Lucent Technologies & Juniper Networks: Why Converge on MPLS?

Turning a profit in a deregulated world

Breaking the one-network, one-service paradigm with MPLS

Reduce costs by converging individual Layer 2 and Layer 3 networks onto a single multiservice architecture. Migrate to a network architecture that can scale existing services and add support for new IP services.

This paper describes how service providers can use MPLS to evolve to a converged network that enables them to:

- Shed expensive overlay networks in favor of a seamlessly interconnected multiservice network
- Take advantage of service opportunities created by deregulation
- Quickly introduce new services without sacrificing service quality or requiring a large capital investment

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This paper describes the rationale for converging existing service networks using a multiservice core network built with Multiprotocol Label Switching (MPLS). It is intended for network planners and engineers interested in exploring this convergence solution and the expanded market opportunities created by recent Federal Communications Commission (FCC) deregulation rulings.

Contents

Introduction 3

Market forces can obscure service provider options 3

Deregulation creates a unique opportunity for network consolidation 3

Layer 2 networks are here to stay 4

Competing priorities for Layer 2 and Layer 3 networks have delayed consolidation 5

Breaking the one-service, one-network paradigm with MPLS 6

Supporting Layer 2 services 6

Supporting Layer 3 services 8

Preparing for the transition from circuit- to packet-based network services 8

Industry groups agree MPLS is the right protocol for convergence 8

MPLS is the logical choice for converging networks today 9

MPLS is the choice for network expansions and new services 9

Introducing the Lucent/Juniper Multiservice MPLS Core Solution 10

Conclusion 11

Appendix A: Acronyms 12

Introduction

A few years ago, the most important problems service providers faced were achieving network growth and gaining market share. Today, network efficiency and cost management are paramount. To remain competitive, service providers need an economical network design that leverages existing network investments, reduces capital and operating costs, and positions them for future growth.

Most carriers maintain some combination of Time Division Multiplexing (TDM) – voice, ATM, Frame Relay, and IP networks. Each network supports a unique service set with its own protocols, management systems, and operating staff. This one-service one-network approach creates an immense cost structure, which service providers must overcome to achieve profitability and remain competitive.

Service providers can significantly cut capital and operating expenses by consolidating multiple single-service networks into a seamlessly interconnected multiservice network. Shedding expensive and inefficient overlay designs in favor of a converged network can sharply reduce costs by limiting equipment requirements and streamlining network management. To effectively consolidate services, the network core must transport data reliably and efficiently while maintaining QoS for all Layer 2 and Layer 3 services. This enables providers to maintain quality and sustain revenues from tariffed services backed by service level agreements (SLAs).

This paper explains the rationale for converging multiple single-service networks onto an integrated Multiprotocol Label Switching (MPLS) core. MPLS can simultaneously support both Layer 2 and Layer 3 services and with nearly universal industry and standards acceptance, is becoming the technology of choice for delivering new services — making MPLS the logical platform for network convergence.

Market forces can obscure service provider options

Service providers are buffeted by opposing market forces when it comes to network consolidation. The service opportunities created by deregulation and the need to streamline costs push providers toward converging their networks. Yet the gulf between Layer 2 and Layer 3 service requirements seems to make network convergence impossible. This section surveys these market forces and how they influence network design.

Deregulation creates a unique opportunity for network consolidation

Recent regulatory activity in the United States has made network consolidation over MPLS more attractive for three reasons.

First, the FCC Triennial UNE Review, published in August 2003, creates an opportunity for Regional Bell Operating Companies (RBOCs) to connect regional data networks across local access and transport area (LATA) boundaries. Over the next few years, RBOCs are expected to use inter-LATA data networking to offer ubiquitous Frame Relay and ATM data services. To create these nationwide data services, however, RBOCs require an extremely efficient, scalable network core capable of connecting all of their regional LATA networks.

Second, faced with increased competition for long-distance Frame Relay and ATM services, Interexchange Carriers (IXCs) are more focused than ever on gaining access to local Points of Presence (POPs) and transporting services from end users through the POP to their national network backbone. The FCC Triennial UNE review requires Incumbent Local Exchange Carriers (ILECs) to give IXCs access to their voice networks. To successfully share network resources, ILECs and IXCs require a standard interface based on either ATM Private Network to Network Interface (PNNI) or MPLS User Network Interface (UNI) that interconnects the service providers' networks — without sharing each network's internal topology information.

Finally, the FCC review affects local broadband access deployments. Although ILECs must give competitors access to voice networks, incumbent carriers do not have to share packet networks or new broadband deployments. With this ruling, the FCC effectively steps out of the way of new broadband and packet network development. Increased broadband access at the edge will inevitably increase the bandwidth required to support the new, primarily IP, traffic in the core.

To compete effectively in this new environment, service providers must be able to offer a wide range of Layer 2 and Layer 3 services tailored for their respective markets. At the same time, providers rely on revenues from traditional voice, enterprise data, or private line services to finance these new ventures. To thrive, they must be able to offer services more economically than their competition. Consequently, service providers need a network architecture that can reliably deliver both new and existing services on a single platform to reduce both near-term capital costs and long-term operating expenses.

Layer 2 networks are here to stay

To date, network protocols have been developed to support one or two specific services. For example, industry engineers designed TDM specifically to support voice; Frame Relay and ATM for high-capacity, reliable data services; and IP to efficiently transport best-effort data. As a result, most service providers support and maintain several parallel, incompatible networks to meet changing service demands. Operating discrete ATM, Frame Relay, Ethernet, and IP overlay networks introduces organizational inefficiencies and creates an inflated cost structure.

Several years ago, the industry assumed that new IP-based services and transport would completely eclipse services based on Layer 2 technologies. This would justify replacing existing Layer 2 network services with services carried over a Layer 3 IP network. The net effect would be that service providers would consolidate all services onto a single IP network.

That did not happen. While providers have deployed some IP-based Virtual Private Network (VPN), IP security (IPsec), firewall, and Network Address Translation (NAT) services, the deployments have been both slow and limited. Layer 2 ATM and Frame Relay services are simply too pervasive and profitable — while the Layer 3 services are not yet profitable enough — to justify replacing billions of dollars of revenue-producing Layer 2 network equipment. Also, service providers have

closely aligned their network operating systems and processes around circuit-based Layer 2 technology. The profit imperative and this operations alignment means that Layer 2 multiservice networks and Layer 3 IP networks will coexist for several more years. To converge these networks, service providers require a core network protocol that can meet the transport and management requirements of both.

Competing priorities for Layer 2 and Layer 3 networks have delayed consolidation

Although the industry has been talking about convergence for years, the migration to a converged network has been relatively slow. One reason is that Layer 2 ATM and Layer 3 IP networks have very different service delivery philosophies. This disparity makes it harder to consolidate them into one full-service platform.

Service providers use Layer 2 multiservice networks to:

- Provide private line point-to-point and point-to-multipoint ATM and Frame Relay connections to carry QoS-sensitive traffic between end-user sites
- Consolidate Digital Subscriber Line (DSL) services
- Aggregate tandem voice circuits

Supporting these Layer 2 services requires a protocol that strongly emphasizes point-to-point connections and maintains appropriate QoS for the traffic carried over those connections. As a result, ATM development work has been focused on guaranteeing reliability, providing precise QoS, and allocating bandwidth efficiently to individual traffic flows.

In contrast, service providers primarily use Layer 3 IP networks to provide best effort Internet access. Freed from the need to meet specific QoS and bandwidth requirements for point-to-point connections, the IP protocol has evolved to efficiently deliver data over the entire network. Consequently, IP networks are typically not concerned with providing more than best-effort service for any given traffic flow.

As a result of this disparity between ATM and IP service requirements, equipment vendors planned for future network development in one of two ways. Multiservice equipment vendors pushed service providers to deploy larger ATM switches in the core, often without providing a feasible plan for migrating to future IP-based services. Meanwhile, IP router vendors pushed service providers to deploy new services exclusively on IP overlay networks, completely bypassing current multiservice networks. Neither approach addresses the capital constraints facing most service providers today.

Service providers need to reduce costs and increase competitiveness by converging single-service networks over a unified multiservice core. However, their network strategy relies on a gradual evolution to new technologies. To meet cost constraints, service providers plan to use existing multiservice switches to maintain Layer 2 services, while gradually deploying new IP-based services to avoid large capital investments.

Breaking the one-service, one-network paradigm with MPLS

Since the converged network will support services found in both multiservice and IP networks, its architecture must span the requirements of both. MPLS bridges the gap between connectionless IP networks, where routing decisions are made at every hop, and connection-oriented networks that deliver point-to-point services such as ATM, Frame Relay, and voice.

As a result, MPLS can replace the old one-service one-network paradigm with a more flexible approach that consolidates multiple networks under a single set of protocols. Migrating to an MPLS core enables service providers to evolve their networks to deliver new services, while protecting revenues from current ATM, Frame Relay, IP, and Ethernet services.

This section describes how MPLS can simultaneously support both Layer 2 and Layer 3 services.

Supporting Layer 2 services

MPLS standards are evolving to support a wide range of technical features required to meet the QoS and SLA requirements for current Layer 2 services including:

1. The ability to support connection-oriented services

MPLS uses pre-determined data connections, known as Label Switched Paths (LSPs), to transport traffic through core networks. Like ATM virtual circuits, these MPLS LSPs have defined properties such as bandwidth availability, bandwidth utilization, and a QoS level. LSPs can be either static or established dynamically through signaling. As a result, service providers can create MPLS LSPs to support connection-oriented services with specific service parameters.

2. Encapsulation for most Layer 2 network protocols

The MPLS standards for signaling and data encapsulation allow Layer 2 services, such as ATM, Frame Relay, and Ethernet Virtual LAN (VLAN) services, to run over MPLS.

3. QoS and bandwidth allocation

MPLS standards define traffic engineering features to support QoS and reserve bandwidth for individual connections — enabling service providers to implement SLAs for point-to-point connection services. The MPLS LSPs sort incoming traffic streams by QoS level or to assure bandwidth availability to conform to these SLAs. The MPLS core sorts ATM traffic into high-priority LSPs.

4. Traffic engineering and optimization

Service providers can engineer MPLS LSPs to optimize network bandwidth. Directing traffic flow over specific core LSPs maximizes throughput, reduces congestion, and better utilizes the optical trunks between specific network switches.

5. Network and equipment reliability

MPLS networks adopt Fast Reroute recovery mechanisms to survive link or nodal failures. Some vendors' routing software and control planes enable or disable specific modules and protocols so operators can perform upgrades or restarts without interrupting services.

6. MPLS UNI and Service Interworking efforts

The MPLS/Frame Relay Alliance is working on two initiatives to expand the services offered over MPLS networks:

- Enhancing the MPLS UNI to enable MPLS networks to better support voice traffic. This simplifies connecting customer premises equipment (CPE) to the public MPLS network and allocating bandwidth to those connections.
- Developing standards for interworking ATM, Frame Relay, and Ethernet services over the MPLS core. This can help reduce the cost of multi-site VPNs, while enabling providers to offer customer flexible VPN access.

7. OAM support

MPLS standards have defined Operations, Administration, and Management (OAM) methods, comparable to those used in Layer 2 networks, to test and monitor data flows as they traverse the network. The standards do not define an end-to-end network management system but some MPLS core solutions, such as the Lucent/Juniper Multiservice MPLS Core Solution provides integrated network management today.

Together, these capabilities uniquely equip MPLS to bridge connection-oriented services between Layer 2 networks. As a result, service providers can use MPLS to protect existing Layer 2 service revenues, while increasing overall network scalability. (See Figure 1.)

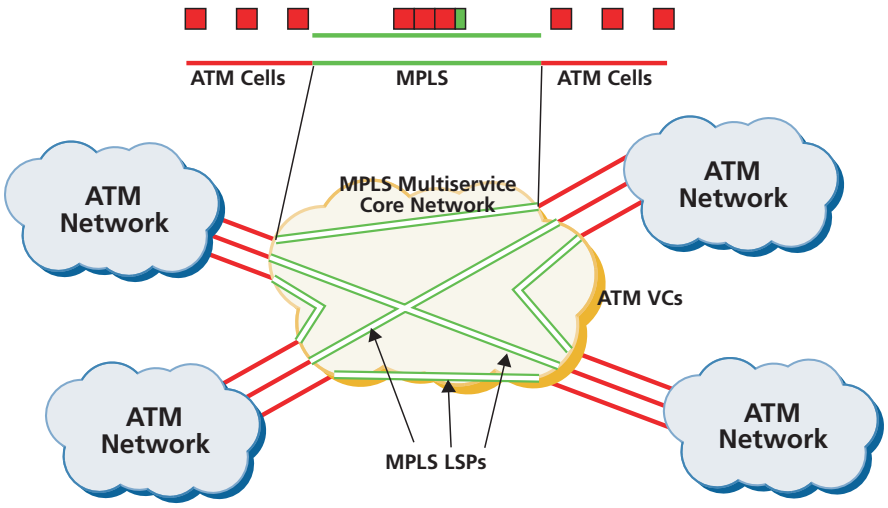

Figure 1 — Two ATM networks are connected through an MPLS core network. The MPLS signaling and encapsulation standards allow the MPLS core to transport the ATM virtual circuits (VCs) as if the two ATM networks were directly connected.

Supporting Layer 3 services

MPLS is a connection-oriented protocol for routed IP networks supporting IP addressing, signaling, and routing protocols. When the network establishes an MPLS LSP, it uses IP addresses to identify the ingress, egress, and intermediary switches along that LSP. IP interior routing protocols, such as Open Shortest Path First (OSPF) and Intermediate System-to-Intermediate System (IS-IS), distribute the topology information required to identify the LSP's path through the network. Meanwhile, traffic-engineering protocols, such as OSPF-TE and IS-IS-TE, disseminate information about bandwidth availability and overall resource utilization.

Service providers can use the MPLS core to direct traffic across an IP network, to minimize points of congestion points, and to balance the traffic load on network links. At the same time, MPLS provides enough connection-oriented capability to support the Layer 3 VPNs that will eventually replace ATM and Frame Relay VPNs.

Preparing for the transition from circuit- to packet-based network services

Deploying an MPLS core helps transition the network from circuit- to packet-based network services by providing the high-speed line interfaces and optical signaling needed to link the MPLS core directly to the optical network.

Most core MPLS routers currently support Packet-over-SONET (POS), 10 Gigabit Ethernet (10GigE), and Dense Wavelength Division Multiplexing (DWDM) interfaces, which run at higher speeds than traditional Frame Relay and ATM interfaces. MPLS does not require these higher-speed interface technologies. However, by supporting them, MPLS provides the option to create a high-speed core network with available hardware.

MPLS supports critical optical switching extensions, such as Generalized Multiprotocol Label Switching (GMPLS) and Optical Internetworking Forum (OIF) UNI signaling. The GMPLS and OIF UNI signaling protocols allow Layer 2 and Layer 3 switches in the core data network to directly request discrete bandwidth wavelengths from optical devices. This enables service providers to extend the benefits of traffic engineering from their MPLS core to their optical transport mesh and offer new wavelength-based services to end users.

Industry groups agree MPLS is the right protocol for convergence

Trade groups, equipment vendors and service providers are focusing on MPLS as the protocol for converging networks today and for adding new services and scaling their networks tomorrow.

MPLS is the logical choice for converging networks today

Perhaps the most encouraging sign that MPLS is the right protocol to support network convergence is the unprecedented agreement among many standards organizations. The ATM Forum, MPLS/Frame Relay Alliance, Internet Engineering Task Force (IETF), Metro Ethernet Forum (MEF), and Telecommunication Standardization Sector of the International Telecommunications Union (ITU-T) have all adopted MPLS as the standard protocol for unifying multiple data networks. These industry organizations are all working on a closely related set of MPLS standards. The sheer number of organizations working on MPLS standards and the efforts to coordinate this work is unprecedented in the history of data networking.

As a result, the industry has ratified several standards critical to using an MPLS core to consolidate network services including:

- Baseline encapsulation standards for transporting ATM, Frame Relay, and Ethernet services over MPLS

  The MPLS/Frame Relay Alliance is currently developing standards for interworking ATM, Frame Relay, and Ethernet services over MPLS. Meanwhile, the IETF has released pseudo-wire emulation end-to-end (PWE3, also known as draft-Martini) encapsulation[1] and draft signaling[2] standards, designed to support the extension of Layer 2 point-to-point connections across an MPLS core. Other drafts address MPLS Layer 2 point-to-multipoint services.[3] Meanwhile, the MEF has released standards for using MPLS to create virtual LANs across wide area networks.

- Standards for creating Layer 3 VPNs that will eventually assume the positions of current ATM and Frame Relay VPNs

  The IETF standard RFC2547 and associated BGP/MPLS standards and Internet drafts use MPLS and Border Gateway Protocol (BGP) to augment or replace private Frame Relay networks with VPNs on a routed IP/MPLS backbone. Although work on network management standards continues, scaling the MPLS core, IP-enabled Frame reliability, and signaling between multiple network types, as a group, the MPLS standards are solid enough to support interoperability today.

[1] "Encapsulation Methods for Transport of ATM Cells/Frame Over IP and MPLS Networks" *draft-ietf-pwe3-atm-encap-01.txt*

[2] "Pseudowire Setup and Maintenance using LDP" *draft-ietf-pwe3-control-protocol-03.txt*

[3] *draft-ietf-ppvpn-vpls-requirements-00.txt* and *draft-lasserre-vkompellappvpn-vpls-00.txt*

MPLS is the choice for network expansions and new services

The nearly universal acceptance of MPLS as the future of networking by the Ethernet, ATM, Frame Relay, and IP standards bodies has important implications for network planners.

Agreement on one set of protocols encourages interoperability among multiple switch and router vendors. In fact, the MPLS/Frame Relay Alliance was created in part to verify that network equipment vendors fulfill their public pledge to develop interoperable MPLS equipment. This alliance periodically sponsors interoperability tests at George Mason University (GMU) and the University of New Hampshire (UNH) to ensure vendor implementations remain consistent. This focus on interoperability means that service providers will have more flexibility in purchasing future equipment and a better chance of leveraging existing network investments to support new services.

Since the industry has largely agreed that MPLS is the protocol of choice to transport future services, almost all new services use it as their delivery mechanism. Already, key industry organizations are proposing ways of using MPLS to implement VPNs over a common backbone, deliver data to wireless devices, and deliver video content over data networks. Since MPLS is the key technology for delivering these services, the ideal platform to deploy them is in the MPLS core.

Service providers can use the enhanced MPLS UNI to enable new services and extend MPLS to the network edge.

Consequently, service providers can use their existing MPLS core network to deploy new services on a trial basis. Successful new services can be rapidly introduced to other customers. By enabling providers to trial services without building a new network and without interrupting other existing services, the MPLS core can reduce the cost of deploying new services, speed time to market, and protect existing revenues.

Introducing the Lucent/Juniper Multiservice MPLS Core Solution

Lucent Technologies and Juniper Networks have developed a multiservice MPLS core solution to meet service provider requirements for the converged network architecture. The Lucent/Juniper Multiservice MPLS Core Solution delivers the carrier-grade reliability, scalability, and QoS support providers require to scale profitable Layer 2 services. And it prepares the network to support enhanced IP services, such as IP/MPLS VPN, Optical IP, Ethernet access, and IP Centrex.

The Lucent/Juniper Multiservice MPLS Core Solution offers a cost-effective way to scale ATM and Frame Relay networks and support new IP services. To migrate to the MPLS core, service providers use existing Lucent multiservice switches at the network edge to create and manage all end-user services. Providers then add Juniper T-series™ routers to build an IP/MPLS core network. This world-class MPLS core uses accurate MPLS traffic engineering to transport all IP/MPLS and multiservice traffic according to its QoS.

The Lucent /Juniper solution is backed by the industry-leading Lucent *Navis*® iOperations software and Lucent Worldwide Services' (LWS) professional services. The award-winning *Navis*® software reduces operating expenses by delivering exceptional operational efficiencies and by integrating network management and service provisioning across all services, solutions, and products. The Lucent/Juniper offering is the only MPLS core solution that both preserves the efficient *Navis*® iOperations environment and extends it to support enhanced IP services. Meanwhile, LWS' support speeds solution deployments by providing a single point of contact for comprehensive and professional deployment, maintenance, and managed services across multivendor networks.

Conclusion

Service providers can use MPLS to consolidate IP and ATM networks onto a common core. By migrating their Layer 2 and Layer 3 services to a converged MPLS core, service providers can:

- Significantly reduce capital and operating expenses by replacing multiple overlay networks with a single core infrastructure
- Scale networks over an MPLS core to support more subscribers and increase revenue potential
- Evolve their networks to support new services like IP VPNs and Virtual Private LAN Services (VPLS)

Shedding expensive and inefficient overlay network designs in favor of a multiservice MPLS core solution can sharply reduce capital costs by limiting equipment requirements. Service providers can use the MPLS core to gradually evolve their network to new technologies, without sacrificing existing investments in multiservice switches and IP routers. Providers can use the MPLS core to quickly introduce new services without large capital investments or building expensive overlay networks.

To reduce costs and increase overall profitability, providers require an MPLS core that can seamlessly support both legacy and new services and a unified network management system that can manage all Layer 2 and Layer 3 services. The Lucent/Juniper Multiservice MPLS Core Solution offers a cost-effective way to scale ATM and Frame Relay networks and support new IP services. Built using world-class Lucent multiservice switches and Juniper IP/MPLS routers, the Lucent/Juniper offering both preserves the efficient *Navis*® iOperations environment and extends it to support enhanced IP services.

Appendix A: Acronyms

The following table lists the acronyms used in this paper.

Acronym	Meaning
10GigE	10 Gigabit Ethernet
BGP	Border Gateway Protocol
CPE	Customer Premises Equipment
DSL	Digital Subscriber Line
DWDM	Dense Wave Division Multiplexing
FCC	Federal Communications Commission
GMPLS	Generalized Multiprotocol Label Switching
GMU	George Mason University
IETF	Internet Engineering Task Force
ILECs	Incumbent Local Exchange Carriers
IPsec	Internet Protocol Security
IS-IS	Intermediate System-to-Intermediate System
IS-IS-TE	IS-IS Traffic Engineering
ITU-T	Telecommunication Standardization Sector of the International Telecommunications Union
IXC	Interexchange carriers
LAN	Local Area Network
LATA	Local access and transport areas
LSP	Label Switched Path
LWS	Lucent Worldwide Services
MEF	Metro Ethernet Forum
MPLS	Multiprotocol Label Switching
NAT	Network Address Translation
OAM	Operations, Administration, and Management
OIF	Optical Interworking Forum
OSPF	Open Shortest Path First
OSPF-TE	OSPF Traffic Engineering
PNNI	Private Network-to-Network Interface
POP	Point of Presence
POS	Packet over SONET
PWE3	Pseudowire Emulation End-to-End
QoS	Quality of Service
RBOCs	Regional Bell Operating Companies
SLA	Service Level Agreement
TDM	Time Division Multiplexing
UNH	University of New Hampshire
UNI	User to Network Interface
VC	Virtual Circuit
VLAN	Virtual LAN
VPLS	Virtual Private LAN Services
VPN	Virtual Private Network
WAN	Wide Area Network

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