VCs. The most fundamental piece of information in this regard is given by the IP–forwarding information. However, implementation of VPN services and policy-based treatment of traffic (such as CoS) can also influence the selection.

Figure 3. The Relationship between ATM and SONET



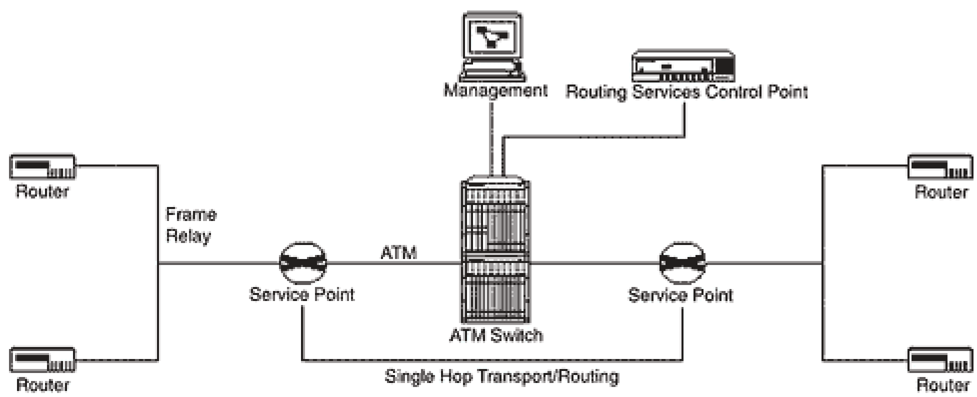
There are a number of ATM–based technologies required to support such an infrastructure. One of the key technologies is next hop resolution protocol (NHRP), which allows the IP/ATM infrastructure to use a set of shortcut virtual circuits to carry IP traffic over ATM without causing problems for the routing protocols.

Transporting IP over ATM has the following advantages:

- secure, easy to provision VPNs

- CoS options for public Internet and VPN connectivity
- superior bandwidth-management capabilities
- shared network and management infrastructure with other transport services, including frame relay, cell relay, circuit emulation, voice services, and SMDS
- IP traffic–path monitoring for and by specific customers to assure that SLAs are being met
- variable bandwidth capability via over-subscription
- advanced network management

Figure 4. An ATM–Based IP Service



7. Transporting IP over SONET/SDH

The terms *IP over SONET/SDH* or *packet over SONET/SDH* as they are used in the industry today, refer essentially to the addition of SONET/SDH interfaces to a router that terminates the PPP. Faster routing represents a natural migration for original network-routing equipment, and, with the widespread adoption of PPP as a framing protocol for IP traffic, it made sense to combine the two standards to create devices for the rapid transport of IP traffic from point to point.

IP traffic on a SONET/SDH router is treated as a serial datastream that travels hop by hop through the network using PPP for its framing and encapsulation functions. The datastreams are mapped into STS frames in accordance with Request For Comment 1619 (RFC 1619), PPP over SONET/SDH. Frames travel at optical carrier level three/synchronous transport module one (OC–3/STM–1), OC–12/STM–4 and OC–48/STM–16 rates.[1] At each node, the IP packet is unwrapped from its PPP frame, the destination address is examined, the routing path is determined, and the packet is rewrapped in a new PPP frame and sent on its way.

Transporting IP over SONET has the following advantages:

- efficient/low overhead point-to-point transport of IP traffic
- provision of large amounts of bandwidth for nondifferentiated services

8. IP over ATM and PoS—How Do They Compare?

Bandwidth Management and Network Engineering

The foundation of bandwidth management in ATM technology is a traffic contract that is used to assign bandwidth to a specific customer requesting an IP–based service. ATM can accommodate this by allocating more or less cells (containing encapsulated IP traffic) within a given VC to the customer. Because the cells are identified as belonging to that customer, they can be monitored throughout the end-to-end connection to ensure that the customer is getting the service that it requested and to ensure that the customer's use of bandwidth does not exceed its contract and use up bandwidth that belongs to another customer on the same link. This bandwidth can be asymmetrical such that the user at one end can contract for more or less than the user at the other end. Because the service is connection oriented, ATM ensures that only the required bandwidth is reserved on each node, thus making the most efficient use of physical resources within the network and preventing the need for frequent upgrades to nodes. Additional bandwidth efficiency is created with ATM–based IP networks through the use of the ATM point-to-multipoint feature.

Within a connectionless PoS network, all bandwidth is available by all customers and all applications at all times. There are no end-to-end traffic guarantees that allow the user to be sure that the data will arrive in a timely fashion. If a node or a link becomes congested, packets are often dropped in a random fashion (depending on the features employed on the router). When this happens, the transmission control protocol (TCP) layer at the end node must ask for a

[1] To ensure compatibility with deployed SONET/SDH infrastructures, RFC 1619 is being revised by the Internet Engineering Task Force (IETF) to include scrambling of data before it is handed to the SONET/SDH layer.

retransmission of packets. When this happens, there are obviously considerable delays in receiving and reassembling the entire datastream. Network providers can manage bandwidth demands by over-provisioning their networks and ensuring that there are no bottlenecks at critical points. The general guideline is that the provider must over-provision by approximately 30 percent to prevent excessive packet loss. Point-to-multipoint connections are not possible in PoS networks as a result of the point-to-point nature of SONET connections.

Provisioning and Selling Services

Traditional Internet-access services are based on selling best-effort access for a fixed, often tiered, price. The focus for service providers who are providing this type of service is to reduce costs in order to increase or create margins. Now there is a new opportunity to sell differentiated IP services to business customers who want to outsource their wide-area-networking business. The focus of this opportunity is to provide secure, reliable, private, IP–based interconnection. For business customers, the alternative is costly private networks, so price is less of an issue: their priority is the quality of the service and their ability to prove the value received for the money spent.

Using an IP over ATM network, the service provider has an opportunity to sell differentiated IP VPN services. To start, the service provider can create a service contract that defines a CoS that is associated with a particular end-to-end data path. Because the data path is defined by an ATM VC, it is an easy matter for the service provider to then provision a VPN for an individual customer. VPNs that are provisioned this way are isolated from each other and run over independent ATM VC. Given this isolation of customer bandwidth and the deterministic nature of ATM traffic management, providers can deliver deterministic guarantees of service levels.

Such VPNs can be provisioned quickly by allocating the necessary resources on a network-management terminal, in a similar manner to the way that plain old telephone service (POTS) is provisioned through the signaling system seven (SS7) network today. Service-level monitoring can be provided by a service terminal located at the customer's site that allows the customer to monitor statistics for its specific data paths. Through similar mechanisms, it is also possible to provide service-level guarantees for Internet services.

PoS networks are well suited to selling access services to a broad range of customers who want the same level of best-effort service. By consolidating traffic onto bigger, more efficient routers, PoS networks offer the service provider the opportunity to reduce overall costs for bulk transport of IP traffic. These networks are not well suited, however, to providing differentiated VPN services, because they are not designed to set up and manage an end-to-end connection for an individual customer. There are several IP–protocol enhancements available that will improve this capability, including resource reservation protocol (RSVP), layer two tunneling protocol (L2TP), secure Internet protocol (IPSEC), differentiated services (DiffServ), and random early detection (RED). To date, the combination of these has not proven effective at providing the secure, reliable, manageable, and monitored services for which customers are looking when they outsource their wide-area network (WAN) business. For example, while IP tunneling schemes can provide isolation of customer forwarding tables, they require either the provider or end user to construct a set of point-to-point tunnels to provide connectivity. Managing this set of tunnels is equally as hard as managing the equivalent of a mesh of permanent virtual circuits (PVCs), an approach long ago rejected by all.

Network Management

The focus of network management in an IP–over–ATM network is to manage services rather than individual devices or point-to-point connections. This is accomplished by configuring policies for specific customers within the network-management system and having these policies automatically propagated to all network elements that participate in providing a service to that customer. To maintain management flexibility within this environment, the network manager has the ability to preconfigure long-hold switched VCs or allow the end user to negotiate admission to the network under a specific traffic contract as part of a user-initiated switched virtual circuit (SVC). Because the management system associates a customer with an end-to-end connection and a policy, it can maintain the appropriate accounting and performance statistics that are vital for billing, general customer service, and the monitoring of IP SLAs.

The focus of network management within an IP/PPP over SONET/SDH environment is to manage a collection of point-to-point links and individual routing devices. Because IP traffic is routed through the network as a connectionless service, individual datastreams are invisible to the network-management device (and the network manager), making it difficult to monitor or to offer SLAs. This system is, however, perfectly suitable for delivering network services to customers who are looking for best-effort services.

Scaling

Scaling IP over ATM networks to accommodate additional IP traffic is accomplished by growing resources within each of the following four areas as required: network management, routing management, data forwarding, and data transport.

- Network-management resources grow to accommodate an increased number of network elements that are part of a larger user base. The network-management system hides the complexity of individual links and nodes from the operator, who only needs to see this level for troubleshooting purposes. The majority of the commissioning work for individual nodes is done automatically when the node is brought on line.

- Routing management grows by adding more IP route–calculation devices (routing services control points or RSCPs) to the pool of redundant resources already within the system. As routing SCPs are independent of the forwarding elements, they can be scaled independently to provide capacity when required. They provide an effective means of aggregating routing resources to reduce the number of physical devices and hence failure points and entities that must be managed.

- IP–data forwarding scales by adding devices at the edge of the network according to the user demands within a particular geographic location. As these devices do not perform any routing calculations, they are relatively inexpensive to own and operate.

- Data-transport capacity is increased by scaling the ATM network, which uses an address scheme that allows for multiple hierarchies and a route-calculation mechanism that sets up connections through a hierarchy of groups of resources. As ATM data streams are divisible via VCs, the addition of new customers to the network does not necessarily require the addition (or the purchase) of new physical ports on the affected network nodes.

Scaling PoS router networks is accomplished either by adding more routers or increasing the capacity of core routers or both. As routing and forwarding capacity are provided on the same device, any upgrade to one implies an upgrade to the other, with the associated cost impact. Further, each additional routing entity places increased load on the routing system. This is particularly unfortunate if the addition was an unwanted side-effect of adding more forwarding capacity. Although each router and each of the links between them have traditionally been managed as separate entities, the management software from individual router vendors has improved recently to provide a more consolidated view of the network as a whole. Network design is critical as the network scales to prevent bottlenecks and to limit the amount of routing chatter associated with the networkwide propagation of routing-table updates.

Overhead Issues

IP achieves about 80 percent of the available line rate when operating over ATM, whereas it achieves 95 percent of the line rate when running over PPP/SONET/SDH. This is because, in the latter case, frames are transported directly into the SONET/SDH payload, thus eliminating the overhead required to support ATM (for example, the ATM cell header, IP over ATM encapsulation, and the partial fill resulting from the fixed-length nature of ATM cells). However, although there is this decreased efficiency with ATM, the cost expressed as a percentage is almost the same as the difference in utilization between ATM and PoS. As discussed, the benefits that come with the additional ATM overhead include the following:

- ability to sell differentiated services such as VPNs
- customer isolation without the management overhead of IP–level tunneling schemes
- ability to engineer the network and thus control the use of bandwidth, specifically to ensure that it is used to derive maximum profits
- ability to provide deterministic guarantees of CoS and QoS, which in turn makes it feasible to offer SLAs the ability to manage services for individual customers, as opposed to nodes and links for a pool of customers

9. Multiservices Networks

ATM was designed to work as a multiservices-network fabric. It accommodates various types of transport services including frame relay, cell relay, circuit emulation, and switched multimegabit data service (SMDS), as well as various types of user traffic, including data, voice, and video. The blending of these services and traffic types within a single network allows service providers to manage all of them in a consistent management environment and to present a consistent interface to the customer for all types of services. This also allows service providers to coexist with existing non–IP equipment within their own and their customers' networks.

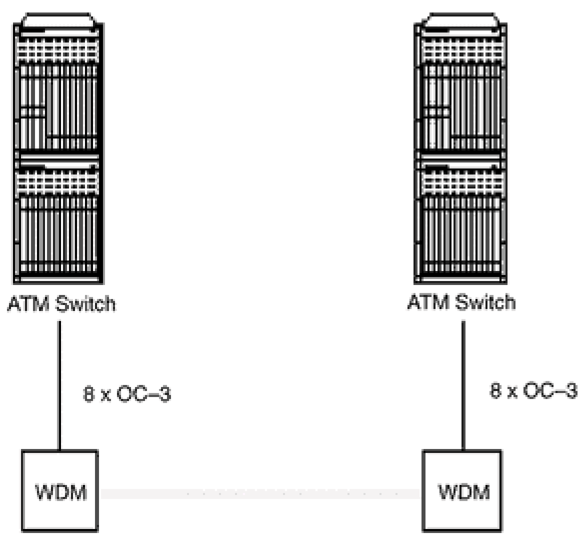
SONET/SDH routers were designed to handle IP traffic only. Service providers who operate these networks must also run separate networks for frame relay, leased line, cell relay, and SMDS traffic. In many cases, these other networks are being consolidated onto ATM backbones to provide the advantages listed previously.

10. Related Technologies

Wave Division Multiplexing (WDM)

WDM is an emerging technology that supports the multiplexing of multiple ATM/SONET streams onto a single fiber-optic cable. WDM hardware will be colocated with ATM switches and will be used to create long-haul point-to-point fiber-optic connections between these switches. In some cases, it will be used to create a mesh structure with the redundancy of a SONET ring but with much greater capacity (for example, 32 x OC–48 instead of the more typical x OC–48 SONET ring). The immediate benefit to service providers will be to significantly increase the bandwidth available for a point-to-point ATM connection and thus offset the 15 percent cell tax that is often associated with ATM transport. The long term benefit will be to ensure that the future capacity of IP networks will be sufficient to accommodate the current 100+ percent year-over-year growth.

Figure 5. Using WDM to Consolidate Bandwidth Demand

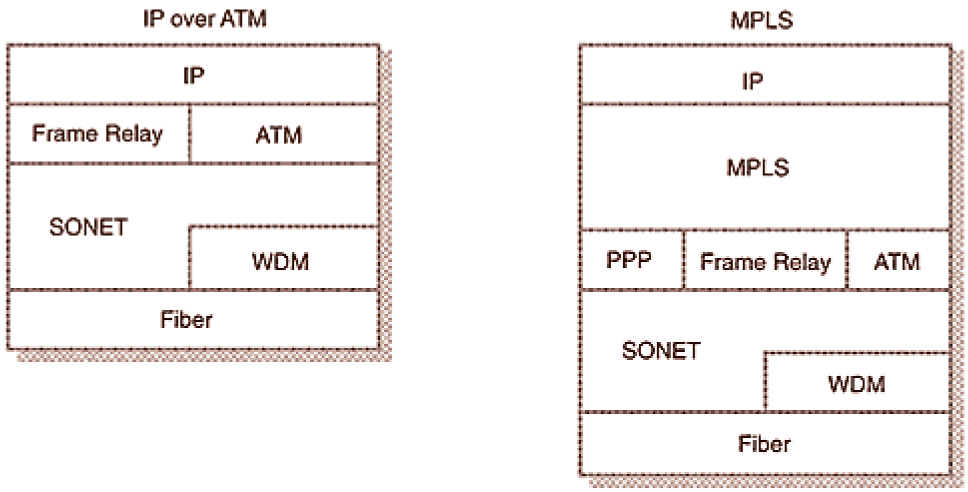


Multiprotocol Label Switching (MPLS)

When completed, MPLS will provide additional functionality in IP over SONET/SDH implementations by appending labels onto each IP packet. These labels are associated with paths through the network and may be used (in an as yet undefined manner) to specify traffic-handling characteristics in order to guarantee a QoS or CoS. The goal of MPLS is to take advantage of the higher bandwidth offered by IP over SONET/SDH, without the additional overhead of ATM.

Version 1 of MPLS, due out some time in 1999, provides public Internet functions and enables routing equipment to set up a path through the network for a particular packet stream. The primary advantage of this implementation will be to allow operators to increase the efficiency of their router networks, because a label is easier to switch than an IP packet is to route. Version 2, which has an undefined ratification date, may offer some VPN and QoS guarantees, but there is no clear definition of this part of the standard at this point in time.

Figure 6. IP over ATM and IP over SONET/SDH: A Comparative View



11. Conclusions

Within today's WANs, IP is transported using both IP over ATM and PoS technologies. PoS is primarily used for the aggregation of backbone router traffic to extend the capacity of the original routers that supplied the backbone for Internet connectivity. Some of the largest IP providers use ATM for the same purpose—backbone transport of IP traffic. In addition, IP over ATM is used in the WAN to provide efficient aggregation of IP traffic toward the backbone and to provide transparent LAN services that interconnect remote sites over an ATM infrastructure. The next step is to adapt one or both of these infrastructures to respond to end-user demands for extended IP–based WAN services.

IP over ATM is uniquely suited to providing differentiated IP–VPN services to end-user business customers. The fundamental technology differentiator that makes this possible is the VCs that allow a service provider to provision, manage, monitor, and bill for an end-to-end connection that has a specific CoS for a specific customer. In addition, the built-in traffic-management and QoS parameters allow the adoption of IP SLAs for the first time. Combining IP with other ATM services also provides significant advantages in terms of mixing many different types of transport services (frame relay, cell relay, circuit emulation, voice services, SMDS) and different media (data, voice, video) and managing them as part of the same infrastructure.

PoS is a good solution for efficiently transporting bulk, undifferentiated IP–only traffic from point to point. It is not, however, suitable for providing end-to-end IP–based services such as VPNs. Future standards such as MPLS and new protocols such as RSVP and L2TP may allow service providers to offer VPNs with guaranteed service levels, but it is unclear when or if they will be able to work together, or if these networks will be manageable when they grow to accommodate hundreds of thousands of VPNs. In addition, networks of such complexity are not likely to be adapted to anything other than IP–based traffic. If and when all IP networks become a reality, and if the emerging standards are ratified to provide ATM–like traffic-and-network-management features, PoS may become a viable solution for providing true differentiated IP–based services.

Self-Test

1. SONET, used in North America, and SDH, used in Europe, are almost identical standards for the transport of data over optical media between two fixed points.

    a. true

    b. false

2. When transporting IP over ATM, the IP/ATM infrastructure must construct a set of VCs (either permanent or switched) required to provide connectivity across the infrastructure.

    a. true

    b. false

3. IP traffic on a SONET/SDH router is treated as a serial datastream that travels hop by hop through the network using TCP for its framing and encapsulation functions.

    a. true

    b. false

4. The general rule of thumb is that the provider must over-provision by approximately 10 percent to prevent excessive packet loss.

    a. true

b. false

5. Scaling IP over ATM networks to accommodate additional IP traffic is accomplished by growing resources within each of the following four areas as required: network management, routing management, data forwarding, and data support.

   a. true

   b. false

6. The most frequently considered options for providing IP transport include _______________.

   a. IP over PoS

   b. IP over PPP over SONET/SDH

   c. IP over ATM over SONET/SDH

   d. IP over ATM

   e. all of the above

   f. none of the above

7. _____ is a high-speed method of transporting IP traffic between two points.

   a. PoS

   b. ATM

   c. IP–VPN

   d. PPP

   e. none of the above

8. Residential drivers for IP–based services include __________.

   a. faster access to the Web for personal use

   b. faster access to the corporate network for work use

   c. low-cost access (primarily a personal issue)

   d. new multimedia application services (corporate and personal)

e. all of the above

9. To respond to customer demands and manage exponential growth within their networks, service providers must be able to ___________.

   a. provide more bandwidth at the network edge and less at the core

   b. sell bandwidth at varying increments

   c. engineer networks to prevent CoS for IP traffic

   d. off-load analog data traffic to voice networks

   e. all of the above

10. ____ is a standards-based multiplexing and switching technology used to deliver multimedia services over broadband networks.

   a. ATM

   b. CoS

   c. TCP

   d. PTT

   e. none of the above

Correct Answers

1. SONET, used in North America, and SDH, used in Europe, are almost identical standards for the transport of data over optical media between two fixed points.

   a. true

   b. false

   See Topic 5.

2. When transporting IP over ATM, the IP/ATM infrastructure must construct a set of VCs (either permanent or switched) required to provide connectivity across the infrastructure.

   a. true

   b. false

See Topic 6.

3. IP traffic on a SONET/SDH router is treated as a serial datastream that travels hop by hop through the network using TCP for its framing and encapsulation functions.

   a. true

   b. false

   See Topic 7.

4. The general rule of thumb is that the provider must over-provision by approximately 10 percent to prevent excessive packet loss

   a. true

   b. false

   See Topic 8.

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   a. true

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   See Topic 8.

6. The most frequently considered options for providing IP transport include _______________.

   a. IP over PoS

   b. IP over PPP over SONET/SDH

   c. IP over ATM over SONET/SDH

   d. IP over ATM

   e. all of the above

   f. none of the above

   See Definition and Overview.

7. _____ is a high-speed method of transporting IP traffic between two points.

   a. PoS

   b. ATM

   c. IP–VPN

   d. PPP

   e. none of the above

   See Topic 1.

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   b. faster access to the corporate network for work use

   c. low-cost access (primarily a personal issue)

   d. new multimedia application services (corporate and personal)

   e. all of the above

   See Topic 2.

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   b. sell bandwidth at varying increments

   c. engineer networks to prevent CoS for IP traffic

   d. off-load analog data traffic to voice networks

   e. all of the above

   See Topic 3.

10. ____ is a standards-based multiplexing and switching technology used to deliver multimedia services over broadband networks.

   a. ATM

   b. CoS

c. TCP

d. PTT

e. none of the above

See Topic 4.

Glossary

ANSI
American National Standards Institute

ATM
asynchronous transfer mode

BGP
border gateway protocol

CoS
class of service

DVMRP
distance vector multicast routing protocol

IETF
Internet Engineering Task Force

IP
Internet protocol

IPSEC
secure Internet protocol

ITU
International Telecommunications Union

L2TP
layer two tunneling protocol

MPLS
multiprotocol label switching

NHRP
next hop resolution protocol

PIM
protocol independent multicast

PoS
packet over SONET/SDH

PPP
point-to-point protocol

PTT
post telegraph and telephone associations

PVC
permanent virtual circuit

OAM
operations, administration, and maintenance

QoS
quality of service

OSPF
open shortest path first

OSS
operations support system

RED
random early detection

RFC
request for comment

RIP
routing information protocol

RSCP
routing services control point

RSVP
resource reservation protocol

SDH
synchronous digital hierarchy

SLA
service level agreement

SMDS
switched multimegabit data service

SONET
synchronous optical network

STM
synchronous transport module

STS
synchronous transport signal

SVC
switched virtual circuit

TCP
transfer control protocol

TDM
time division multiplexing

VCC
virtual channel connection

VC
virtual circuit

VPN
virtual private network

WAN
wide-area network