State of the Art Packet and
Optical Networking

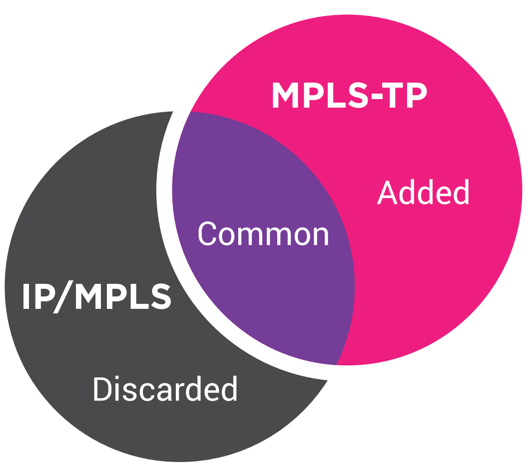
MPLS-TP

For Mission Critical Networks

Introduction

Mission-critical communication networks are essential for strategic national assets such as energy (electricity, gas & oil, nuclear), transportation, water, government agencies, and military organizations. Traditionally, these networks have relied on SDH/SONET transport infrastructure to deliver the deterministic performance, extensive OAM capabilities, and high reliability required for their operations. However, with the rise of data services and the ubiquity of IP and Ethernet, SDH/SONET is becoming obsolete. Today, the migration to a packet transport network (PTN) using circuit emulation (CES/CEP) technologies is well-proven. MPLS-TP, when used in conjunction with CES, provides the low latency, high availability, centralized management and determinism which is mandatory for mission-critical communication networks.

MPLS-TP (MPLS Transport Profile) is widely recognized as a technology which, when used in conjunction with circuit emulation (CES/CEP), facilitates the retirement of legacy SDH/SONET transport networks. It is based on IP/MPLS but modifies it to provide the predictability, reliability, centralized management, and OAM (Operations, Administration, and Maintenance) required in mission-critical transport networks. With MPLS-TP, network operators have a modern packet transport technology which supports digital evolution while still providing the deterministic performance characteristics of legacy SDH/SONET networks.



Carrier Ethernet

Ethernet is the standard packet transport technology used in Local Area Networks (LANs). However, native Ethernet is not suitable for providing carrier-class or mission-critical class transport in Wide Area Networks (WANs). To address this, MEF enhanced Ethernet by adding five key attributes, making it suitable as a transport technology for the WAN:

Carrier Ethernet

Standardized Services
enables the coordination of subscribers, service providers, and operators to achieve Carrier-Ethernet based data connectivity between multiple subscriber sites across multiple operator networks.

Reliability
enables end-user services to run on transport layers that comply with stringent resiliency and recovery constraints.

Scalability
enables the coordination of subscribers, service providers, and operators to achieve Carrier-Ethernet based data connectivity between multiple subscriber sites across multiple operator networks.

Quality Of Service
enables a single network to run multiple services to multiple end-users, running a wide variety of applications with different bandwidth and latency requirements. It also provides the required tools to ensure that services maintain performance requirements according to Service Level Specifications (SLS).

Service Management
enables service providers to roll out, maintain, and troubleshoot data-connectivity services in a cost-effective and timely manner.

When MEF defined the attributes for Carrier Ethernet compliance, it did not define the underlying transport protocol method.

MPLS-TP (MPLS Transport Profile)

IP/MPLS was introduced to simplify the routing of packet traffic across the WAN and to meet the attributes defined by the Metro Ethernet Forum (MEF) for Carrier Ethernet. It routes traffic based on a Label Switched Path (LSP), which is established and calculated by label distribution protocols (LDP) such as MPLS-LDP, BGP, or RSVP-TE. Recently, segment routing (SR) has emerged as an alternative to LDP for identifying LSPs. However, IP/MPLS does not provide the determinism required in mission-critical networks. This gap led to the development of a deterministic packet transport mechanism, namely MPLS Transport Profile (MPLS-TP).

MPLS-TP is the result of a joint effort by IETF and ITU-T. Its primary objective is to enable a packet transport network (PTN) to be deployed in a mission-critical transport network by providing similar deterministic transport characteristics to SDH/SONET

Comparison of MPLS-TP and IP/MPLS

MPLS-TP a variant of IP/MPLS designed for mission-critical transport networks.it acts as both a subset and an enhancement of the latter. Additional functionality brought by MPLS-TP ensure deterministic performance, improve operational efficiency, and improve network visibility and complex functionality which do not support deterministic transport are removed. One of the most significant advantages of MPLS-TP is its interoperability with IP/MPLS. This compatibility allows for seamless coexistence and integration within the same network infrastructure, ensuring that both protocols can function together efficiently.

Common Features

MPLS-TP and IP/MPLS shared functionality.

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Multi-Protocol

MPLS is L2-protocol independent and, therefore, is agnostic to the underlying transport protocols. In addition, using a mechanism called pseudowire (PW), it is also agnostic to services running on top of it. MPLS PW is a mechanism that emulates the essential attributes of a native service, while transporting over a packet switched network. With MPLS PW, native services like ATM, Frame Relay, PDH, SONET/SDH, Ethernet, and others, are tunneled through the packet network. Multi-protocol support is well suited to the mixed-technology environment of mission-critical networks (like TDM-based SCADA and packet-based SCADA) and allows gradual and controlled transition.

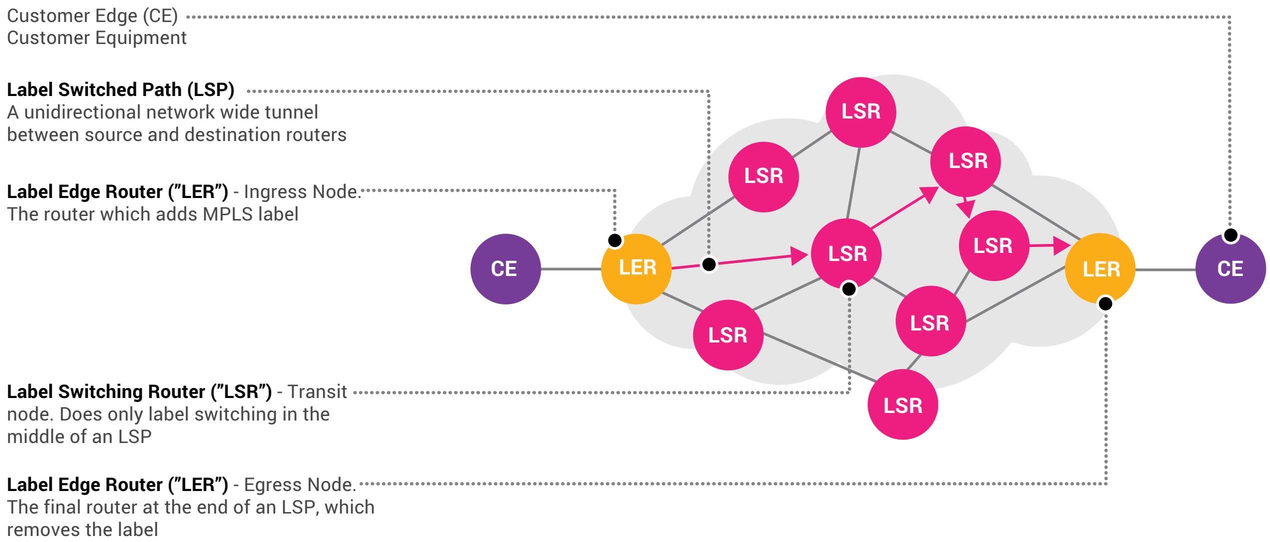
Transport and Service Agnostic

Service	IP	Ethernet	TDM	ATM
Layer 2.5	MPLS			
Layer 2	Ethernet	TDM	xDSL	ATM
Layer 1	Fiber	Copper	Wireless	

Label Switching

In traditional IP routing, each router makes independent routing decisions and determines the next hop, based on its routing table. With MPLS, on the other hand, a path (LSP) from the source to the final destination is predetermined and a "label" is applied to it.

The first device in the path adds the MPLS label. Subsequent devices along the path use this label to route the traffic, without any additional IP lookups. The label switching process is considered faster and simpler to implement than routing. The final destination device removes the label and the packet is delivered via normal IP routing, in the case of IP service.



Added Features

MPLS-TP adds features to provide deterministic performance, improve operational efficiency, and improve network visibility.

Data Plane
for packet forwarding

Control Plane
for label distribution and LSP setup

OAM
for monitoring and troubleshooting information

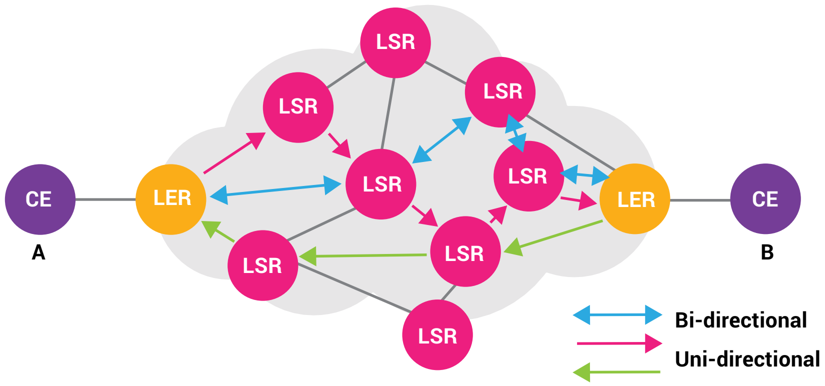
Protection and Resiliency
for maintaining undisrupted service

Data Plane

Bidirectional LSPs

A key difference between MPLS-TP and IP/MPLS involves the LSP. IP/MPLS uses unidirectional LSPs. This means that traffic from A to B and from B to A can follow different paths. MPLS-TP on the other hand, uses bidirectional LSPs, meaning that traffic in both directions uses exactly the same path.

Bidirectional LSPs are required for deterministic performance. They simplify network operation and provide easier SLA control.



Control Plane

Management/Control and Data Plane Separation

IP/MPLS does not separate between control and data planes. With MPLS-TP, the management/control plane is totally isolated from the data plane.

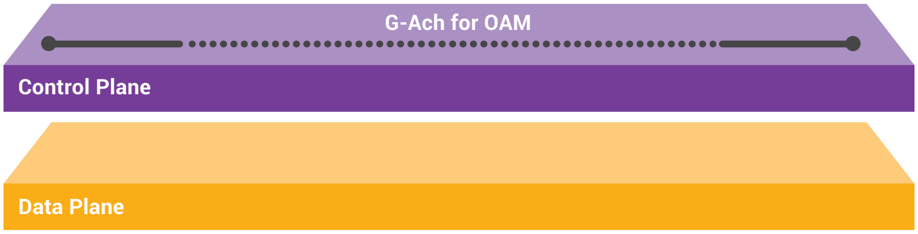
The importance of total separation is that a failure in the management/control plane cannot impact the traffic. The result is a much more robust, reliable and secure network.

OAM (Operation Administration and Maintenance)

OAM includes all connectivity verification tools for checking PW and LSP integrity. With IP/MPLS, OAM data is transmitted out-of-band and might not take the same path as data traffic.

With MPLS-TP, as with SDH/SONET, OAM is carried with the user traffic within the MPLS-TP frame using G-Ach (Generic Associated Channel).

In-band OAM ensures transport-like operation, supporting the connection-oriented concept. Moreover, MPLS-TP OAM proactive monitoring triggers fast switch-to-protection. This enables faster troubleshooting and makes the network performance more predictable.



Protection

With IP/MPLS, sub-50 msec convergence cannot be guaranteed when using the LDP signaling protocol. A Fast Reroute (FRR) protection scheme that can guarantee sub-50ms switching, requires the RSVP-TE signaling protocol. This is not scalable in large networks and does not fit all topologies

With MPLS-TP, sub-50ms switching is guaranteed for any network topology, using hardware-based proactive OAM, static FRR provisioning, and a variety of protection schemes.

Guaranteed sub-50ms switching is essential for maximum network availability and undisrupted service continuity.

Removed Features

The features and mechanisms removed in by MPLS-TP do not comply with the connection-oriented nature of mission-critical transport networks, and therefore, impair predictable deterministic performance.

PHP (Penultimate Hop Popping)

PHP is a mechanism utilized by IP/MPLS networks to streamline router processing. This technique involves removing the MPLS label one node before reaching the egress node, thereby reducing the processing load on the final router. However, while PHP offers efficiency advantages, it introduces specific challenges.

When the outer MPLS label is removed, it invalidates the MPLS-TP OAM functions. Consequently, the network's protection schemes are rendered ineffective. Furthermore, PHP operates under the assumption that traffic is always in packet form, which may not hold true in all scenarios. Due to these limitations, MPLS-TP does not use PHP.

Label Switched Path (LSP) Merge

LSP merge refers to the process of combining two or more LSPs with the same destination into a single MPLS label. This technique effectively reduces the number of labels used across the network, which can be advantageous for label management. However, one significant drawback of LSP merge is the loss of source information. This loss prevents the original LSPs from being monitored end-to-end, which is critical for certain network operations. Consequently, LSP merge is not employed in MPLS-TP (Transport Profile).

ECMP (Equal Cost Multiple Path)

ECMP enables the division of traffic within the same LSP over multiple paths that have the same cost. This load-balancing method results in different packets taking different routes through the network. While ECMP can enhance bandwidth utilization and redundancy, it lacks determinism and contradicts the connection-oriented principles of MPLS-TP. Hence, MPLS-TP does not utilize ECMP.

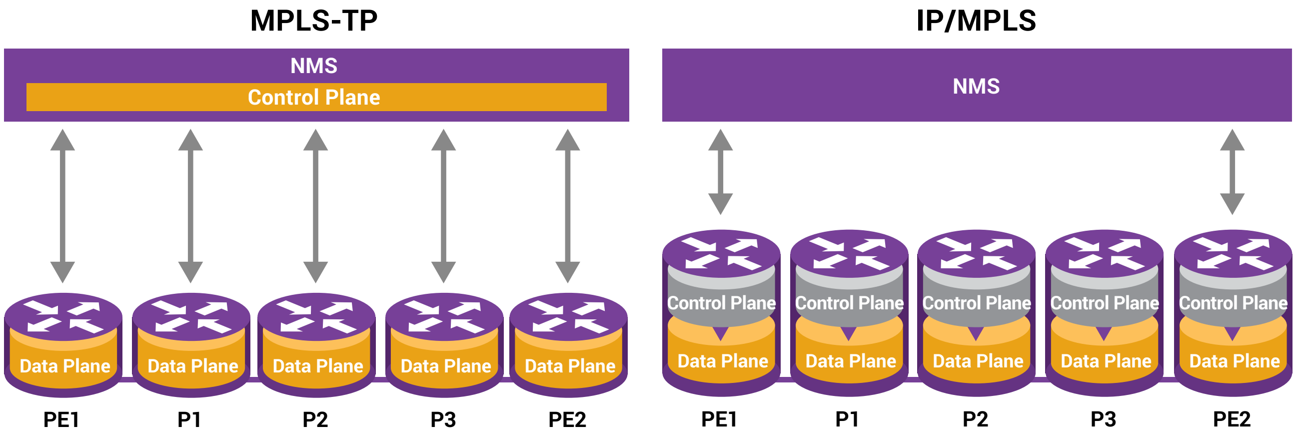
Control Plane

An LSP (Label Switched Path) spans across the network, but the label value assigned to it is local to each segment and can be modified at various points along its path. To map LSPs to specific label values, MPLS (Multiprotocol Label Switching) relies on signalling protocols such as:

- Label Distribution Protocol (LDP): A straightforward protocol that does not support traffic engineering.
- Resource Reservation Protocol with Traffic Engineering (RSVP-TE): A more complex protocol that facilitates traffic engineering through network resource reservation. However, its traffic engineering (TE) and fast reroute (FRR) capabilities are intricate and do not scale efficiently for large networks.
- Segment Routing Traffic Engineering (SR-TE): Offers a simple, automated, and scalable architecture for engineering traffic flows in a network. It imposes a segment list comprising a series of Node-SIDs and/or Adj-SIDs at the ingress router, providing a highly scalable traffic engineering capability. It utilizes a Segment Routing Path Computation Element (SR PCE) to compute a constraint-based end-to-end path. Nevertheless, SR-TE has not yet been proven reliable for mission-critical networks.

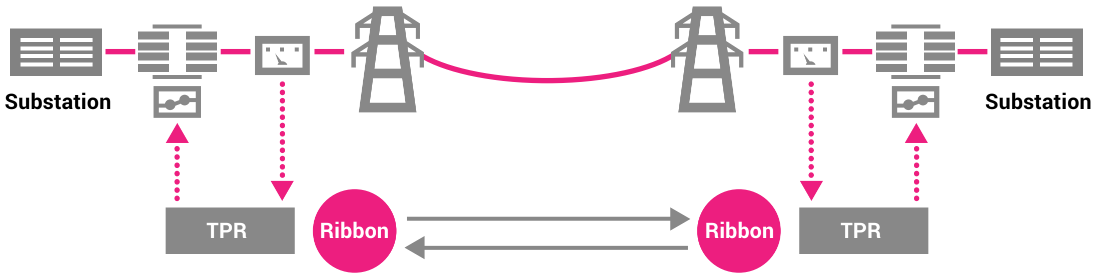
In MPLS_TP a Network Management system is used to provide centralized control of the path provisioning. Eliminating the control plane and using central control provides all fast reroute and traffic engineering features.

MPLS-TP does not require any control plane protocols for its operation. LSPs and pseudowires can be provisioned statically using a Network Management System (NMS). Using NMS provisioned path management is the same as used in legacy SDH/SONET transport network.



Examples of MPLS-TP In Action In Mission Critical Networks

Teleprotection



Teleprotection systems play a vital role in maintaining the integrity of the power grid by detecting faults and utilizing circuit breakers to prevent these faults from causing widespread disruptions. The swift detection of failures and the quick response of teleprotection systems are essential for ensuring a robust and reliable electric grid.

These systems rely on the exchange of data via communication channels between teleprotection relays (TPRs) situated on either end of a power line. The effectiveness of a teleprotection system is significantly influenced by the quality of the communication channel that transmits information between the relays. Consequently, it is crucial to maintain low and symmetric latency and jitter within the communication channel to ensure the proper functioning of the teleprotection system.

1588v2 Synchronization

Accurate timing and synchronization is vital for a diverse range of applications used in mission critical networks:

- Circuit Emulation Services (CES): Precise timing is necessary to map TDM services (such as SCADA, E1/T1, and PCM) onto the packet transport network seamlessly.
- Synchronous Phasor Measurement (Synchrophasors): These systems use synchronized measurements of electrical waves at various points in the power grid to enhance system visibility and control.
- Control of Intelligent Electronic Devices (IEDs): Accurate time synchronization is crucial for precise analysis of time stamped events recorded by IEDs.
- Teleprotection: Requires extremely accurate timestamps on measurements taken from both sides of a protected line.

The two techniques for providing synchronization over packet transport networks are Synchronous Ethernet (SyncE) and 1588v2. In mission-critical environments, typically only 1588v2 offers the necessary precision.

1588v2, a Timing over Packet (ToP) technique, relies on the exchange of timestamp information between network ends. The key factor affecting synchronization accuracy is Packet Delay Variation (PDV). Therefore, achieving precise synchronization necessitates the deterministic packet transport provided by the bidirectional LSPs used in MPLS-TP.

MPLS-TP and MPLS-TP: Complementary or Competing?

MPLS-TP and IP/MPLS are complementary technologies, each offering distinct advantages. MPLS-TP is designed to provide packet efficiency combined with mission-critical performance, making it the preferred choice for operational technology (OT) networks.. IP/MPLS serves as the backbone for the packet transport networks used in information technology (IT) networks. With the push for IT/OT convergence, and even the business driver to deliver telco services, modern mission critical networks need both MPLS-TP and IP/MPLS.

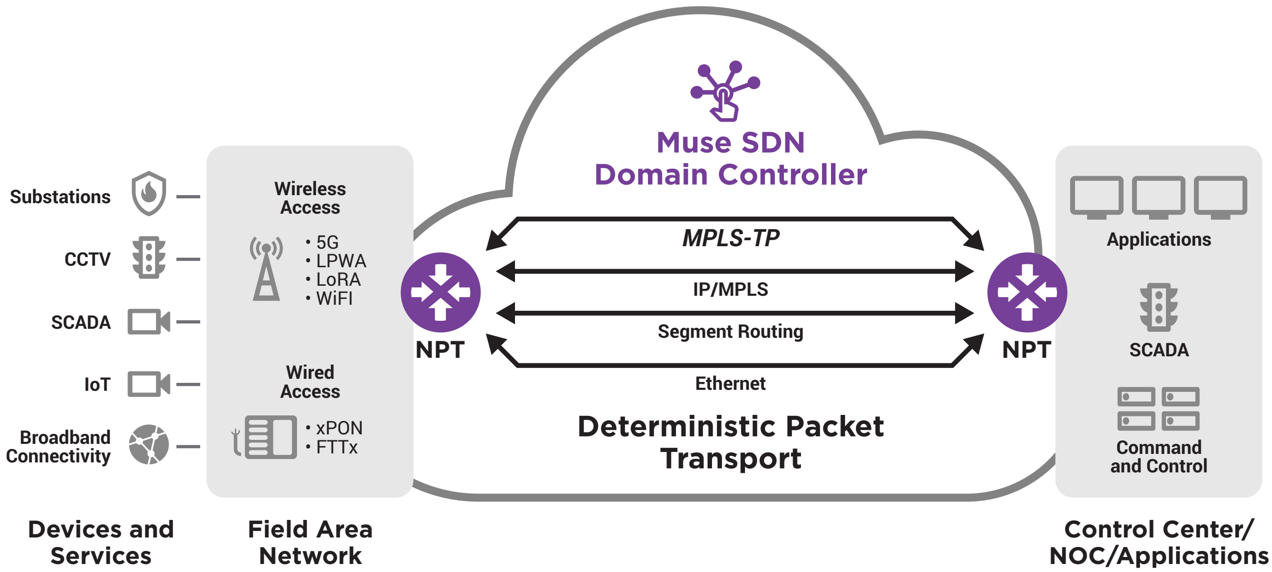
Data Plane
- Bidirectional LSPs
- No LSP merging, ECMP or PHP

Control Plane
- Optional
- NMS static control

OAM
- In band OAM channel
- Proactive grade OAM

Protection and Resiliency
- Sub 50 msec protection switch for any topography

Ribbon's Multi-stack MPLS



Ribbon's Multi-stack MPLS is a field-proven solution for mission-critical networks, allowing the simultaneous operation of various protocol types within a single network. This advanced technology supports multiple protocol stacks. To ensure optimal performance for a diverse set of network requirements, this advanced technology supports multiple protocols simultaneously:

- **MPLS-TP:** Used where deterministic packet transport, OAM and centralized management is required. It is used to support mission critical OT services, such as SCADA and teleprotection. MPLS-TP, combined with Circuit Emulation (CES), is recognized by Cigre Green Books as an effective method for replacing SDH/SONET transport networks.
- **IP/MPLS:** Used for services that are not mission critical, such as the IT network and Utelco services
- **SR-TE:** Used to provide deterministic transport in IP/MPLS networks, it is not yet widely field-proven in OT networks Multi-stack MPLS allows operators to evolve their MPLS-TP network to SR-TE if necessary.
- **Network Slicing:** A toolkit of hard and of slicing techniques allows the network to be segregated to meet the strict segregation rules required for IT/OT convergence to provide the multitenancy required for UTelco evolution.
- **New protocols:** The multi-stack MPLS architecture makes it straightforward to add new protocols when they become certified

With Ribbon's multi-stack MPLS operators can use the most appropriate packet transport technology for each service being transported, on a service-by service basis.

Contact Us Contact us to discover how Ribbon ensures risk-free and future-proof transition to packet

About Ribbon

Ribbon Communications (Nasdaq: RBBN) delivers communications software, IP and optical networking solutions to service providers, enterprises and critical infrastructure sectors globally. We engage deeply with our customers, helping them modernize their networks for improved competitive positioning and business outcomes in today's smart, always-on and data-hungry world. Our innovative, end-to-end solutions portfolio delivers unparalleled scale, performance, and agility, including core to edge software-centric solutions, cloud-native offers, leading-edge security and analytics tools, along with IP and optical networking solutions for 5G. We maintain a keen focus on our commitments to Environmental, Social and Governance (ESG) matters, offering an annual Sustainability Report to our stakeholders. To learn more about Ribbon visit **rbbn.com**.