MPLS-TP – The New Technology for Packet Transport Networks

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Abstract: The Internet Engineering Task Force (IETF) and the Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T) have undertaken a joint effort to standardize a new transport profile for the multi-protocol label switching (MPLS) technology that is intended to provide the basis for the next generation packet transport network. The fundamental idea of this activity is to extend MPLS where necessary with Operations, Administration and Maintenance (OAM) tools that are widely applied in existing transport network technologies such as SONET/SDH or OTN. This paper provides a brief history of the MPLS-TP standardization activities and addresses the MPLS-TP OAM functions. These functions are targeted at making MPLS comparable to SONET/SDH and OTN in terms of reliability and monitoring capabilities, i.e., MPLS-TP will become a true carrier grade packet transport technology. An MPLS-TP network can be operated in an SDH-like fashion and a network management system (NMS) can be used to configure connections. Connection management and restoration functions, however, can alternatively be provided utilizing the Generalized MPLS (GMPLS) control plane protocols which are also applicable to the MPLS-TP data plane. In addition to the simplification of the network operation leading to reduced operational expenditures (OPEX), the GMPLS control plane provides network restoration capabilities in addition to the network protection features that the MPLS-TP data plane already provides; this results in a further improved network resiliency. The MPLS-TP technology is also multi-service capable leveraging the pseudo-wire technology that has been developed at the IETF and which is still evolving. Some applications require synchronization, e.g. mobile services and interconnection of telephony switches. Ethernet is an asynchronous network protocol and hence protocol extensions are necessary. This paper discusses the different emerging standards. One of the key requirements is that the new MPLS-TP network layer must be capable to utilize the existing physical infrastructure and the paper lists the various adaptation or encapsulation techniques that allow MPLS-TP packets to be carried over a variety of different physical technologies ranging from SONET/SDH and OTN to Gigabit Ethernet.

1 Introduction

The purpose of a transport network is to provide a reliable aggregation and transport infrastructure for any client traffic type. With the growth of packet-based services, operators are transforming their network infrastructures while looking at reducing capital and operational expenditures. In this context, a new technology is emerging: a transport profile of Multi-Protocol Label Switching called MPLS-TP. MPLS-TP is currently under development at the IETF in collaboration with ITU-T experts. The objective of this standardization effort is to develop MPLS extensions where necessary in order to meet the transport network requirements depicted in Figure 1.

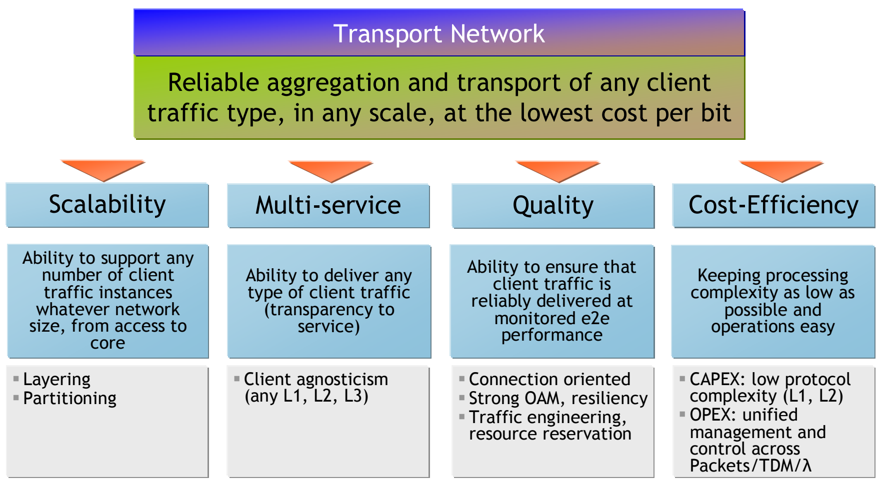

Figure 1: Transport Network Requirements

2 MPLS-TP Overview

The goal of MPLS-TP is to provide connection-oriented transport for packet and TDM services over optical networks leveraging the widely deployed MPLS technology. Key to this effort is the definition and implementation of OAM and resiliency features to ensure the capabilities needed for carrier-grade transport networks – scalable operations, high availability, performance monitoring and multi-domain support.

MPLS-TP key characteristics are:

- It is strictly connection oriented
- It is client-agnostic (can carry L3, L2, L1 services)
- It is physical layer agnostic (can run over IEEE Ethernet PHYs, SONET/SDH [G.783] and OTN [G.709],[G.872] using GFP [G.7041], WDM, etc.)

- It provides strong operations, administration and maintenance (OAM) functions similar to those available in traditional optical transport networks (e.g., SONET/SDH, OTN); these OAM functions are an integral part of the MPLS-TP data plane and are independent from the control plane
- It provides several protection schemes at the data plane similar to those available in traditional optical transport networks.
- It allows network provisioning via a centralized NMS and/or a distributed control plane
- The GMPLS control plane is also applicable to the MPLS-TP client or server layers and allows to use a common approach for management and control of multi-layer transport networks

Current transport networks (e.g. SONET/SDH) are typically operated from a network operation center (NOC) using a centralized network management system (NMS) that communicates with the network elements (NEs) in the field via the telecommunications management network (TMN, see ITU-T Recommendation M.3010 [M.3010]). The NMS provides well-known FCAPS management functions which are: fault, configuration, accounting, performance, and security management as defined in ITU-T Recommendation M.3400 [M.3400]. Together with survivability functions such as protection and restoration, availability figures of >99,999% have been achieved thanks to the highly sophisticated OAM functions that are existing e.g. in SONET/SDH transport networks. This well proven network management paradigm has been taken as basis for the development of the new MPLS-TP packet transport network technology.

Moreover, MPLS-TP provides dynamic provisioning of MPLS-TP transport paths via a control plane. The control plane is mainly used to provide restoration functions for improved network survivability in the presence of failures and it facilitates end-to-end path provisioning across network or operator domains. The operator has the choice to enable the control plane or to operate the network in a traditional way without control plane by means of an NMS. It shall be noted that the control plane does not make the NMS obsolete – the NMS needs to configure the control plane and also needs to interact with the control plane for connection management purposes.

2.1 Main Drivers for MPLS-TP

Carriers are experiencing an unprecedented combination of demand for service sophistication and expansion (e.g. Triple Play, LTE in mobile radio communications) coupled with economic pressure to minimize the cost for providing these services. MPLS-TP is being defined to meet these divergent requirements by introducing SDH-like OAM features to packet transport networks.

3 History of MPLS-TP Standardization

MPLS-TP started as Transport-MPLS at the ITU-T (see G.81xx series of ITU-T Recommendations), which was renamed to MPLS-TP based on the agreement that was reached between the ITU-T and the IETF to produce a converged set of standards for MPLS-TP.

3.1 T-MPLS Standardization Efforts at the ITU-T

Transport-MPLS (T-MPLS) was a standardization effort that was undertaken by the ITU-T. It is a packet-based transport network that will provide a key evolution path for next-generation networks reusing a profile of existing MPLS as defined by IETF and complementing it with transport-oriented OAM and protection capabilities. T-MPLS promises multi-service provisioning, multi-layer OAM and protection resulting in optimized circuit and packet resource utilization.

ITU-T approved the first version of its packet transport recommendation called Transport MPLS (T-MPLS) Architecture in 2006. By 2008, the technology had reached the stage where some vendors started supporting T-MPLS in their optical transport products. At the same time, the IETF was working on a new mechanism called Pseudo Wire Emulation Edge-to-Edge (PWE3) that emulates the essential attributes of a service such as ATM, TDM, Frame Relay or Ethernet over a Packet Switched Network (PSN), which can be an MPLS network [RFC3916].

A Joint Working Group (JWT) was formed between the IETF and the ITU-T to achieve mutual alignment of requirements and protocols.

3.2 MPLS-TP Standardization Efforts at the IETF

On the basis of the JWT activity, it was agreed that future standardization work will focus on defining MPLS-Transport Profile (MPLS-TP) within the IETF using the same functional requirements that drove the development of T-MPLS. When MPLS-TP RFCs will have reached a technical maturity level comparable with the existing T-MPLS Recommendations,, the ITU-T will align the latter with the MPLS-TP accomplishments from the IETF. The history and the process to produce a converged and consistent MPLS-TP standard consisting of IETF RFCs and ITU-T Recommendations is depicted in Figure 2.

Table 1 below provides an overview of the Internet Drafts on MPLS-TP that were published as of Mar 30, 2009 (Status: WG=working group draft, Ind.=individual draft). The MPLS-TP specifications are currently progressing at a good pace as the ITU-T G.81xx Recommendations already laid the foundations. The first stable IETF specifications for MPLS-TP are expected in 2009 and further expansions and refinements in 2010.

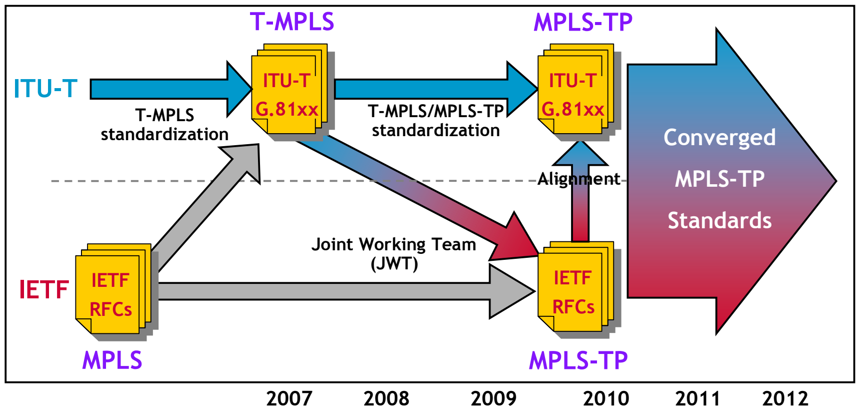

Figure 2: ITU-T/IETF Convergence towards Consistent MPLS-TP Standards

RFC / Internet-Draft	**Title**	Status
RFC 5317	JWT Report on MPLS Architectural Considerations for a Transport Profile	RFC
draft-ietf-mpls-tp-requirements-05	MPLS-TP Requirements	WG
draft-ietf-mpls-tp-framework-00	A Framework for MPLS in Transport Networks	WG
draft-ietf-mpls-tp-oam-requirements-01	Requirements for OAM in MPLS Transport Networks	WG
draft-ietf-mpls-tp-oam-framework-00	MPLS-TP OAM Framework and Overview	WG
draft-ietf-mpls-tp-nm-req-00	MPLS TP Network Management Requirements	WG
draft-ietf-mpls-tp-gach-gal-02	MPLS Generic Associated Channel	WG
draft-ietf-mpls-tp-gach-dcn-00	An Inband Data Communication Network For the MPLS Transport Profile	WG
draft-abfb-mpls-tp-control-plane-framework-00	MPLS-TP Control Plane Framework	Ind.
draft-andersson-mpls-tp-oam-def-01	"The OAM Acronym Soup"	Ind.
draft-andersson-mpls-tp-process-00	Joint IETF and ITU-T Multi-Protocol Label Switching (MPLS) Transport Profileprocess	Ind.
draft-bhh-mpls-tp-oam-y1731-01	MPLS-TP OAM based on Y.1731	Ind.
draft-boutros-mpls-tp-cv-01	Connection verification for MPLS Transport Profile LSP	Ind.
draft-boutros-mpls-tp-fault-01	Fault Management for the MPLS Transport Profile	Ind.
draft-boutros-mpls-tp-loopback-02	Operating MPLS Transport Profile LSP in Loopback Mode	Ind.
draft-boutros-mpls-tp-performance-01	Performance Monitoring of MPLS Transport Profile LSP	Ind.
draft-bryant-mpls-tp-ach-tlv-01	Definition of ACH TLV Structure	Ind.
draft-ceccarelli-mpls-tp-p2mp-ring-00	P2MP traffic protection in MPLS-TP ring topology	Ind.
draft-fhbs-mpls-tp-cv-proactive-00	MPLS-TP Proactive Continuity and Connectivity Verification	Ind.

RFC / Internet-Draft	Title	Status
draft-fulignoli-mpls-tp-ais-lock-tool-00	MPLS-TP OAM Alarm Suppression Tools	Ind.
draft-helvoort-mpls-tp-rosetta-stone-00	A Thesaurus for the Terminology used in Multiprotocol Label SwitchingTransport Profile (MPLS-TP) drafts/RFCs and ITU-T's Transport NetworkRecommendations.	Ind.
draft-liu-mpls-tp-bnm-00	Multiprotocol Label Switching Transport Profile Backward Notify MessagePacket	Ind.
draft-mansfield-mpls-tp-nm-framework-00	MPLS TP Network Management Framework	Ind.
draft-martinotti-mpls-tp-interworking-01	Interworking between MPLS-TP and IP/MPLS	Ind.
draft-sprecher-mpls-tp-survive-fwk-01	Multiprotocol Label Switching Transport Profile Survivability Framework	Ind.
draft-weingarten-mpls-tp-linear-protection-01	MPLS-TP Linear Protection	Ind.
draft-yang-mpls-tp-ring-protection-analysis-00	Multiprotocol Label Switching Transport Profile Ring Protection Analysis	Ind.

Table 1: Internet Drafts on MPLS-TP (March 30, 2009)

4 OAM Tools for MPLS-TP

The MPLS-TP OAM tool set is currently under definition at the IETF and comprises the OAM features listed in Figure 3. The detailed requirements for the various OAM functions can be found in the related Internet Drafts listed in Table 1. The fundamental idea is that dedicated OAM packets are interspersed into the associated user traffic flows. These OAM packets are created and processed by maintenance end point. Maintenance intermediate points can also process these OAM packets and may collect data or raise alarms. The tools can be categorized in proactive OAM functions that are running all the time and on-demand monitoring functions.

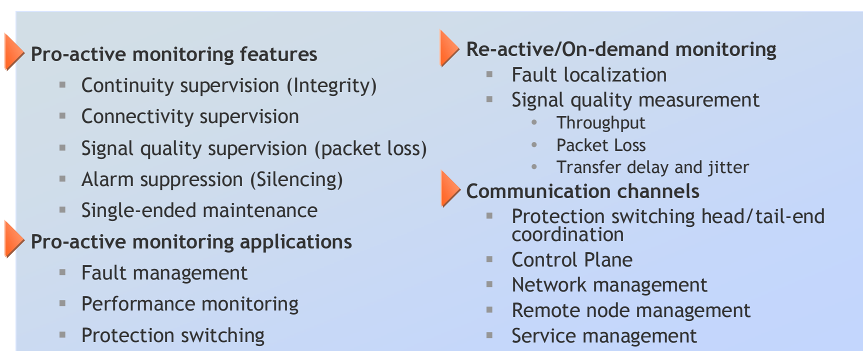

Figure 3: MPLS-TP OAM Tools

5 Control Plane for MPLS-TP

The IETF further defined Generalized MPLS (GMPLS) as a generalization of the MPLS control plane to develop a dynamic control plane that can be applied to packet switched and optical networks. The GMPLS architecture is described in [RFC3945]. The GMPLS control plane, or its ITU-T counterpart, Automatically Switched Optical Network (ASON) [G.8080], supports connection management functions as well as protection and restoration techniques and thus providing network survivability across networks comprising routers, MPLS-TP LSRs, optical ADMs, cross connects, and WDM devices.

MPLS-TP may utilize the distributed control plane to enable fast, dynamic and reliable service provisioning in multi-vendor and multi-domain environments using standardized protocols that ensure interoperability.

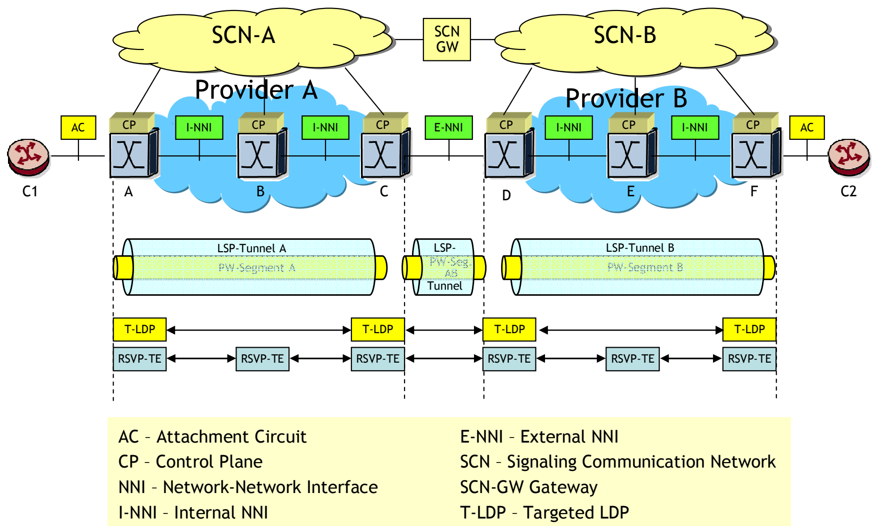

Figure 4: Control Plane View of a Multi-Segment Pseudowire

The MPLS-TP control plane is based on a combination of the MPLS control plane for pseudowires and the GMPLS control plane for MPLS-TP LSPs, respectively. This is illustrated in Figure 4. The distributed MPLS-TP control plane provides the following basic functions:

- Signaling
- Routing
- Traffic engineering and constraint-based path computation

Moreover, the MPLS-TP control plane is capable of performing fast restoration in the event of network failures.

The MPLS-TP control plane provides features to ensure its own survivability and to enable it to recover gracefully from failures and degradations. These include graceful restart and hot redundant configurations. The MPLS-TP control plane is as much as possible decoupled from the MPLS-TP data plane such that failures in the control plane do not impact the data plane and vice versa.

6 Synchronization in Packet Networks

SONET/SDH networks inherently provide synchronization whereas packet based network protocols like e.g. Ethernet are by nature asynchronous. To deploy an Ethernet based infrastructure for mobile backhauling, protocol extensions are required that provide these synchronization functions.

6.1 Clock Hierarchy

Starting at the Primary Reference Clock and ending at the clock in the node closest to the application we have a hierarchy of Master and Slave Clocks.

6.2 Synchronization Approaches

There are three different approaches to solve the synchronization issue:

1. An overlay synchronization network
2. A distributed reference clock solution
3. Forwarding of clock information across the packet domain

The overlay solution would require a synchronization network in parallel to the packet data network. In a distributed reference clock solution there is, at least at the edges of the packet network access to a primary reference clock, this could be provided by GPS. Forwarding clock information requires a synchronization protocol.

6.2.1 Packet Based Clock Recovery Solutions

There are two different clock recovery approaches:

1. Adaptive Timing
2. Differential Timing

6.2.1.1 Adaptive Clock Recovery (ACR)

In adaptive timing or adaptive clock recovery (ACR) the reference clock information is encapsulated and de-capsulated at the packet edge nodes that provide interworking function between TDM and packet domains:

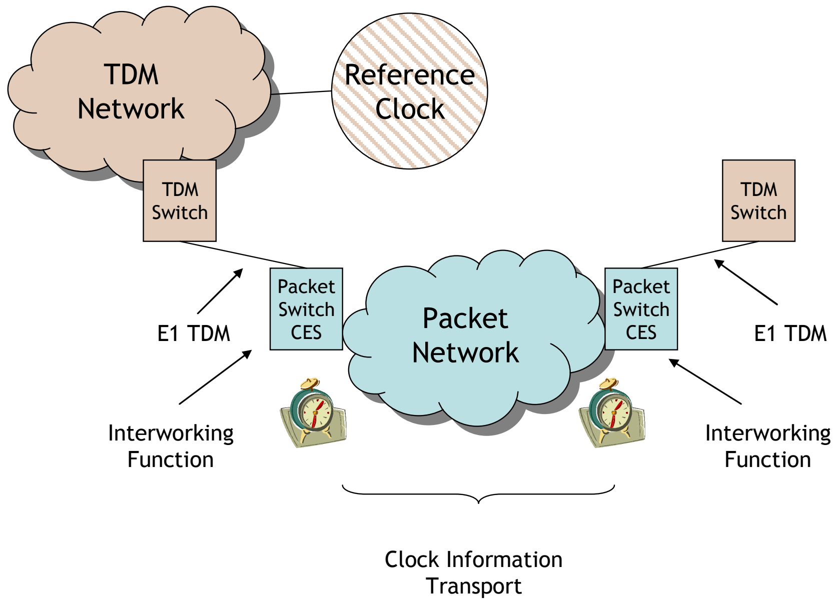

Figure 5: Clock Synchronization across a Packet Network

Here a protocol is required that regenerates at least frequency. This can be done by analyzing either inter packet arrival times or egress buffer fill grades. In general there are three different protocols in use today:

1. Network Time Protocol (NTP) according to RFC 1305; NTP is sufficient for OAM functions as it is precise within a range of hundreds of microseconds.
2. Proprietary implementations derived from NTP; these sometimes are sufficient for mobile backhauling. The number of nodes between master and slave is important here
3. Precision Time Protocol (PTP) according to IEEE 1588v2; this protocol recommends hardware generated timestamps. It is possible to transfer time of day and precise frequency. Intermediate nodes do not need to be compliant, though the number of non-compliant nodes has a drastic impact on the performance achieved by the protocol. Intermediate compliant nodes can either have a transparent clock regenerating clock from one slave port towards one master port or a boundary clock with multiple master ports.

6.2.1.2 Differential Clock Recovery

In differential clock recovery (DCR) both edge elements performing the interworking function have to have access to a common reference clock. Hence frequency is not calculated from the time interval between incoming packets. Still, time stamp based time of day delivery has to be taken into account.

6.2.2 Hardware based Frequency Distribution in Packet Networks

Like in SDH networks frequency can be distributed over a packet network independently of utilization. Under heavy network load packet based distribution of frequency will not always meet the stringent precision requirements of standards G.812 and G.813. In ITU standard G.8261 frequency transport on the physical layer of Ethernet is defined. The requirements for the node clocks are set in ITU standard G.8262. Since frequency distribution over Ethernet physical layer does not take into account time of day a combination with IEEE 1588v2 time stamping is the best way to implement Synchronous Ethernet.

Frequency distribution over Ethernet physical layer requires every node in the chain to adhere to ITU-T G.8262

6.3 Synchronization Status Messaging

To guarantee for SDH like redundancy in Synchronization distribution an additional protocol is required, that, in case of failing access to one PRC calculates the path to the secondary PRC. This SSM protocol does not have to have real time qualities since the equipment clocks can run independently from any PRC for a matter of days.

7 Physical Infrastructure Supporting MPLS-TP

It is mandatory for MPLS-TP that it can be carried over the existing and still evolving physical transport technologies such as SONET/SDH, OTN/WDM, and Gigabit Ethernet. The encapsulation techniques for these technologies are briefly described below.

7.1 MPLS-TP over SONET/SDH, PDH and OTN

ITU-T Recommendation G.7041 [G.7041] defines a generic framing procedure (GFP) to encapsulate variable length payload of various client signals for subsequent transport over SONET/SDH, PDH, and OTN networks. The GFP header contains a User Payload Identifier (UPI) field for which values are defined that indicate that the carried protocol data unit is an MPLS packet. MPLS-TP uses that same UPI code point as MPLS. The OTN [G.709] includes a WDM network layer for the transport of a variety of OTN client signals. In the SONET/SDH case, virtual concatenation can be applied to form transmission pipes with larger capacities (n x 150 Mbit/s).

6.2 MPLS-TP over Gigabit Ethernet

Similar to GFP, MPLS-TP can be carried across Ethernet links. A two-octet Ether Type field has been defined by the Ethernet II framing networking standard to indicate which protocol is encapsulated in the payload area of the frame.

7 Conclusions

MPLS-TP is intended to enable next-generation converged packet networks tying together service routing and transport platforms. Major advantages are consistent operations and OAM functions across the different network layers and the seamless interworking with IP/MPLS networks. MPLS-TP is highly scalable due to its multiplexing capability that can be used to create a network with multiple hierarchical layers. MPLS-TP supports a huge variety of services that are encapsulated into pseudowires and it can be carried over the existing and evolving transport network infrastructure.

References

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