

MRV Communications

OS9000 - MPLS Scope of Services

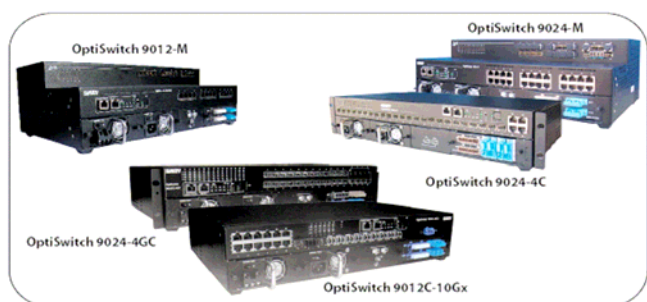


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Introduction

The OptiSwitch® 9000 series is a carrier-class Ethernet/IP/MPLS switch/router developed specifically for optical Metro Ethernet Aggregation services. The OS9000 series offers a wide range of aggregation models, which is reinforced with WDM technology to address carrier migration from copper local loop to ultra-broadband fiber transport for business and residential services.



Metro Ethernet service providers consistently see a growing demand for value-added VPN services along rigid SLA and for meeting customers' expectations for the maintenance of the same levels of availability, manageability & performances as they were used to in legacy SDH/SONET networks.

By integrating the MPLS technology on the OS9000 series, MRV introduces industrial hard-QoS with end-to-end traffic engineering, ATM-like QoS signaling, and path and node protection.

The new Metro Ethernet services supersede the connectivity provided by the traditional local loop and they leverage future plans of unified triple play (voice, video and data) over Ethernet/MPLS switched networks.

The objective of this document is to define the OS9000 MPLS Aggregation functionality and identify its benefits in various networking environments.

Abstract

The OS9000 series enables Layer 2 VPN services based on Ethernet over an MPLS protocol.

It supports Martini MPLS L2VPN, and Hierarchical VPLS (H-VPLS) PE-r spoke services that scale the VPLS service and simplifies multipoint topology. The MPLS L2VPN offers Virtual Leased Line (VLL) services or so-called Pseudo Wire Emulation Edge-to-Edge (PWE3) regardless of traversing protocols. The MPLS functionality is reinforced with highly flexible mechanisms to create traffic engineering (RSVP-TE & CR-LDP) connection-oriented paths and predefined rules for protection.

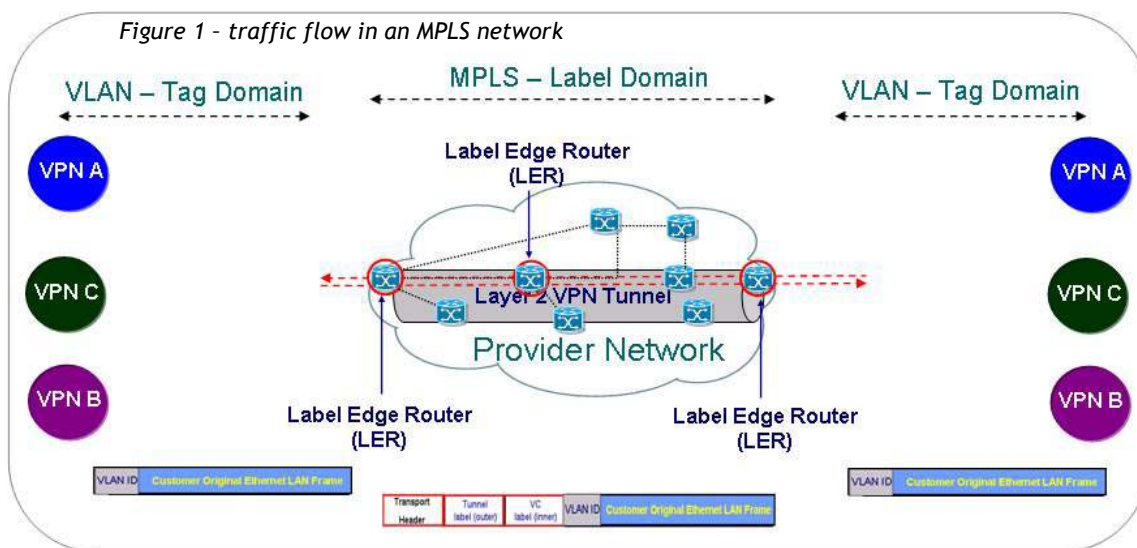
The MPLS functionality is incorporated in all OS9000 models and offers the following solutions:

- ▶ MPLS over Ethernet - Martini VC (LER & LSR)
 - Pseudo-wire L2 VPN tunneling
- ▶ H-VPLS
 - PE-r spoke & dual homing
- ▶ Signaling - RSVP-TE, CR-LDP & LDP
- ▶ MPLS DiffServ - E-LSP/L-LSP
- ▶ Traffic Engineering
 - CSPF, RSVP-TE, OSPF-TE
- ▶ MPLS protection
 - Fast Reroute
 - LSP path protection
- ▶ MPLS OAM
 - LSP ping
 - Verification Virtual Circuit Connectivity

What is MPLS?

MPLS means Multi Protocol Label Switching. A label (a number) is placed in a packet header and is used in place of an address (an IP address, usually) to direct the traffic to its destination. The basic idea is to take the customer's Ethernet packets, and move these packets seamlessly to other locations without modifying them.

An MPLS domain is built of LERs (Label Edge Routers) that reside at the edge of the MPLS domain and interior LSRs (Label Switch Routers) that are located within the MPLS domain. The LERs need to deal with both MPLS frames and native-mode user traffic while Interior LSRs have to forward only MPLS frames (Figure 1).



Following are the main functions performed in a flow on an MPLS network:

1. The Ingress Label Edge Router (LER) examines the inbound packets, classifies the packet into a Forwarding Equivalence Class (FEC), generates an MPLS header and assigns (binds) an initial label.
2. All the other routers inside the MPLS domain look at labels only, not at the IP address
3. Interior Label Switch Router (LSR) forwards the MPLS packets using label swapping (the processing is always on the top label)
4. The Egress LER removes the MPLS header and forwards the packet based on the destination address.

The OS9000 series can work as a Label Edge Router (LER) or a Label Switch Router (LSR).

With MPLS, it is possible to overcome the major drawbacks of conventional routing:

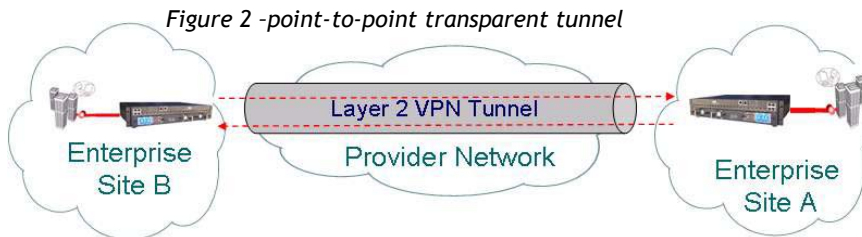
1. Connectionless IP does not support traffic engineering.
2. It's not sufficient to implement QoS architectures with IP.

Additionally, MPLS has other advantages:

1. Scalable solution - Labels are local and many IP addresses can be associated with one or several labels.
2. Simple solution - The interior Label Switch Routers perform simple label switching. Only the edge device performs the more complicated task of classifying the packets into FEC and binding a label.
3. Lower latency - Usually label-switching is a simple task compared to longer prefix match and IP forwarding.

Layer 2 VPN Services

Layer 2 VPNs are established by one or more point-to-point transparent tunnels (figure 2). Subscribers' Layer 2 traffic, sent through the MPLS VPNs, is moved seamlessly across a core network running MPLS. The OS9000 MPLS VPNs solution provides a high-bandwidth cost effective alternative to legacy Telco circuit leased lines.



The OS9000 offers the following functions at the provider edge:

1. MPLS signaling to establish layer 2 tunnels and to define their parameters
(draft-martini-l2circuit-trans-mpls)
2. MPLS data encapsulation to forward service-specific data over the MPLS backbone
(draft-martini-l2circuit-encap-mpls)
3. Binding subscribers/services to MPLS VPNs.
4. Provision of QoS and SLA services for subscribers VPNs.

Martini MPLS L2VPN - technology outline

Martini draft is a method for transporting layer 2 customer data over a scalable provider MPLS network. The idea is to use MPLS in order to emulate virtual channels (VCs) and mask from the user the fact, that the same physical link is being shared by other users.

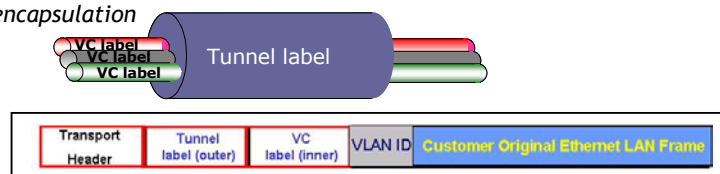
MPLS technology was adopted by IETF to provide virtual circuit (VC) provisioning over multi-protocol networks. In legacy ATM networks, VCs defined the connection-oriented service. With Martini draft, the same functionality is provided by Ethernet in an MPLS networks.

MPLS Layer 2 VC actually extends the customer LAN across an MPLS network.

In order to pass frames transparently from the VC ingress to the VC egress the whole Ethernet frame is first encapsulated (figure 3) with a VC label that identifies the VC on both ends.

Another label (Tunnel label) is used for forwarding the frame along the established Label Switch Path (LSP). The interior LSRs forward the frame according to the Tunnel label till the frame arrives to the egress LER. Then the Tunnel label is popped and according to the VC label (which is also popped) the OS9000 knows the outgoing interface/VLAN identifier and delivers the Ethernet frames to their intended destination.

Figure 3 - VC & tunnel encapsulation



OS9000 supports MPLS layer 2 Virtual Circuit (VC) based on draft-martini & PWE3 working groups.

MPLS L2 VPN Advantages

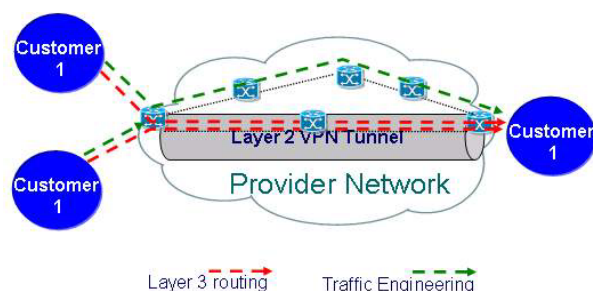
1. The Provider's network is transparent to customer networks; therefore there is no need for complicated configuration (routing protocols) on the customer's side.
2. Scalable solutions for Service Provider to implement.
3. Common MPLS backbone does not require any special customer configuration. VC is configured only at the LERs. Interior LSRs do not maintain customer VC information.
4. Layer 2 tunneling service supports any Layer 2 or Layer 3 traffic.
5. Lower TCO solution for Provider & Customer versus legacy alternatives.

In essence, the MPLS VPNs based on Martini draft provide transparent L2 VPN services that can seamlessly connect customer's remote branches. The customer's network administrator has complete control over how the network is running without any protocol interaction with the provider's network.

MPLS and Signaling

Traffic Engineering (TE) can be used to resolve congestion and improve network utilization. Routing protocols usually create a single "shortest path" and all the traffic is sent through that path. The consequence is that the "shortest path" becomes congested while at the same time "longer" paths become underutilized. Instead of adding more and more bandwidth to avoid congestion, the TE's approach is to "put the traffic where the bandwidth is" (figure 4). It implies the ability to diversify routes and to "explicitly" route traffic.

Figure 4 - Traffic engineering vs. IP routing



MPLS Traffic Engineering allows for explicit routing and set-up of LSPs. It also provides control over how LSPs are recovered in the event of failure. Such functionality enables value-added services like Traffic engineered VPNs, Service Level Agreements (SLA) and Multi-media over IP solutions.

In order to implement MPLS Traffic Engineering, enhancements were added to the routing protocols and to the MPLS signaling protocols.

The traditional routing protocol is extended to provide explicit route selection while preserving predefined constraints. Examples for such constraints are bandwidth requirements, include or exclude nodes, include or exclude specific links. The goal of constraint-based routing is to compute a path from a given node to another, such that the path doesn't violate the constraints and remains optimal.

The enhancements to the MPLS signaling protocols, to allow explicit constraint-based routing, produced the following extended protocols:

1. Resource Reservation Protocol - Traffic Engineering (RSVP-TE)
2. Constrained Routing enabled Label Distribution Protocol (CR-LDP).

The enhanced Signaling protocol can provide:

1. Coordinate label distribution
2. Explicit routes (strict & loose)
3. Bandwidth reservation
4. Class of Service
5. Preemption of existing LSPs
6. Loop prevention
7. Protection LSP

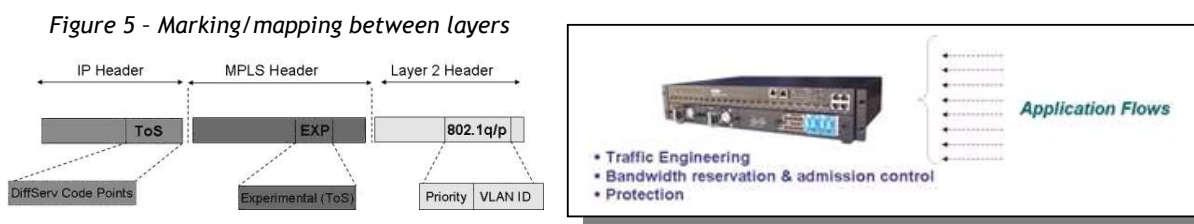
Using the above technology and protocols the OS9000 is able to provide many of the new services that Service Providers seek to offer, relying on TE functions. Examples are bandwidth assurance, diverse routing, load balancing, path redundancy, preparing alternative path for fast recovery and other services necessary for providing QoS.

MPLS and Quality of Service Functionality

MPLS is a QoS-enabling technology that forces application flows into connection-oriented paths and provides mechanisms for Traffic Engineering and bandwidth guarantees along these paths. As explained in the previous paragraph, the OS9000 has the ability to create traffic engineered LSP called tunnels. These tunnels can be created using either CR-LDP (LDP tunnels) or RSVP-TE (RSVP tunnels). One of the important constraints that the administrator can define for a tunnel, is the amount of bandwidth needed for the tunnel. While the tunnel is established, the bandwidth is reserved on all the MPLS devices along the path. If according to the internal admission control there is not enough bandwidth available on one of the OS9000, that tunnel will either fail or replace an existing tunnel with lower priority.

After the tunnel creation the OS9000 applies policing and shaping to the traffic sent through the tunnel to make sure it doesn't cross the reserved bandwidth boundary as specified in the tunnel definition.

Another important feature of the OS9000 is its ability to provide differentiated service levels to specific flows that use the same Virtual Circuit (VC). Since VC is used for Layer 2 VPNs and the traffic is not necessarily IP packets, the OS9000 uses the 802.1Q Tag VPT bits to classify packets into service levels. Then, the EXP bits in the MPLS header encapsulation are marked with an equivalent value (figure 5). When the frame is label switched from one LSR to the other, it receives priority based on the EXP bits value.



OS9000 MPLS QoS - Mapping Profiles Advantages

1. Bandwidth reservation for CR-LDP and RSVP-TE trunks
2. Policing MPLS VPN bandwidth reservation
3. Option to map either 802.1Q VPT bits or IP DSCP bits to MPLS EXP bits
4. Option to mark MPLS EXP bits to specific value
5. EXP bits are marked on both Tunnel and VC labels
6. VC ingress/egress class-based accounting

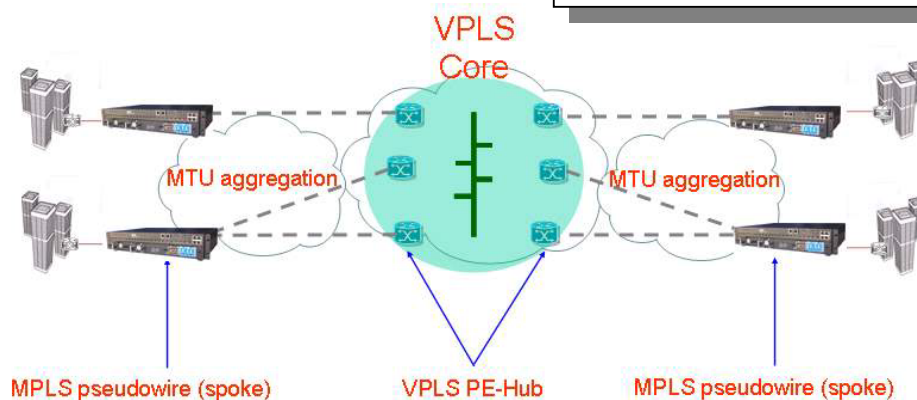
Hierarchical VPLS (H-VPLS) - technology outline

This is an innovative method to scale multipoint Virtual Private LAN Service (VPLS) that was adopted by the industry as a de-facto solution for MPLS extension for 1st mile networks.

Extension of VPLS-based services to MTUs will increase significantly the full mesh of tunnels between PEs. As a result, the VPLS standards (draft-ietf-ppvpn-vpls-ldp) allow the creation of a hierarchical design with a hub-and-spoke mode. The full mesh of tunnels is maintained between the hub sites (designed as PEs), while the MTU devices act as spoke pseudo-wires in a single or a dual-homed manner (figure 6). Such method creates hierarchy and reduces the configuration and service complexity.

Figure 6 - Hierarchical hub-and-spoke mode

The OS9000 provides an H-VPLS MTU spoke functionality that scales the VPLS service and simplifies multipoint topology.



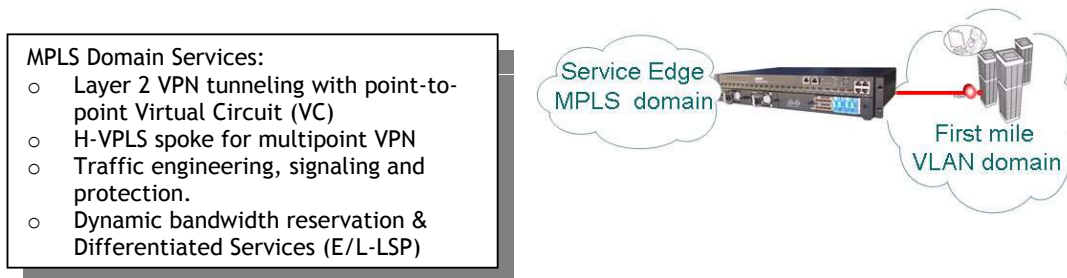
OS9000 H-VPLS - 1st & 2nd mile PE-r Spoke Advantages

1. Simplifies multipoint network architecture
2. Reduces signaling overhead for control plane
3. Minimizes the number of LSPs to be managed
4. Minimizes LDP peers in the core
5. RSVP protection
6. Encapsulation of customer's MAC addresses into external MAC between spoke & hub

Note: The same underlying IP/MPLS protocols (LDP, RSVP-TE, OSPF-TE etc.) are used to signal and route circuits.

Network Scenarios - A field impacts/advantages

The demand for private-line and LAN services over Ethernet/MPLS has created a new set of layers in today's metropolitan networks. The development has been propelled by the Metro Ethernet Forum (MEF) standardizing body and uses MPLS and VLAN bridging as network fundamentals.

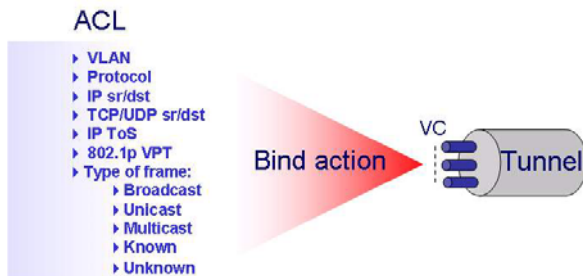


A typical scenario of network is a Layer 2 VLAN-based access and an MPLS-based service edge/core. However, in many networks the goal of engineering groups is to extend the MPLS technology closer to the first aggregation due to the following reasons:

1. Service scalability - MPLS label technology is scalable far beyond VLAN 4K tags
2. MAC explosion - MPLS header is encapsulated with an external Ethernet MAC, and the MPLS hops only see the outer MAC, thus offering a significant saving of MAC learning tables
3. Traffic engineering & protection - MPLS offers highly flexible mechanisms to create connection-oriented paths and predefined rules for protection
4. QoS signaling - signaling protocols that are part of an MPLS create an effective mode for admission-control and resource reservation for class-based traffic
5. Service OAM based on unified MPLS control plane from aggregation to core

MRV's OS9000 series offers a simple migration path from VLAN to MPLS modes and uses an ACL engine for binding the relevant flows into Virtual Circuits. This allows for a flexible mode to map a flow of frames or packets to predefined paths (figure 7) and to offer application awareness with carrier-class VPN and hard-QoS concept.

Figure 7 - Any classified flow can be bound to Virtual Circuit



Integration of IP/MPLS Intelligence with WDM Services

WDM and IP/MPLS technologies enable service providers and network architects to build scalable, reliable, secure and optimized public networks. The WDM technology represents a unique opportunity for an almost unlimited potential bandwidth, addressing intensive demand for broadband services. The MPLS technology is an intelligent state-of-the-art layer that combines carrier-class traffic control with connection-oriented service. The combination of both technologies delivers the best offering for converged service provision and intelligent traffic control over a transport network.



MRV's WDM & IP/MPLS solution - The integrated structure between layers

MRV consolidates both technologies in its service aware solution to enable sophisticated E-LAN and E-Private Line services with a modular design by economics of scale. MRV's intelligent services integrated into WDM offer advanced traffic management and Quality of Service along with optical VPN optimization.

By incorporating MPLS into WDM, MRV introduces a new array of services based on physical layer fiber transportation with end-to-end traffic engineering, ATM-like QoS signaling, path and node protection and multilayer OAM. MRV's multilayer OAM facilitates SLA enforcement with deep inspection of applications and services that are monitored for statistics, connectivity and fault management.



MRV's WDM & Intelligent IP/MPLS portfolio introduces a new and advanced approach to the carrier market by means of its unique level of application awareness and flexible tailor-made solutions for enhanced optical services.

Summary

There are differences in technological and economical advantages that depend on a specific customer need. The OS9000 series enables the combination of multiple technologies on the same platform to facilitate the services with rigid SLAs and economical sense.

MRV provides one of the broadest ranges of Metro Ethernet solutions for Ethernet Service demarcation, aggregation, and IP/MPLS service creation. Such a comprehensive portfolio offers the best breed of choices to any carrier network and delivers true versatility and a standards-based solution, meeting the most demanding network scenarios while offering a virtually unlimited range of network topologies from which to choose.

General Interoperability

MRV offers only standard non-proprietary features to enable networking interoperability with other vendors. Our code is compatible with 3rd party vendors based on industry IEEE, IETF & ITU-T standards:

- IEEE Link layer based on all 802.3 standards
- IEEE data layer based on 802.1 standards
- IETF Network layer based on IP RFCs
- IETF QoS model based IETF DiffServ
- IETF MPLS control plane signaling LDP, RSVP-TE, CR-LDP, OSPF-TE, CSPF
- ITU-T grid wavelengths
- MEF Service specifications (UNI/NNI)

MRV tested the MPLS interoperability of its OS9000 during the MPLS world congress 2006 interoperability event held in Berlin, organized and facilitated by the EANTC (European Advanced Network Test Center) and the University of New Hampshire Interoperability laboratories (UNH-IOL). The OS9000 series was found fully interoperable with the other main vendors such as Alcatel, Cisco, Ciena, RiverStone, Nortel and Tellabs.

MRV is a member of the following standardization organizations and industry forums:

IEEE - The Institute of Electrical and Electronics Engineers, Inc
IETF - The Internet Engineering Task Force
MEF - The Metro Ethernet Forum - interoperability and MEF certification
MPLS Forum - MPLS/VPLS interoperability events

Contact:
Zeev Draer
Zdraer@mrv.com