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Innovation in Access and Metropolitan Area Networks - Combining Ethernet and MPLS

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Introduction

There can be no doubt that both business and residential subscribers would derive significant benefit from higher speed connections to the public network. However, the traditional suite of TDM access connectivity options and legacy Layer 2 WAN services are too expensive on a cost per Mbps basis to allow subscribers to purchase all the bandwidth that they could viably use.

A more cost-effective access technology would allow service providers and enterprise IT organizations to eliminate the access bottleneck while simultaneously opening the door to a wide range of additional value added services. These services include higher speed Internet access, VoIP, broadcast video, Video on Demand (VoD), Transparent LAN Services (TLS), and remote storage options.

As Multi-Protocol Label Switching (MPLS) continues to gain acceptance as a mainstream backbone technology, service providers are extending MPLS functionality into the metropolitan and access network segments in order to further simplify their networks and develop a true end-to-end architecture for the delivery of packet data services. This paper will be devoted to a discussion of the complementary nature of Ethernet-in-the-first-mile (EFM) and MPLS and the innovative role that they will play in the next generation access network.

Background

Ethernet is clearly the leading candidate for a next generation broadband network access technology. It is one of a number of technologies that can be used to offer Bandwidth on Demand services. With Ethernet, services can readily be scaled to any desired bandwidth up to 1 Gbps, and extensions to 10 Gbps are a future possibility.

Using Ethernet access at both ends of the network, essentially resulting in an end-to-end Ethernet service, is very cost-effective because it eliminates protocol layers and protocol conversions over the end-to-end network path between Ethernet-

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attached systems. The result is a much simpler architecture that brings both lower equipment and operating costs. In particular, the high volume and competitive nature of the markets for Ethernet equipment and components ensures that Ethernet solutions will continue to be the leader relative to offering the lowest cost per Mbps of capacity.

The existing standards processes also contribute to the cost effectiveness and usefulness of Ethernet solutions. For example, the IEEE 802.3ah Ethernet in the First Mile (EFM) working group last year completed its work to adapt Ethernet technology to the physical media of the local loop, including Ethernet over dedicated single mode fiber (point-to-point) or shared fiber (point-to-multipoint via a Passive Optical Network or PON). EFM also supports Ethernet over copper twisted pair by leveraging technology from the DSL Forum. A key focus of the 802.3ah working group has been to add the OAM (Operation, Administration and Maintenance) features required to make Ethernet first mile links suitable for carrier networks, as well as for enterprises that want to run a carrier-class network.

As Ethernet becomes the network transport of choice for new investments in access and Metropolitan Area Networks (MANs), Ethernet access networks will need to coexist and interoperate with incumbent networks that may span a range of previously installed transport technologies. In this regard, IP/MPLS is rapidly emerging as the most flexible service provider backbone technology because it allows the IP packet backbone to serve as a consolidated or converged backbone that supports the installed base of Layer 3 and Layer 2 services, including Ethernet, Frame Relay, and ATM.

From an access and metropolitan network perspective, MPLS is a highly complementary technology because it supports a Virtual Private LAN Service[1] (VPLS) that provides the multipoint-to-multipoint LAN-to-LAN connectivity needed to allow numerous dispersed Ethernet access networks and MANs to function as a single virtual LAN. Where the requirement is for a point-to-point link to connect two sites by emulating a point-to-point link over Ethernet access and/or metropolitan networks, a Virtual Private Wire Service[2] (VPWS or Martini service) can be used.

Ethernet in the First Mile

A typical carrier requirement is that every Layer 2 network technology should be capable of being operated and managed without reliance on a higher-level protocol for reporting and communicating management information. In recognition of this requirement, the EFM working group made it a priority to add native Ethernet OAM features for the first mile link.

The following EFM OAM functions are implemented using special Ethernet frames called OAMPDUs (OAM Protocol Data Units) for communication between OAM entities at opposite ends of the EFM link:

- **Discovery:** Identification of OAM-capable devices and their capabilities. Discovery allows OAM-capable devices to form associations without the time and errors that are associated with manual configuration.
- **Link monitoring:** Detection and reporting of link faults, including errored frame rates and the percentage of errored seconds. Link statistics can be used as a troubleshooting aid or to identify degrading links before a failure occurs.
- **Remote fault detection and signaling:** Reporting failure conditions, including loss of the signal on a link, dying gasp due to an unrecoverable failure, and the occurrence of a critical event. The definition of the conditions that trigger dying gasp or critical event notifications is an implementation details left to individual

[1] *MPLS in Private Networks: Is it a Good Idea? http://www.webtorials.com/abstracts/Juniper23.htm*

[2] *Ibid.*

vendors. Remote reporting of a range of failure conditions reduces the time and resources that are required to do fault detection and isolation.

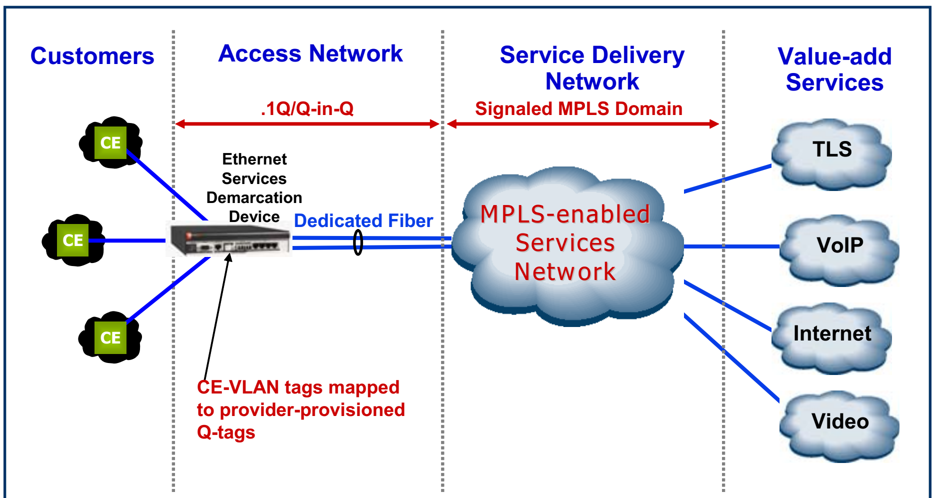
- **Remote loopback testing:** A centralized OAM entity can place its remote OAM partner in loopback mode to verify link quality during installation or troubleshooting. Loopback is useful as a means of eliminating the EFM link as the possible cause of a service availability problem.
- **MIB variable retrieval:** OAM provides read-only MAC-layer access to the IEEE 802.3 CMIP MIB variables. There is also a separate EFM MIB for SNMP, which is for use with inband and/or direct SNMP access to the EFM OAM protocol and procedure state on an EFM entity. This approach means that communications, including 802.3 MIB retrieval, can be restricted to the MAC layer. This has the benefit of allowing the Ethernet service to be managed without resorting to Layer 3 communications, which can then be reserved entirely for customer traffic.

While EFM OAM is focused on single Ethernet links, the Metropolitan Ethernet Forum (MEF) is developing Layer 2 OAM for multi-hop Ethernet networks based on the definition of a Ping/Traceroute-like functionality at the Ethernet frame level. A multicast version of the protocol is used for automated discovery of edge devices and a unicast version is used to support SLAs by determining connectivity, latency, loss, and jitter.

Ethernet Access to an MPLS Network

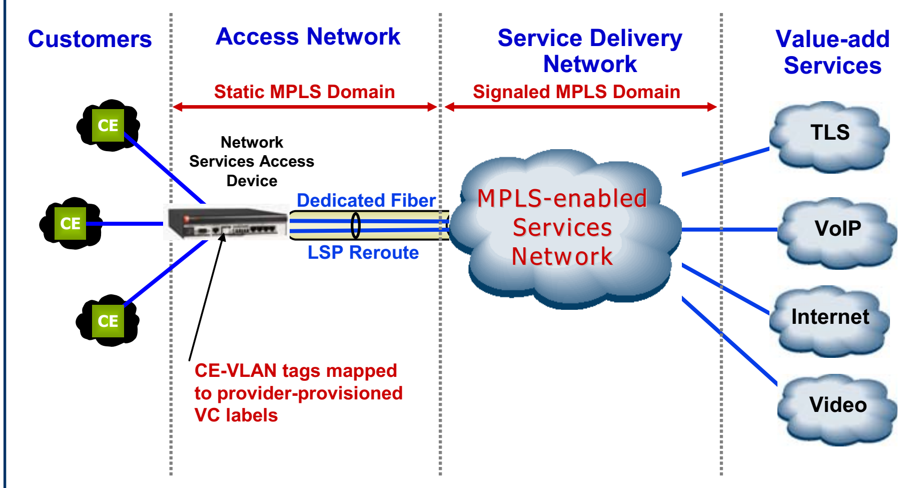
Figure 1 shows a typical Ethernet Extended MAN based on point-to-point optical Ethernet. A Layer 2 Transparent LAN Service (TLS) is delivered within the metropolitan area using Ethernet bridging as well as 802.1Q tagging and "Q in Q" or VLAN stacking. VLAN stacking allows 802.1Q tunneling of the customer's private VLANs throughout the MAN. The full MAN would consist of additional Q in Q-capable PE (Provider Edge) bridges/switches (not shown in the diagram) that are typically connected in a hub-and-spoke or a ring topology. With Q in Q encapsulation, the service provider's ingress device, now the Ethernet Services Demarcation Device, applies a provider-edge VLAN ID in every frame header, which is later removed by the provider egress device. The TLS may be extended to customer sites in remote metropolitan areas over the MPLS network. In traversing the MPLS core, the Label Edge Router (LER) router at the edge of the MPLS network maps the VLAN IDs to VPLS tunnel labels with the inverse mapping occurring at the egress LER. It should be noted that a number of providers have eliminated the Q in Q encapsulation within their metropolitan and access networks by extending the use of MPLS to include both the Core Routers and the PE bridge/switch in the PoP.

Ethernet Extended MAN
Figure 1



Source: Metrobility Optical Systems®

MPLS Access Model
Figure 2



Source: Metrobility Optical Systems

In addition to IEEE 802.1D/Q, which includes the specification for both 802.1Q for tagged VLANs and 802.1p for QoS marking, a number of other fairly recent enhancements to the Ethernet standards have improved the robustness of bridged Ethernet networks. Many existing deployments use such extensions in the access network.

For example, the Spanning Tree Protocol (STP) has been extended to allow for VLAN-specific spanning trees (Multiple-instance STP) and rapidly converging spanning trees (RSTP). MSTP allows the configuration of active-active redundant bridged topologies within the provider's .1Q backbone, while RSTP can reduce STP convergence times after link or node failure to less than one second. In addition, numerous proprietary Ethernet OAM implementations are also available for deployment in Ethernet access networks.

A higher level of carrier control of the network is possible with addition of a carrier-manageable Ethernet Services Demarcation Device at the customer premise. This device extends VLAN-based service provisioning, traffic prioritization, bandwidth provisioning, and diagnostic/OAM features to the customer premise.

MPLS over an Ethernet Access Network

Figure 2 shows how the network depicted in Figure 1 may be evolved to take advantage of the EFM standards and to extend the benefits of MPLS into the access network.

In the diagram, the optical Ethernet link has been upgraded to EFM. This can be accomplished by adding an EFM-compliant Network Services Access Device (NSAD) at the customer site as well as EFM capability to the PE bridge/switch.

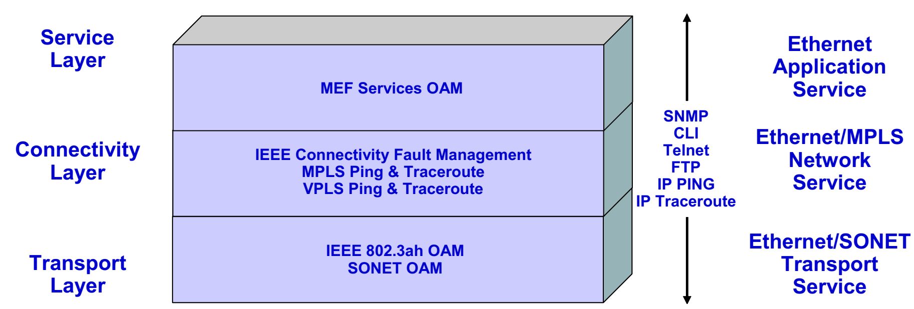
The other major change in evolving to the network depicted in figure 2 is the replacement of IEEE 802.1Q tagging and Q-in-Q tunneling with MPLS. Therefore, MPLS is extended end-to-end throughout the provider's access and metropolitan network. This modification requires that the EFM Network Services Access Device be a Layer 2+ bridge that supports standard Ethernet bridge functionality, including 802.1D and Q, plus a basic set of MPLS LER and VPLS functions.

In order that VPLS be extended end-to-end, the device must map the customer's 802.1Q VLAN tags to the appropriate VPLS VC labels and bridge the traffic to the Provider's PoP. The NSAD moves the demarcation of the edge of the provider network to the customer premise and can potentially be evolved to deliver multiple customer services multiplexed over the single Ethernet access link; i.e., VPLS Layer 2 VPN, MPLS Layer 3 VPN, Circuit Emulation services, Internet Access, etc.

The end-to-end MPLS network shown in Figure 2 is hierarchical in nature. This means that only the core of network is fully meshed, while the systems in the metro section of the network are not fully meshed. For example, with a hub-and-spoke topology, VPLS bridge/switches act as hubs with simple Ethernet Services Demarcation Devices terminating each spoke at the customer site. This enhances the scalability of the solution because it minimizes the total number of LSPs required and the number of LDP peers versus what would be required in a fully meshed network.

Figure 3 shows the service layering for the end-to-end architecture depicted in Figure 2. If the EFM Network Services Access Device also supports 802.1p Class of Service (CoS) and rate limiting with committed and peak information rates (CIR and PIR), Ethernet connectivity can be configured to adhere to the Metro Ethernet Forum definitions of E-LAN and E-Line services. This capability would make it possible to leverage future standards work for mapping E-LAN and E-Line services, bandwidth profiles, and SLAs to VPLS and Virtual Private Wire services (VPWS).

OAM Reference Model
Figure 3



Source: Metrobility Optical Systems

Advantages of a Complete MPLS Solution

Making MPLS a common protocol for access, metropolitan, and core networks has a number of technical and operational advantages:

- **Consistent service definitions:** Services can be transported end-to-end across many different network segments and architectures with common quality of service (QoS) and IP/MPLS OAM capabilities. For example, this eliminates the need to rely on 802.1p within the metro and map that to MPLS EXP bits at the core. In addition, a consistent VPLS namespace simplifies provisioning and configuration vs. a hybrid naming scheme involving VLANs and LSPs.
- **Service differentiation and traffic engineering:** An MPLS label-switched path (LSP) can be engineered (via RSVP-TE) to deliver guaranteed performance supporting different classes of service and corresponding SLAs.
- **Transport layer independence:** MPLS can ride over virtually any transport technology in the core or access networks, including SONET/SDH and resilient packet ring.
- **Virtual Private Wire Services support for Layer 2 network technologies:** This capability can allow MAN services to be extended to sites that are only accessible via more traditional technologies, including Frame Relay, ATM, and HDLC/PPP leased lines.
- **Scalability:** MPLS also addresses the scalability issue of access and metro network equipment. VPLS supports more than 40,000 emulated LANs in the provider network vs. the 4,096 LANs possible with Q-in-Q. In addition, label stacking allows aggregation of VCs that share a common forwarding path. This feature not only improves scalability, but also simplifies network maintenance and day-to-day operational tasks.
- **Protection:** MPLS path protection can be provided based on the Fast Reroute feature. This feature invokes a Fast Reroute option of RSVP-TE during the establishment of a primary LSP under hop-by-hop control. With Fast Reroute, a local bypass LSP is established for each potential point of failure along the Primary Path. If the physical layer or RSVP hellos detect a node or link failure, the traffic is Fast Rerouted to the bypass LSP in as little as 50 milliseconds.

In the current generation of edge network, provider management functionality has frequently been restricted to SNMP or TELNET for performing VLAN provisioning and other management tasks on the PE bridge/switch. OAM functionality was restricted to Layer 3 OAM based on ICMP Ping and Traceroute. Another major advantage of a network architecture that supports Ethernet, IP and MPLS end-to-end is that it sets the stage for implementation of a true multilayer OAM solution comprised of:

- SNMP, CLI, IP Ping and IP Traceroute at Level 3
- EFM OAM and MEF OAM at Level 2
- MPLS Ping and MPLS Traceroute for verification of LSPs
- VPLS Ping and VPLS Traceroute for verification of tunnel LSPs
- Transport level OAM (e.g., SONET OAM) as required in the core and Metro

The combination of consolidated technologies and multilayer OAM spanning the end -to-end network greatly simplifies network operations, which in turn leads to better end-to-end control of service delivery and significantly reduced operational expenses.

Conclusion

First generation Ethernet access and MAN networks were often built using Ethernet platforms and technologies that were initially designed with enterprise LANs in mind. As Ethernet carrier networks evolve toward the next generation, the traditional simplicity and cost-effectiveness of Ethernet needs to be complemented with carrier-grade technologies such as multi-layer OAM and end-to-end MPLS/VPLS to ensure the reliable delivery of a more complex portfolio of services. In the future, carriers and enterprises that want to build the most robust Ethernet/MPLS WAN networks possible will be selecting both Ethernet edge products and core routers based largely on the richness and quality of their OAM and MPLS/VPLS feature sets.

MPLS: Multi-protocol Label Switching (MPLS)

EFM: Ethernet-in-the-first-mile

CE: Customer Edge

FEC: Forward Equivalence Class

LDP: Label Distribution Protocol

LSP: Label Switched Path

MPLS: Multi Protocol Label Switching

LSR: Label Switch Router

PE: Provider Edge

LER: Label Edge Router

PW: Pseudo-Wire

RSVP: Resource Reservation Protocol

TE: Traffic Engineering

RSVP-TE: Resource Reservation Protocol - Traffic Engineering

OAM: Operations, Administration and Maintenance

OAMPDU: OAM Protocol Data Unit

VPWS: Virtual Private Wire Service

VPLS: Virtual Private LAN Service

MAN: Metropolitan Area Network

TLS: Transparent LAN Service

VLAN: Virtual LAN

A word from the sponsor

Metrobility Optical Systems' fourth generation of intelligent optical Ethernet demarcation devices, the Ethernet Services Provisioning Platform (ESPP), is the first multi-port optical Ethernet demarcation device that delivers IEEE 802.3ah EFM/OAM-managed services over VLANs and MPLS in a metro Ethernet network.

Located at the customer premises, the ESPP addresses the demands of business for Voice over IP (VoIP) and high-speed data and video by aggregating multiple services at the customer edge, ensuring more reliable performance end-to-end, and enabling a more scalable and expandable MPLS infrastructure. These services can be provisioned and monitored using IP/SNMP and IEEE802.3ah OAM concurrently, while providing advanced multi-layer interworking between IEEE 802.1D, IEEE 802.1Q, MPLS, and the emerging IEEE 802.1ad networking domains.

The ESPP incorporates Metrobility's AccessMPLS™ technology to provide total flexibility in the deployment, provisioning and delivery of Ethernet services. The ability to download firmware allows future upgrades for MPLS providing static MPLS tunnels using Martini-based pseudo-wires for point-to-point applications, and hierarchical VPLS (HVPLS) multi-tenant unit (MTU) extensions for multi-point applications. AccessMPLS aggregates data flows that share a common forwarding path at the customer site to enable greater network scaling and security, the ability to engineer end-to-end QoS and SLAs, as well as OAM and performance monitoring.

For additional information about Metrobility's solutions for optical Ethernet demarcation, go to http://www.metrobility.com.