Ascend

WHITE PAPER

IP Navigator MPLS Executive Overview



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Introduction

The growth of the Internet over the last several years has placed a tremendous strain on the besieged superhighway: in the continual increase in users, connection speeds, backbone traffic, Internet Service Provider (ISP) networks and new applications. Additionally, significant pressure has arisen from the expectations of Internet users. In the early days, the research community used the Internet primarily for e-mail and FTP. Now, the Internet is a worldwide commercial data network. As such, it has been the proving ground for commerce, managed public data services including intranets and a broadcast medium, all of which presuppose a level of service that includes dependability, predictability and consistent performance. As a result, carriers and Internet providers today face the challenge to scale the capacity, performance and predictability of their network infrastructure and to offer enhanced data services to support customers' TCP/IP applications and emerging markets. Ascend leads the industry with technical solutions for scaling large networks, delivering complementary technology that results in flexible and total solutions. Recognizing our customers' requirements to function with diverse equipment and protocols and anticipating industry trends, Ascend has maintained its commitment to develop standards-based products that lend themselves to the easy integration of new technologies and standards. The Ascend mission is to provide products, technologies and services for network service providers and users of the public network, meeting our customers' technical and business needs.

IP Navigator MPLS: Carrier-class MPLS

The convergence of routing and switching is the inevitable consequence of the evolution of IP wide area networking. With the benefits of such a combination, it is not surprising that vendors increasingly are interested in the MultiProtocol Label Switching (MPLS) standard being developed in the IETF as a means of scaling large IP networks and offering value-added IP services. IP Navigator MPLS employs IP routing at the ingress and egress points of the network, and core label switching. MPLS allows ATM switches, Frame Relay switches, and IP routers/switches to cooperate in setting up IP *Label Switched Paths* (LSPs) through networks of any size, principally wide-area backbone networks, both public and private, and Internet Service Provider networks. The IP Navigator MPLS supports several types of label switched paths so as to address the array of IP services in demand today. Types of LSPs are: Multipoint-to-Point LSP, Multicast LSP, Point-to-Point LSP and Demand LSP. The IP applications and LSP types are the topics of this document and its companion the IP Navigator MPLS Architecture Guide. As an early implementation of MPLS, IP Navigator MPLS was built on the strong switching experience of Ascend, allowing IP Navigator MPLS to be the first shipping implementation of Label Switching technology.

Ascend History of MPLS and Why We Need MPLS

Ascend has been involved as a major participant in the planning and development of MPLS since its inception in December 1996. As a charter member of the IETF working groups on MPLS, Ascend was instrumental in authoring the IETF MPLS framework and architecture specifications. Currently, Ascend has co-authored the specification for MPLS over Frame Relay and is a key member of the MPLS Traffic Engineering Design Group. Ascend also chairs the IETF Interworking over Non-Broadcast Multiple Access Networks Group, whose work has served as the foundation for MPLS design and which continues to provide impetus to MPLS development.

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IP Navigator MPLS

IP Navigator MPLS™ addresses the requirements of carriers and ISPs to scale IP Wide Area Networks (WANs) and to increase WAN performance. IP Navigator MPLS integrates the efficiency of WAN switching and the intelligence of IP routing in a single platform. The addition of the TCP/IP protocol suite to the Ascend multiservice switch platform allows service providers to offer standard or enhanced IP services based on the end-to-end "Absolute" Quality of Service (QoS) parameters available from the Ascend cloud. IP Navigator MPLS includes the array of the necessary protocols (below) that a service provider needs to offer Internet and intranet services. (See Figure 1.)

- Transmission Control Protocol/Internet Protocol (TCP/IP)
- Routing Information Protocol-1/2 (RIP-1/2)
- Open Shortest Path First (OSPF)
- Intermediate System to Intermediate System (IS-IS)
- Border Gateway Protocol-4 (BGP-4)
- Distance Vector Multicast Routing Protocol (DVMRP)
- Multicast OSPF (MOSPF)
- Protocol Independent Multicast (PIM)

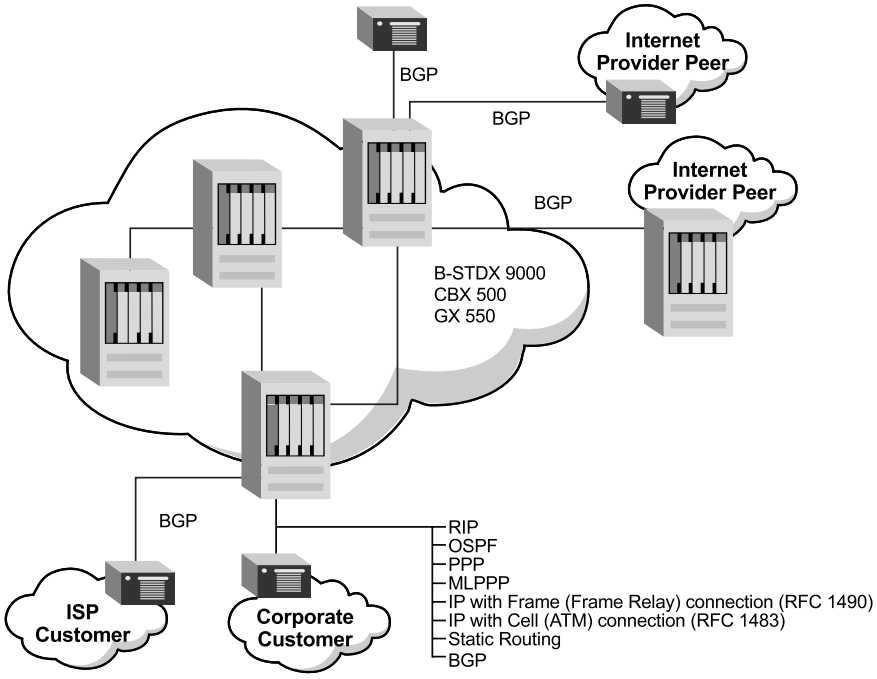


Figure 1 – IP Navigator MPLS Multiservice Network.

The Internet and transport protocols supported include the following:

- Address Resolution Protocol (ARP)
- Reverse Address Resolution Protocol (RARP)
- File Transfer Protocol (FTP)
- Telnet Protocol (Telnet)
- Internet Control Message Protocol (ICMP)
- Transmission Control Protocol (TCP)
- Internet Group Multicast Protocol (IGMP)
- User Datagram Protocol (UDP)
- Internet Protocol (IP)
- Inverse Address Resolution Protocol (IARP)

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Adding IP Navigator MPLS to the 'Net

IP Navigator MPLS offers a standards-based, well-proven solution that is fully interoperable with the existing Ascend multiservice environment. IP Navigator MPLS scales capacity and service offerings for both new and existing networks.

Existing Ascend Networks

A software upgrade for Ascend multiservice switches, IP Navigator MPLS enables service providers to offer new, value-added IP services to new and existing customers.

Existing Ascend Networks with Route Servers

IP Navigator MPLS can be employed in the existing infrastructure to address specific capacity and performance needs. (See Figure 2.) IP Navigator MPLS reduces the number of Virtual Circuits (including PVCs) to "one arm bandit" route servers and provides the market's highest density aggregation of user ports from DS0/E0 to OC-3/STM-1 and beyond. In addition, it optimizes data traffic flow, removing the need for all data packets to pass through the route server. The remaining IP Navigator MPLS features can be phased in, as required, for new service offerings.

Router-based Networks

Ascend switches utilizing IP Navigator MPLS supplement an existing router network with high-speed switching. This increases network performance, user port counts and trunk speeds, while delivering the bandwidth management and QoS features that enable network providers to address customers requirements for new applications.

New Network Buildout

Ascend delivers the necessary architecture for a service provider to offer Internet and intranet services. High-density, low-cost port aggregation, multiservice offerings and a high-performance, scalable network architecture enable service providers to offer high-quality services with Service Level Agreements (SLAs).

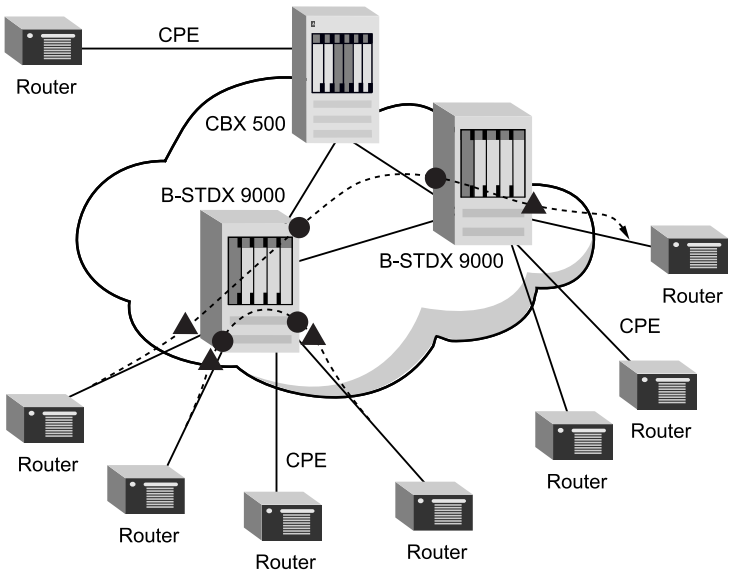


Figure 2 – IP Navigator MPLS reduces route server dependence and optimizes data traffic flow.

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Switching and Routing in the Internet

Switching technologies have driven major changes in WAN network infrastructures. The benefit of switching technology versus shared media is most obvious in the dedication of bandwidth for predictable communications as opposed to the sharing of bandwidth on routed WANs.

The advantages of switching in the WAN are particularly evident in networks based on router internetworking. Benefits include improved traffic management, predictable network performance, varied QoS, substantially lower cost, higher traffic throughput and greater scalability. These benefits have been seen by early ISPs and public Frame Relay carriers who adopted switch-based architectures.

The two most important attributes of switches are the following:

- Lower layer packet handling
- Connection-oriented network service (labeling)

Lower Layer Packet Handling

Instead of processing a packet at Layer-3 (typically a 40 byte header), switches transfer the packet based on the lower layer headers of Frame Relay (two bytes) or ATM (five bytes). This results in a switch having lower latency and processing load per packet.

Connection-oriented Network Service (Labeling)

Unlike routers, which provide connectionless network service, Frame Relay and ATM switches deliver connection-oriented network service. Rather than determining the path of each packet independently, the switches establish a path between the endpoints of a connection in a network and send the packets across that path. That label switched path is still a virtual connection, sharing the bandwidth of the physical circuit. In contrast to connectionless routing, the switches can define the parameters of the virtual connection, including allowable speed and priority. This is crucial to the switch's ability to manage WAN bandwidth and QoS.

The tight integration of switching and routing – with routing at the edge and switching at the core – delivers the following benefits:

- Performance
- Native multicast support
- Logical single-hop networks
- QoS
- Specialized circuit routing/class of service
- Multiple traffic types
- Reliability
- Scalability

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Performance

Switching has lower latency than routing because it uses streamlined protocol switching instead of routing's Layer-3 processing. Frame Relay switching requires only a simple table lookup for the Frame Relay virtual circuit number. ATM reduces latency further by using short, fixed-length cells. The combination of fixed cell size, high throughput, and high speed transmission minimizes end-to-end network transmission delay.

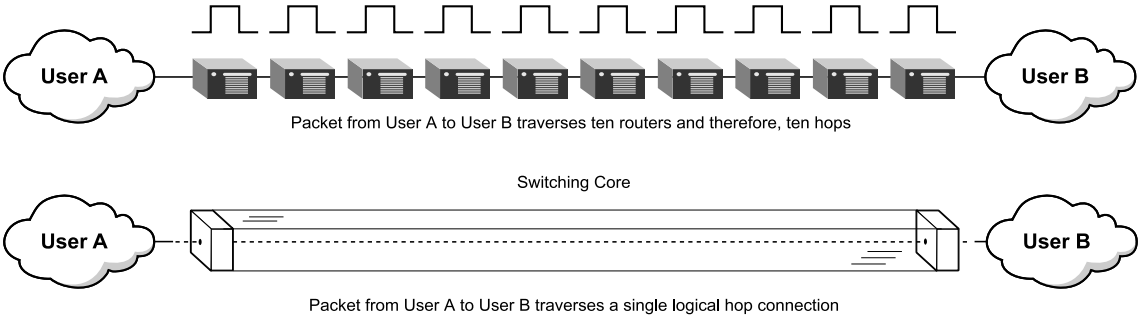


Figure 3 – A switching core makes a complex router network a logical Single-hop network.

Native Multicast Support

Because of their high-speed, low-latency properties, Layer-2 protocols are most efficient for handling raw data delivery tasks including multicast in the core of a WAN. As multicast applications proliferate and Internet architects prepare the Internet to serve as the next broadcast network, Layer-2 and Layer-3 technologies complement each other to deliver high-performance, scaleable IP Multicast solutions. Standard Layer-3 IP Multicast protocols are used to determine group membership and offer interoperability with content providers and other Internet providers while Layer-2 Frame Relay and ATM multicast capabilities deliver high-speed forwarding over a multicast label switched path in the core of a carrier-class network. The Ascend switch architecture performs multicast forwarding, including two-tier packet and cell replication in hardware – first in the switch fabric for distribution to I/O modules then on the I/O module for distribution to individual ports, thus saving valuable network, bandwidth and switch resources. Ascend's Multicast LSPs increase performance and enable the use of ATM QoS attributes for IP applications such as video.

Logical Single-hop Networks

Interconnecting routers with the switching core results in a network that, from the viewpoint of the routers, is a single hop network. Layer-3 protocol processing takes place only in the endpoint routers. (See Figure 3.)

QoS

A fundamental advantage of Ascend switches, compared to routers, is the ability they provide to control QoS. This is due to the connection-oriented nature of Frame Relay and ATM, combined with advanced features offered by individual switch vendors in contrast to the connectionless approach of routers. Distinct features give network managers the ability to tailor network service to the specific needs of diverse applications with varying classes of service. Demand LSPs make use of Frame Relay and ATM SVCs thus deliver the following features:

- Fault tolerance
- Interworking
- Prioritization
- QoS Classes

Specialized Circuit Routing/Class of Service

Network service providers, therefore, can define the desired characteristics of the individual virtual connections so that users receive the QoS/CoS they need, according to their application and priority. For example, managers can segregate different traffic types so that video traffic can be given priority over USEnet or e-mail transmission.

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Multiple Traffic Types

Since switches operate at the lower layers of the OSI Reference Model, they are protocol transparent; that is, they can support any synchronous protocol. For example, both SNA and Frame Relay are based on connection-oriented network service, making Frame Relay's networking characteristics a natural match to SNA's needs.

ATM has even broader support for traffic types, including constant bit rate traffic and variable bit rate realtime traffic. Companies that implement a switching core for their router traffic automatically lay the foundation for future multimedia networking needs. A protocol-transparent switched core gives service providers the ability to offer a wider range of services including Frame Relay, ATM, IP and SNA services.

Reliability

Switch designs have traditionally been targeted at carrier applications and manufacturers have placed high importance on fault tolerant designs, resulting in a greater level of reliability than is normally found in routers. As a result, the cost of complete redundancy within a switch is often quite low. This redundancy is particularly valuable in the core of the network where large volumes of traffic are concentrated.

Scalability

Based on the expertise of Ascend in building the world's largest carrier-class switched networks, IP Navigator MPLS brings a new level of scalability to IP Networks. IP Navigator MPLS's elegant use of multipoint-to-point (reverse multicast) circuits for best-effort services addresses the longstanding industry dilemma of how to support connectionless IP over connection-oriented networks such as Frame Relay and ATM in a scaleable fashion, without precluding the use of circuits for IP services that require traditional ATM QoS attributes. IP Navigator MPLS's fully distributed architecture does not rely on centralized servers which can introduce central points of failure, suboptimal use of network resources and introduce delay in a network architecture. Ascend's use of reverse multicast circuits, called Multipoint-to-Point Label Switched Paths (MPT LSPs) are described in depth later in this document.

A Glimpse Inside the Cloud

Integral to the power of IP Navigator MPLS is the widely-deployed Ascend multiservice switch architecture. This includes the bandwidth management features of the switch and the connection protocols, enhanced with the robust, high-performance features of the management of virtual connections and MPT LSPs. Now IP can have it all. VNN and MPT LSP enable Ascend switches to set up and use virtual paths in a highly scalable fashion. Together, these utilities ensure the conservation of network resources, saving them for data rather than using them for configuration management.

Virtual Network Navigator

Ascend originally developed the VNN OSPF-based networking architecture to provide the reliable and resilient internal network communications that are essential for support of large Frame Relay switched networks. The VNN connection-oriented network routing technology has been refined and extended to add support for ATM, SMDS, ISDN, SNA and, now, IP to the Ascend family of multiservice WAN switches. The use of VNN as a technology base for IP Navigator MPLS ensures a scalable, reliable solution for building large IP WANs that interoperate seamlessly with existing router networks and Ascend switched networks.

In addition to the standard features of OSPF, VNN includes Ascend extensions for managing network-wide Frame Relay and ATM attributes, such as available bandwidth and QoS. In a switched networking environment, VNN performs the routing functions needed to establish end-to-end virtual circuits (paths) through the network. It builds a link state database capturing the physical topology of the network along with the QoS capability and calculates the best routes. VNN distributes the topology database using the standard OSPF algorithm so that every switch (node) has the same network view. With IP Navigator MPLS, VNN is extended to support an IP routing table just like any other OSPF routing table. However, instead of next hop, the end-destination switch for each IP destination address is recorded. VNN complies with OSPF Version 2 and, therefore, includes support for OSPF areas, Non-Broadcast MultiAccess (NBMA) networks, point-to-multipoint networks, and Classless Inter-Domain Routing (CIDR).

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VNN keeps track of all links, bandwidth and existing circuits and makes intelligent circuit routing choices using the best available paths that meet the QoS requirements for each circuit. Using OSPF Link State Advertisements (LSAs), each switch builds a topology database with detailed information about all other nodes. Upon receiving a request to set up a virtual circuit, VNN uses that information to ensure that the path selected can meet the session requirements. If no suitable path exists, VNN will not allow a session to be established. This ensures that QoS requirements for all established sessions are met. If a network outage has an impact on the path of a virtual circuit, VNN quickly calculates an alternate path to ensure that the session stays active. VNN provides a seamless backbone for all services, with shared routing and management.

VNN simplifies network operations and enhances network resiliency and performance by optimizing link and bandwidth management using integrated Frame Relay and ATM features. In this way, hardware and software intelligence automates much of the traffic flow management that is operator-intensive in a purely routed network. VNN operates as an OSPF Autonomous System (AS) to manage end-to-end network reliability, resiliency, and performance. It supports 400 switches per AS. Beyond this, areas may be implemented to partition a large network for further scalability.

Multipoint-to-Point LSPs

Connection-oriented protocols are sometimes perceived to have scaling problems because the establishment of virtual circuits between every switch introduces an N^2 problem. The total number of circuits increases in proportion to the square of the number of switches. Since many of these circuits may converge onto a few central trunks, a risk exists of overflowing the circuit capacity as the network grows. Instead of establishing a full mesh of circuits between all nodes (switches), Ascend has developed MPT LSP (patent approval pending), which limits the number of virtual circuits in a network. (See Figure 4.) By using MPTs, each trunk carries, at most, one circuit for each destination switch.

The sophisticated MPT LSP technology addresses virtual circuit growth and management to deliver a highly scalable solution. Using itself as the root, a switch (for example, switch A) establishes a single multicast or point-to-multipoint circuit to all other switches in the network, adding them as leaves. The multicast circuit informs all other switches of the circuit that is to be used for forwarding data to switch A. The multicast circuit actually functions as a reverse forwarding tree for data destined to switch A. To forward traffic to switch A, another switch looks for the multicast circuit rooted at switch A. The multicast circuit then forwards data in the reverse direction - from leaf to root. Since MPT LSP runs on each switch, all switches are notified of the appropriate multicast circuit to reach every other switch in the network. This information is kept in the VNN link state database.

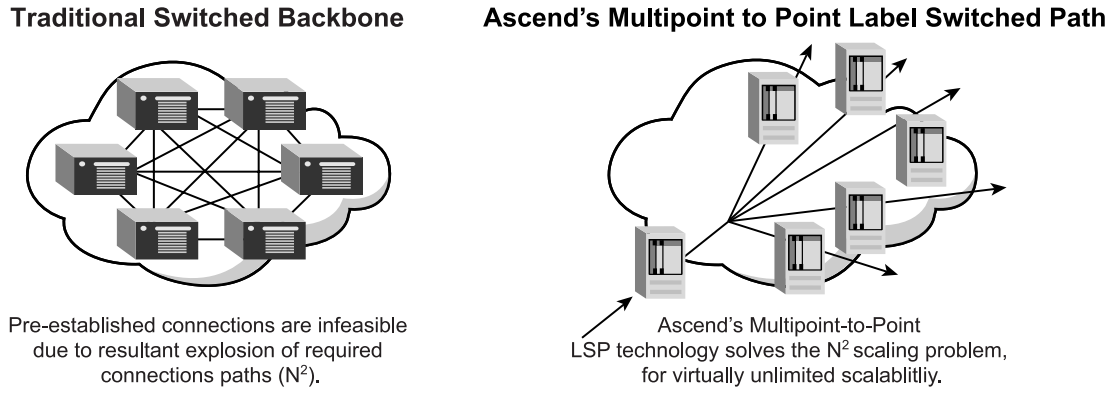


Figure 4 – Ascend solves scalability problem.

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IP Navigator MPLS Architectural Overview

With the IP Navigator MPLS software installed, Ascend switches function as IP routers. When a frame is received by a port configured for IP routing, the frame's IP header is examined for the destination address of the packet. A lookup is made on the VNN routing table to determine the egress switch within the cloud and the label identifying the MPT LSP of the egress switch is applied. Once the label is assigned, the traffic moves rapidly through the pre-established MPT LSP to that switch. Another routing table lookup is performed at the destination switch to determine the proper egress port.

The scaling properties of VNN with the reverse path forwarding solution are recognized by the fact that the state has been reduced in the Ascend IP switch to that held in a traditional IP router. A traditional IP router, however, stores forwarding state per destination in its IP routing table, which translates to next hop. VNN stores forwarding state in reverse paths, which is again per destination; however, this translates to the end destination in the network. For best-effort traffic, the routed path and the MPT LSP are the same. The only difference is that in the latter, the packets are switched in the intermediate nodes, instead of doing IP lookups and header verification at every hop. The packet's Time to Live (TTL) is verified before the packet is sent along the MPT LSP. If the packet's TTL is insufficient, the packet is forwarded hop-by-hop instead. This procedure maintains protection against routing loops and allows the use of all standard IP diagnostic tools (such as traceroute).

IP applications requiring end-to-end QoS routes are accommodated using VNN and ATM QoS guarantees that are extended across the Ascend family of multiservice switches. (See Figure 5.) QoS provisioning can be achieved by configuration or Type of Service (ToS) signalling. Configured QoS guarantees, for example, can be set up for a destination IP address such as a video server for a premium-level service. In either case, QoS routes that support the requested or configured QoS guarantees can be implemented using a variety of LSPs, including Demand LSPs that meet the service requirements.

Carrier-class IP for the WAN

IP Navigator MPLS utilizes the Ascend fully-distributed hardware design. The design allows an Internet provider or carrier to plan a network without a single point of failure and to maximize network uptime. Hot insertion of modules is supported in the entire line of Ascend NEBS-compliant multiservice switches. IP routing tables are fully distributed to each I/O card in a switch. (See Figure 6.) Besides enhancing reliability by fully distributing the routing and route selection function, latency is reduced and wire-speed performance is achieved. IP Navigator MPLS supports the routing table of today's Internet with an architecture designed to scale to a quarter million routes and beyond.

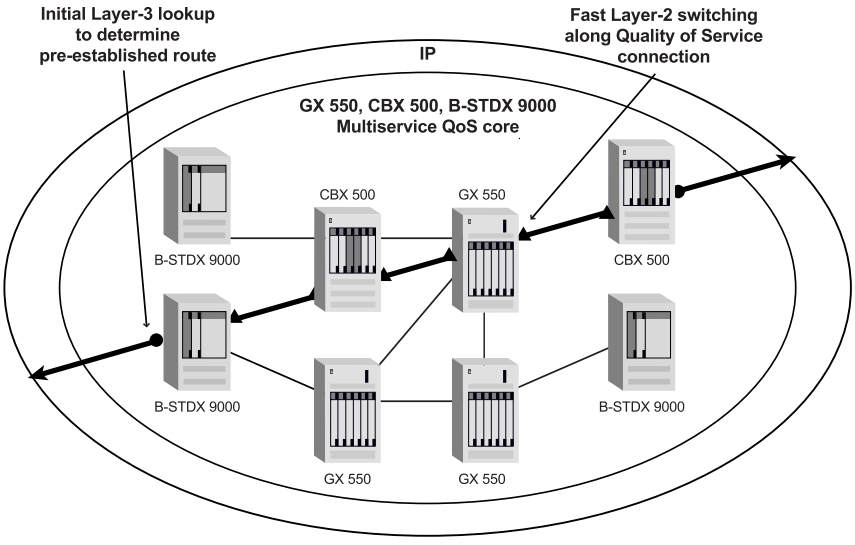


Figure 5 – End-to-end QoS provided for IP.

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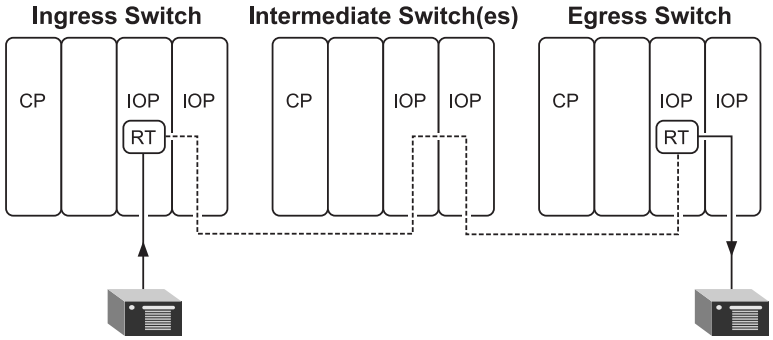


Figure 6 – IP packet flows from ingress switch to egress switch.

IP Navigator MPLS Extended to the Desktop

With the use of industry-standard open interfaces, Ascend ensures that IP Navigator MPLS extends from the interior of the WAN all the way out to the desktop. This open access to a new class of standard edge protocols that exchange relationships between IP address and connection IDs allows network service providers to extend the VNN QoS capabilities to the desktop. This is done by mapping protocol-specific parameters to the IP Navigator MPLS product's QoS. Examples of these protocols are the following:

- ToS byte field in IP header
- Resource Reservation Protocol (RSVP) (being developed in the future)
- Label Distribution Protocol (LDP) (being developed in the future)
- Standard ATM Signalling
- Frame Relay
- Next Hop Routing Protocol (NHRP) (being developed in the future)
- Private Network to Network Interface (P-NNI)

Unlike other vendors' proposals that require "one stop shopping," the Ascend solution offers a multivendor, multiservice, multiprotocol, open strategy. (See Figure 7.) This strategy allows VNN to be the "agnostic" core of the network. It also gives service providers and end users substantial flexibility to design networks using equipment and protocols that best meet their technical and business requirements.

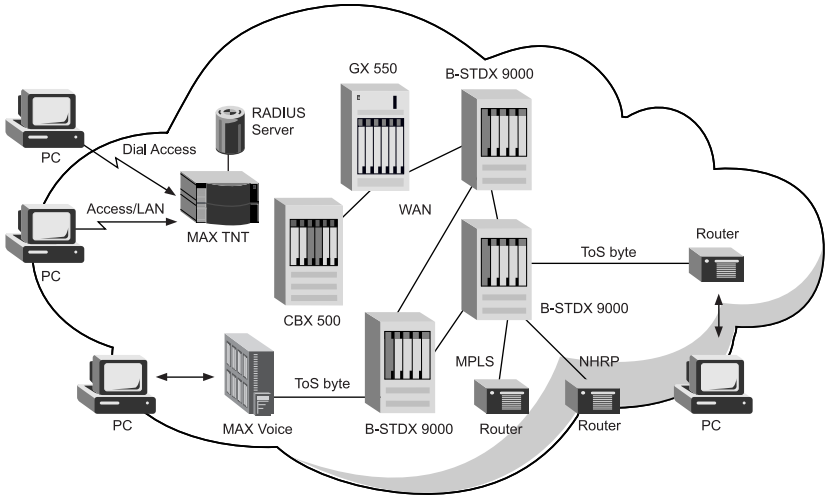


Figure 7 – Ascend offers an open IP architecture.

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Advanced Services Delivery

IP Navigator MPLS delivers the industry's most comprehensive IP solution to solve the problem of scaling large carrier-class IP WANs. The IP Navigator MPLS product constructs the technical foundation for building networks to support the ongoing evolution in global communications. In addition to providing the infrastructure that supports tremendous future growth, Ascend delivers solutions that lead to increased financial profitability through advanced services delivery.

Virtual Private Networks

IP Navigator MPLS includes support for Virtual Private Network (VPN) routing, which enables service providers to deliver tailored IP Service Level Agreements for advanced intranet and extranet services. Service providers can now easily access a rapidly expanding market for these types of services. Enterprise customers can build their internal IP network across a public service provider network while maintaining the same IP addressing space, security and QoS of their private network.

The IP Navigator MPLS architecture supports 1000 VPNs per switch and 64,000 per network. For each VPN, IP Navigator MPLS implements unique instances of one or more of the required routing protocols. The virtual routers support independent route fowarding tables that are updated dynamically with only the route information specific to that VPN. Any routing protocol supported by IP Navigator MPLS can be configured for a VPN. Privacy is ensured between each VPN's routing domain, and private addressing is fully supported in the VPN. (See Figure 8.)

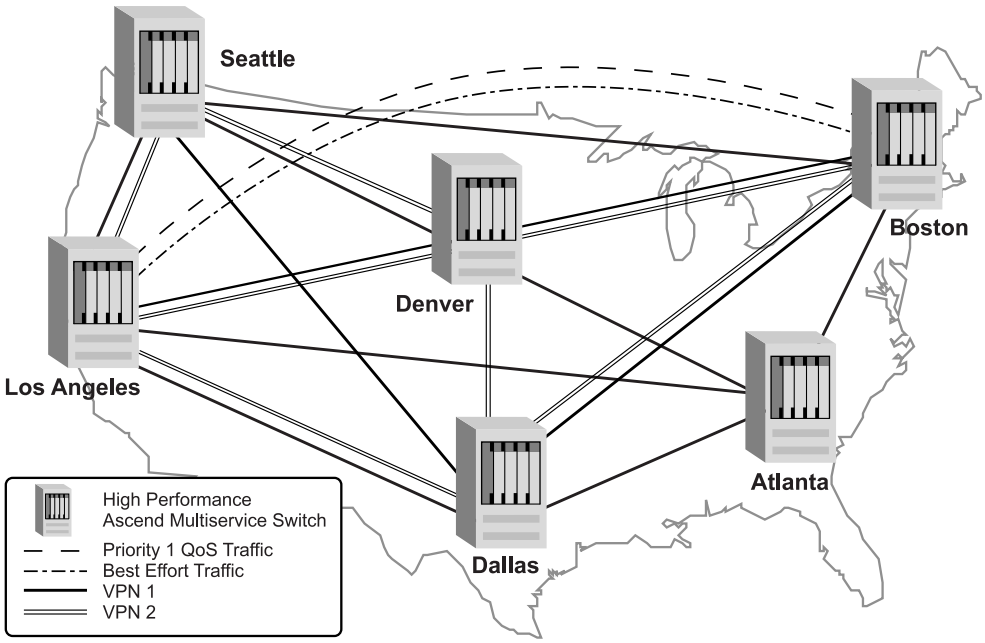


Figure 8 – Virtual private networks with QoS Paths overlay infrastructure.

IP Quality of Service

As time-sensitive voice and video applications migrate to the Internet, the network infrastructure must evolve to meet transmission needs that are much different from those of conventional data applications. In this evolution, the ability to support highly demanding applications will be a key success factor for emerging service providers, including toll quality Voice over IP (VoIP), and video transmission. The following range of service types are in demand on the Internet today.

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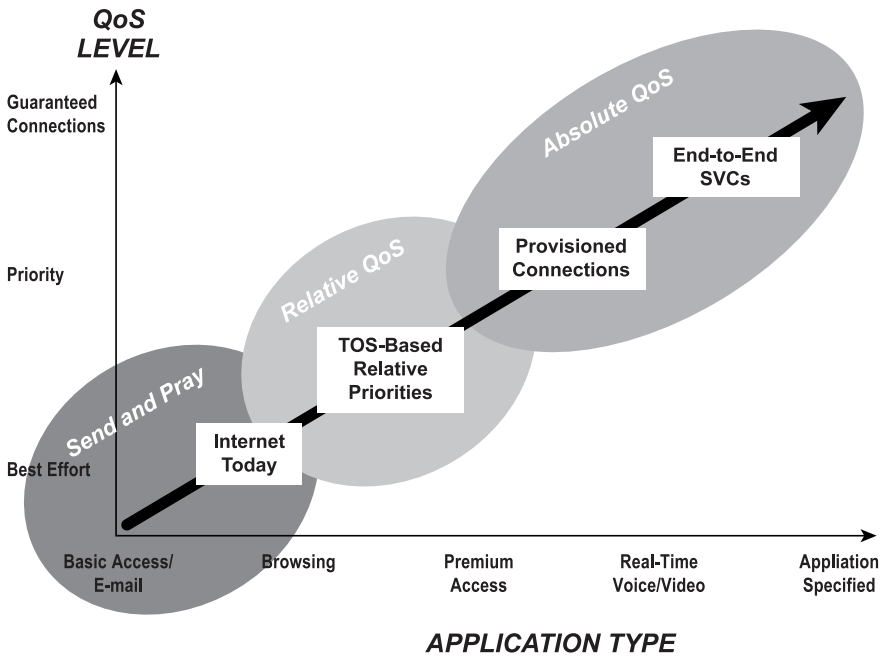


Figure 9 – IP Service Types

IP Navigator MPLS is the first technology to support the full range of quality of service requirements for IP applications across the wide area network. From best-effort to "absolute QoS" for voice traffic, the tunable network characteristics that must be defined for data services include:

- Flow or application type classification
- Priority
- Drop precedence
- Delay
- Bandwidth

IP Navigator MPLS integrates the flexibility, ease of use and simplicity of an IP interface with the QoS and guarantees that only come with a connection-oriented core. Built on top of widely-deployed and well-proven Frame Relay and ATM technologies, IP Navigator MPLS draws from a rich history of telco-quality, carrier-class features that ensure maximum availability and a scalable system-level architecture that addresses the needs of dynamic service environments.

Multicast Applications

IP Navigator MPLS includes robust support for standards-based IP Multicast functionality including Distance Vector Multicast Routing Protocol (DVMRP), Multicast OSPF (MOSPF) and Protocol Independent Multicast (PIM). IP Navigator MPLS Multicast LSPs let network service providers easily support the plethora of next generation applications that are emerging based on multicast functionality, including financial services, broadcast video, and distance learning applications. Ascend has a rich history of delivering robust multicast functionality for Frame Relay and ATM services. In addition to providing the power behind IP multicast protocols and internal VNN node-to-node communications, this functionality is used by service providers to deliver native Frame Relay and ATM multicast solutions. This ensures that the IP Navigator MPLS multicast functionality will scale to support the most demanding applications and users.

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Conclusion

As carriers and regional, national and global Internet providers take advantage of the market opportunity to deliver widespread data services, they are faced with scaling network capacity and performance as well as service offerings. The robust IP Navigator MPLS architecture fully utilizes the advantages of TCP/IP, Frame Relay and ATM on Ascend switching platforms. It scales performance at higher speeds and addresses both the technical and business needs of carriers and service providers, today and well into the future.



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