KEY REQUIREMENTS FOR INTERWORKING BETWEEN MPLS-TP NETWORK AND IP/MPLS NETWORK

Mounir Azizi[1], Redouane Benaini[2] and Mouad Ben Mamoun[3]
Data Mining & Network Laboratory, Department of Computer Science
Faculty of Science Mohammed V-Agdal University
Rabat, Morocco
[1] mounir.azizi@gmail.com
[2] benaini@fsr.ac.ma
[3] ben_mamoun@fsr.ac.ma

***Abstract*—The present article is aimed to explain the essential components of MPLS transport profile (MPLS-TP). We will outline what should be taken in consideration when interconnecting with IP/MPLS subnetwork to an MPLS-TP subnetwork. We highlight some important points regarding Control Plane and Management Plane that can be the key to move forward with interworking both MPLS-TP and IP/MPLS world.**

Keyword-MPLS transport profile, MPLS, overlay model, peering model, pseudo wire, OAM.

I. INTRODUCTION

While Time Division Multiplexing (TDM)-based technologies (ex. SONET,SDH) has been for a long time a major player for transport, it shows weakness on bursty traffic such as packetized voice and video especially because of the fast growth of the demand for service sophistication and expansion (Triple Play, 3G / LTE, Cloud Virtualization). Carriers need to migrate from TDM to packet in order to meet packet transport network PTN requirements and to make efforts to minimize the cost for providing these services.

A Joint Working Team created by ITU-T and IETF is actually developing a new packet transport technology (MPLS-TP) taking benefits from existing MPLS networking infrastructure[1]. This group tries to improve the efficiency of packet based transport networks, while maintaining many of the operational characteristics OAM related to legacy SONET/SDH and compatible with existing IP/MPLS networks.

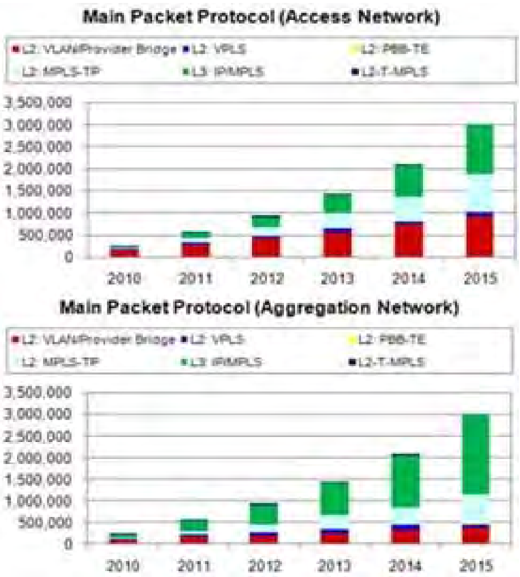

Fig 1. Ethernet Backhaul Quarterly Market Tracker, Heavy Reading's, July 2011

MPLS-TP is aimed to be based on the same architectural concepts of layered network that are already used in legacy SONET, SDH and OTN. Carriers are already arranging their procedures and work processes based on these principles. Fig 1. shows how IP/MPLS and MPLS-TP are willing to be the main packet technologies deployed in Ethernet Backhaul Access's and Aggregation's Network for the next five years.

MPLS-TP is taking the best from two worlds:

- Bandwidth and QOS efficiency from IP/MPLS
- Transport-grade operations from SONET/SDH

II. WHAT IS MPLS-TP ?

MPLS-TP is a subset of IP/MPLS protocol suite with new extensions which allows addressing transport network requirements (Fig 2.). These extensions consists of adapting current MPLS to make it more “Transport like” by inheriting OAM , reliability and operational simplicity from SONET/SDH networks.

MPLS-TP has the following key characteristics:

- Connection oriented: ECMP and MP2P are excluded to ensure that, PHP is disabled by default;
- L2/L3’s client agnosticism;
- Control Plane: static or dynamic Generalized MPLS (GMPLS);
- Physical layer agnostic: allowing MPLS packets to be delivered over a variety of physical infrastructures including IEEE Ethernet PHYs, SONET/SDH and OTN using GFP, WDM, etc;
- Strong OAM functions similar to those available in legacy optical transport networks (e.g., SONET/SDH, OTN); these OAM functions belong to MPLS-TP data plane and are independent from the control plane;
- Path protection mechanisms and control plane-based mechanism;
- Use of Generic Associated Channel (G-ACh) to support FCAPS functions (Fault, Configuration, Accounting, Performance and Security);
- Network provisioning via a centralized NMS and/or a distributed control plane.

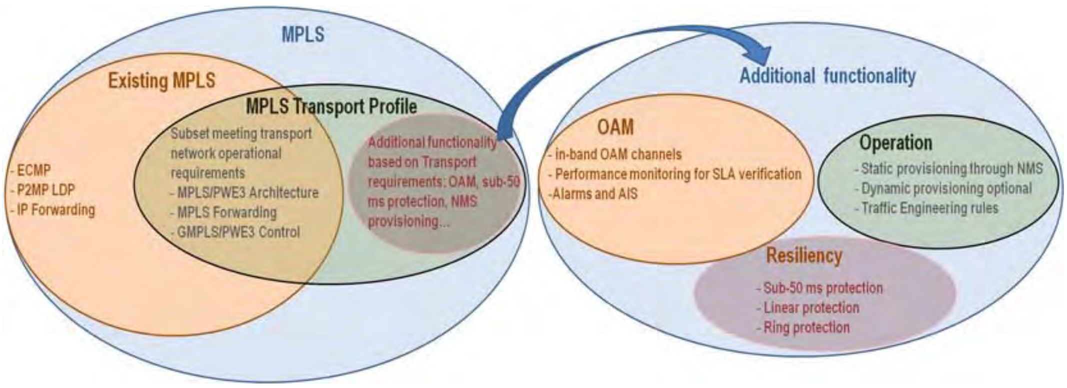

Fig 2. What is MPLS-TP ?

Based on the relative standards and recommendations, MPLS-TP is a solution based on existing Pseudo-wire and LSP. LSPs are used to secure transportation and Pseudo-Wires are reserved to the client layer (Single Segment or Multi Segment PW) as shown in Fig 3. and Fig 4. Client Layer of MPLS-TP LSP can also be “any network layer” [2].

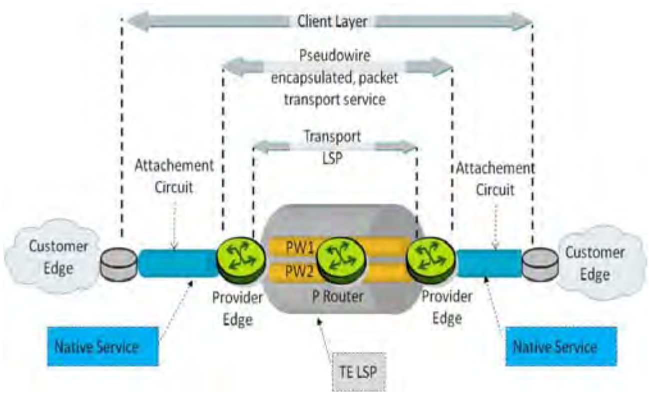

Fig 3. MPLS-TP Architecture(Single Segment Pseudo Wire)

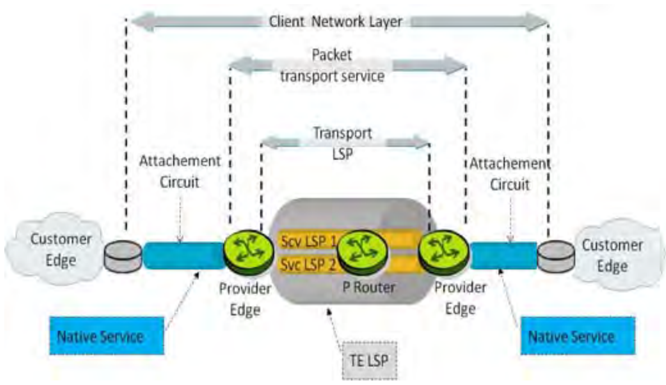

Fig 4 MPLS-TP Architecture for Network-Layer Clients

MPLS-TP supports two native service adaptation mechanisms via:

- a Pseudowire, to emulate certain services, for example, Ethernet, Frame Relay, or PPP / High-Level Data Link Control (HDLC). These adaptation functions are the payload encapsulation;

- an LSP, to provide adaptation for any native service traffic type like IP packets and MPLS-labeled packets (i.e.: PW over LSP, or IP over LSP). The adaptation function uses the MPLS encapsulation format.

The major attributes of MPLS-TP protocol's suite (Fig 5.) are:

- Data Plane : remains exactly the same as MPLS to facilitate interoperability with MPLS;

- Control Plane: optional, dynamic via IP based protocols or static via management platform;

- OAM: transport-like OAM, monitoring and driving switches between primary and backup paths for path segments;

- Protection and Resiliency: Similar operation with SDH;

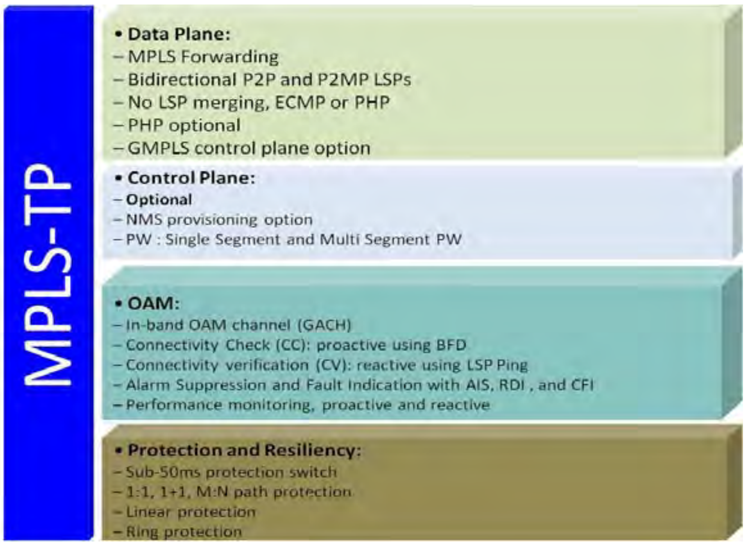

Fig 5. Attributes of MPLS Transport

DATA PLANE

Data plane is one of the most important common elements between MPLS and MPLS-TP. MPLS-TP forwarding plane uses the same standard MPLS forwarding architecture and is totally separated from the control plane. Some of the MPLS functions are turned off, such as Penultimate Hop Popping (PHP), Label-Switched Paths (LSPs) merge, and Equal Cost Multi Path (ECMP).

The MPLS-TP data plane processing procedure reuses the same MPLS standards for single-segment pseudowires and multi-segment pseudowires with no modifications or extensions to the actual standard data plane architectures [3]. Some example -Fig 6.- of pseudowire data plane supported procedures include:

- Pseudowire Emulation Edge-to-Edge (PWE3) Control Word for Use over an MPLS PSN
- Encapsulation Methods for Transport of Ethernet over MPLS Networks
- Structure-Agnostic Time Division Multiplexing (TDM) over Packet (SAToP)
- Encapsulation Methods for Transport of PPP/High-Level Data Link Control over MPLS Networks
- Encapsulation Methods for Transport of Frame Relay over MPLS Networks
- Encapsulation Methods for Transport of Asynchronous Transfer Mode (ATM) over MPLS Networks
- Pseudowire Emulation Edge-to-Edge (PWE3) ATM Transparent Cell Transport Service
- Synchronous Optical Network/Synchronous Digital Hierarchy (SONET/SDH) Circuit Emulation over Packet (CEP)
- Structure-Aware TDM Circuit Emulation Service over Packet Switched Network (CESoPSN)
- Time Division Multiplexing over IP (TDMoIP)
- Encapsulation Methods for Transport of Fiber Channel frames Over MPLS Networks [FC-ENCAP]

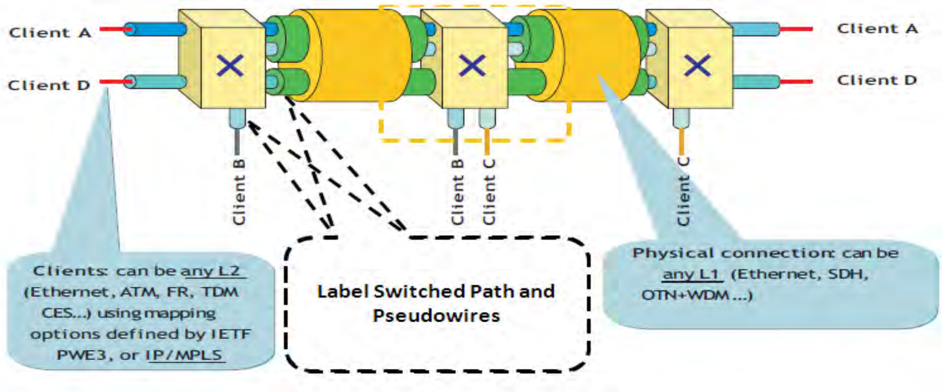

Fig 6. Attributes of MPLS Transport

Some exceptions exist when comparing both MPLS-TP and MPLS forwarding model, the major one is MPLS-TP OAM packets which need to follow the same path as the data flows.

Another major difference concerns LSPs. Since MPLS is supporting only unidirectional LSP, this due to the fact that MPLS is based on the traditional IP routing paradigm: traffic from A to B can flow over different paths than traffic from B to A. The co-routed bidirectional LSPs are supported by MPLS-TP and are defined by pairing the forward and backward directions to follow the same path: same node and same links. In addition to that, MPLS-TP supports unidirectional point-to-point and point-to-multipoint LSPs.

CONTROL PLANE

Control plane is the mechanism responsible for the setup of LSP. MPLS-TP's control plane is optional; LSPs and Pseudowires can be provisioned statically over the packet transport network using a Network Management System (NMS) just like it is already done on the legacy transport network without IP or any routing protocols. Control plane is also totally separated from the data plane, and any failure on that part should not impact the forwarding level[4].

Control plane can also be dynamic –Fig 7.-; LSP and PWs are provisioned using the existing and mature Generalized MPLS (GMPLS) and Targeted label Distribution protocol (T-LDP). Some of their advantages are:

- GMPLS supports traffic engineering, QOS mechanisms and efficient resources utilization, comprehensive mechanisms for protection and fast restoration, Separation between control and data channels guaranteeing that failure of one does not adversely affect the other...

- T-LDP permits service scalability, signals binding of PW label to Forwarding Equivalence Class (FEC), support for single or multiple PW segments, use enhanced pseudowire addressing with MPLS-TP…

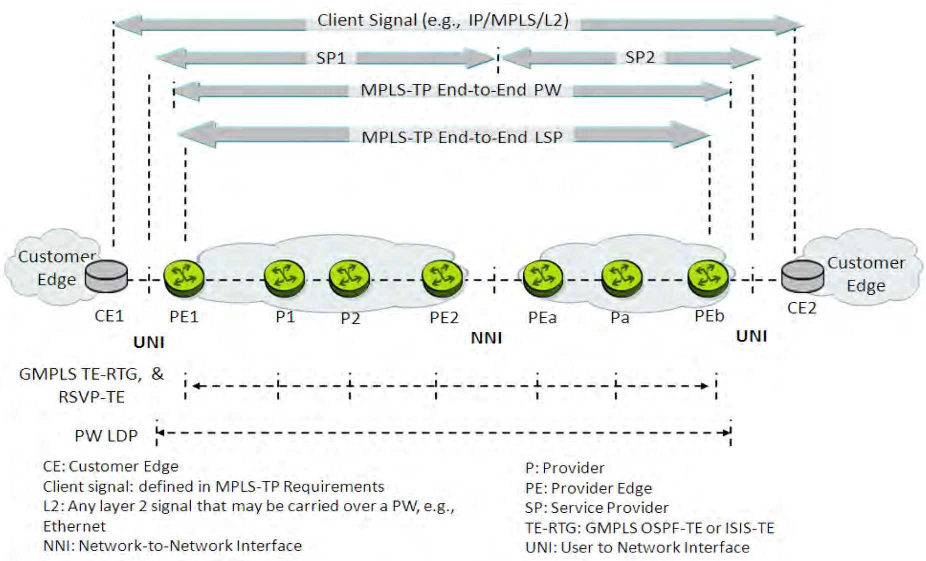

Fig 7. End-to-End MPLS-TP Control-Plane Reference Model

Dynamic control plane is scalable and can provide the following functions: signaling, routing and traffic engineering with constraint-based path computation. Moreover, the MPLS-TP dynamic control plane is capable of performing fast restoration in the event of network failures and reducing provisioning time.

OAM

MPLS-TP has a robust and a transport-like operations and management (OAM) capabilities. It permits guaranteed service level agreements (SLAs), defines protection switching and restoration, enables efficient fault localization, continuity and connectivity verifications, and provides Quality control capabilities and multi-service provider service offerings. MPLS support three kind of OAM: Hop-by-hop (e.g. control plane based), Out-of-band OAM (e.g. UDP return path) and In-band OAM (e.g PW Associated Channel ACH). The last model (PW ACH) is adopted by MPLS-TP and generalized to LSPs and sections level. The OAM packets can than run in-band, share the same path of user traffic, operate on a per-domain basis and/or across multiple domains, and are able to be configured in the absence of a control plane.

The Associated Channel (ACh) is known as technique for in-band Virtual Circuit Connectivity Verification (VCCV) applicable only for Pseudowires, the LSPs have no mechanism to differentiate user packets from OAM packets. Within MPLS-TP, the ACh is extended to the Generic Associated Channel (G-ACh) and a new label is introduced G ACh Alert Label (GAL) to identify packets on the G-Ach –Fig 8-[5]. This constitutes an important toolbox which allows carriers to run OAM at each network level: LSP, Pseudowire and Section.

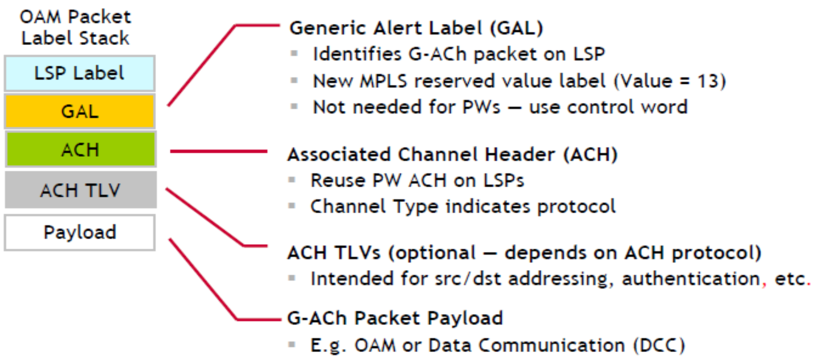

Fig 8. G-Ach label stack

We can split OAM in two major classes [6]:

- Continuous (proactive) which handle 3 level of monitoring: Status (continuity check and connectivity verification), Performance (frame loss and broken) and Maintenance (alarm suppress, lock indication, remote failure indication and client signal indication).

- On-demand (reactive) which handle 3 level of monitoring: Status (connectivity verification), Performance (frame los, frame delay, frame delay variance and throughput) and Failure isolation (path connectivity and stream connectivity)

Table 1 lists some of those monitoring tools:

LM: Loss Measurement; DM: Delay Measurement; FM: Fault Management

MPLS-TP OAM introduces the functional components Maintenance End Point (MEP) and Maintenance Intermediate Point (MIP), which enable running OAM packets between two end points, such as: Continuity checks (CC), Delay and Loss Measurements (DM/LM), Alarm suppress…etc.

The MEP is capable of initiating and terminating OAM packets for fault management and performance monitoring. MEPs define the boundaries of a Maintenance Entity (ME). While the MIP terminates and processes OAM packets that are sent to this particular MIP and may generate OAM packets in reaction to received OAM packets. It never generates unsolicited OAM packets itself.

The Fig 9. presents the end-to-end MPLS-TP OAM model and the positioning of MIP and MEP at each level of the network for both LSPs and PWs[4].

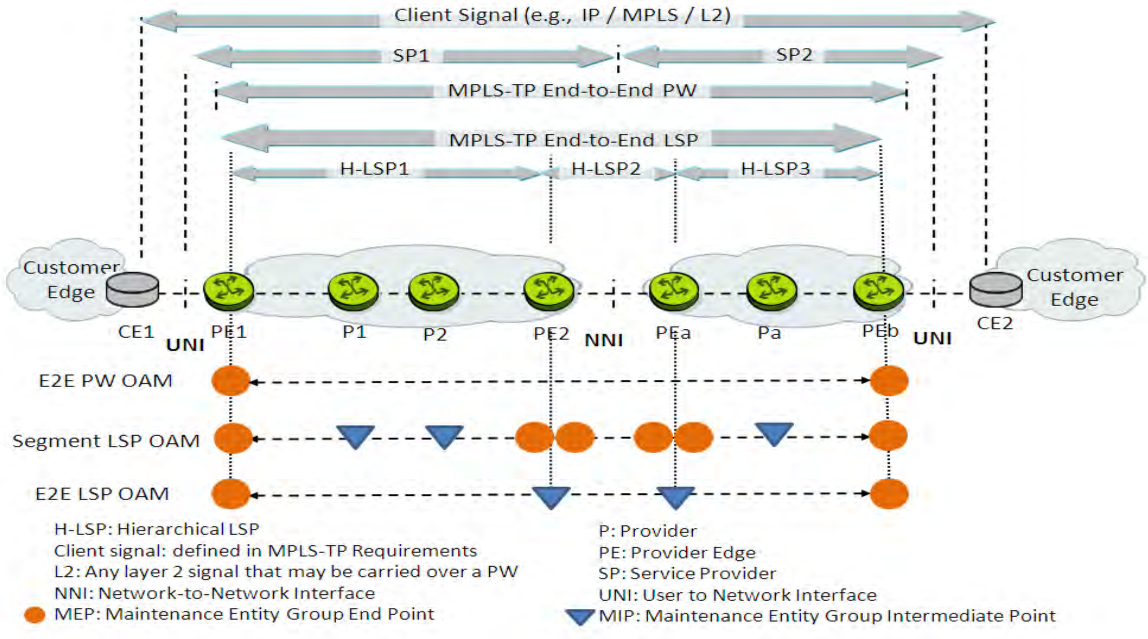

Fig 9. End-to-End MPLS-TP LSP/PW OAM Model

There is a debate actually between ITU-T and IETF on which OAM solution, from two options, should be

TABLE I. OAM FUNCTIONS AND TOOLS

OAM Functions	MPLS-TP OAM ongoing work	
	Continu-ous(proactive)	On de-mand(reactive)
Continuity Check	Extended BFD	Extended LSP Ping
Connectivity Check (Path verification)	Extended BFD	Extended LSP Ping
Performance Mgmt	New LM and DM tools	New LM and DM tools
Fault Localization	New tool - LDI	Extended LSP Ping
Remoe integrity	Extended BFD	Extended LSP Ping
Alarm signal	New FM tool - AIS/RDI	Not applicable

kept as a standard and become part of MPLS-TP toolkit. The first option supported by ITU-T is named G.8113.1 based on Y.1731 with GACh. The second one supported by IETF is named G.8113.2 based on BFD/LSP Ping Extension with GACh. It is hard to say that, until now, it is difficult to have a compromise between both entities IETF and ITU-T to get a unique MPLS-TP OAM mechanism which can result on interoperability problem between carriers using different models.

PROTECTION AND RESILIENCY

As per MPLS-TP requirements, protection and resiliency are key feature for packet transport networks. Protection switching mechanisms are capable of providing recovery time less than 50ms. A Data Plane based protection/restoration mechanism where OAMs share the data plane with the carried transport service in order to optimize the usage of network resources. Several model of protection are showed here –Fig 10.- [7]:

- Linear 1+1 protection: the Permanent Bridge sends traffic over both working and recovery path, and the Selector Bridge selects a working path. A Protection State Coordination (PSC) protocol is sent over the recovery path (using GACh) in case of bi-directional traffic to coordinate both ends;

- Linear 1:n (including 1:1) protection: the Selector bridge at the ingress LSR selects the path to send traffic on. PSC protocol for synchronization between selector bridge (egress/ingress) LSR to select the working path.

- Ring protection: it is using point to multipoint model (p2mp). Several schemes are discussed to be standardized: Fast ReRoute (FRR), Multipoint protection switching, and G.8132-like mechanism.

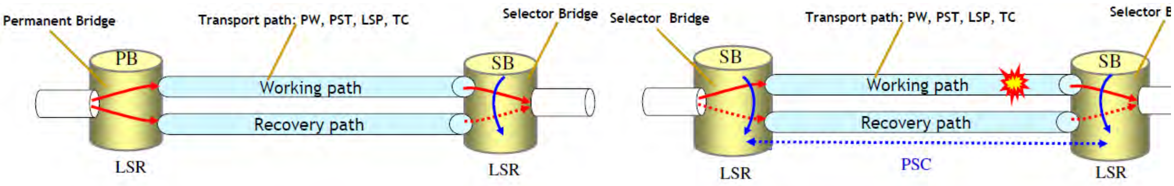

Fig 10. Linear protection mechanisms 1+1 (left) and 1 :1 (right)

Another Control Plane based protection exists which inherits existing mechanism used by GMPLS (RSVP-TE) and PW (static or via T-LDP).

III. Interworking with MPLS

The precedent chapter demystified MPLS-TP from different perspectives and showed how this new packet transport technology can be a serious candidate for Next Generation Networks. MPLS-TP, as a "transport like" technology, cannot alone provide end-to-end service; carriers still prefer to have IP/MPLS at the core level and MPLS-TP at the Access and/or Aggregation level. This mains that interworking both MPLS-TP and IP/MPLS is crucial to get a converged service routing MPLS Network.

Two models –Fig 11.- are discussed here, the first one is the Network Layering model and the second one is the Network Partitioning model. Thus, we will discuss what are the elements that should be took in consideration regarding control plane and management plane[8].

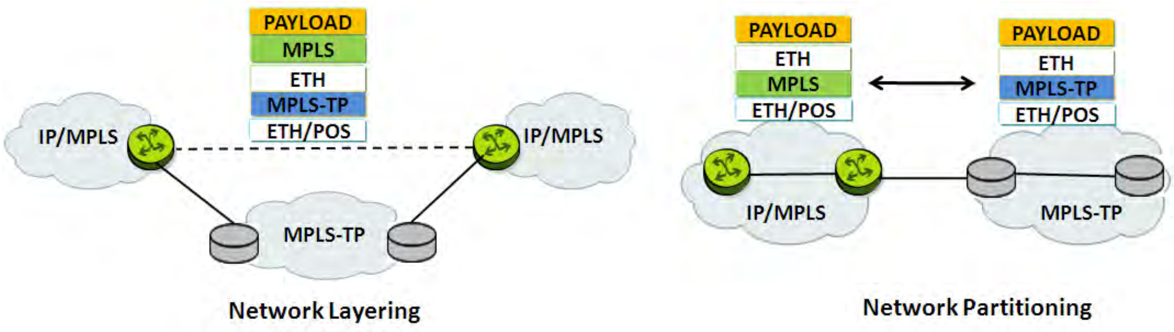

Fig 11. Two proposed interworking model

The first model is called also "Overlay model", it is used when the IP/MPLS network is carried over the MPLS-TP one, or the MPLS-TP network is carried over the IP/MPLS one (this use case will not be discussed).

The overlay model is using uniform OAM capabilities and encapsulations at all MIPs and MEPs in the label stack (PW/LSP) at both level IP/MPLS and MPLT-TP, which mean that the layer interworking function for MPLS-TP servers is simplified and in case of failure at MPLS-TP LSP level, an AIS is sent in downstream direction to the MPLS-TP MEP Client (MPLS-TP PW layer).

Things to consider regarding the control plane are dependent of network layering scenarios. Here are some use cases:

- VLAN/Port based transparent transport of IP/MPLS: The interworking is done via Link Layer (e.g. Ethernet) encapsulation in PW over MPLS-TP and the selection of the route over the MPLS-TP network is done on a per VLAN/port basis. Therefore, the MPLS-TP section may be seen one hop away from the IP/MPLS layer point of view, and both Control Plane & Management Plane of IP/MPLS are transparently transported. The IP/MPLS control messages need to be carried over an Ethernet frame over a PWE3 before being injected into the MPLS-TP LSP.

- Port based transport of IP/MPLS with Link Layer removal: it is like the use case before but the physical interface between the IP/MPLS and the MPLS-TP network may be of different kind (e.g. Ethernet, POS); the interworking is done via Link Layer removal and client packet (MPLS and IP) encapsulation in PW over MPLS-TP.

- IP/MPLS / MPLS-TP hybrid edge node: the interworking is done via client LSP packet encapsulation as per MPLS labeled or IP traffic over MPLS-TP; The Edge nodes on the MPLS-TP network Section have dual function: LSR of client IP/MPLS network and LER of server MPLS-TP subnetwork which means that in this scenario we got only one MPLS PW from End-to-end and two LSPs (MPLS LSP + MPLS-TP LSP). This also is lead to the fact that IP control messages do not need to be carried over a PWE3 along the MPLS-TP domain but can be directly carried over an LSP.

For the first two use cases, the MPLS-TP subnetwork can achieve the interworking by offering either a Point-to-Point (P2P) service (e.g. E-line), or either by mapping Vlans to distinct PWs, at MPLS LER level, such that multiple IP/MPLS adjacencies can be supported over each interface between the IP/MPLS LSR and the MPLS-TP LER. This potentially can require a large number of IP/MPLS adjacencies overlaying the core.

The second model is called also “peering model”, it is used when a customer network is carried partially over IP/MPLS subnetwork (e.g. via PW encapsulation) and partially over MPLS-TP subnetwork. LSPs and PWs of both MPLS-TP and IP/MPLS are interconnected with respect to MPLS-TP constraint: connection oriented, no Equal Cost MultiPath (ECMP) and no Penultimate Hop Popping (PHP) or merging. This model require also some OAM implications due to the presence of concatenated multiple path segments (MPLS-TP + IP/MPLS) which do not necessary have common OAM components (knowledge of MIP capabilities will not figure into MEP negotiation). Therefore, the end-to-end OAM may only serve to coordinate data plane resiliency actions between MEPs with respect to faults in the MPLS-TP subnetworks.

Just like the precedent paragraph, we will be discussing some Network Partitioning use cases:

- Border Link: It is used to deliver an End-to-End P2P service and it is based on MultiSegment Pseudowire (MS-PW) model. The interconnecting PE are called Switching PE (S-PE) permit the interworking and are responsible to forward fault indication from one subnetwork to the other. In this use case, the S-PE represents a single point of failure[9].

- Border Node: it is one that implements, interconnects and interworks LSPs or PWs with segments or sections in different sub-networks. The interworking function at the border node will terminate, swap or encapsulate labels. It may require label merging at border node to secure end to end protection.

- MultiSegment PseudoWire / LSP Stitching: This is a complicated scenario where a notion of Hierarchical LSP (H-LSP) is introduced. Monitoring LSPs is complicated exercise and protection scenario implies the use of RSVP-TE and/or LDP to interwork MPLS-TP LSP with IP/MPLS LSP.

IV. Conclusion

MPLS-TP has almost all requirements to become the packet transport technology for the next generation transport network. It inherits transport-like characteristics from legacy transport network (SONET/SDH) and packet efficiency from IP/MPLS. We focused on the major construct of MPLS-TP and exposed elements to consider when interconnecting with IP/MPLS network. The overlay model is more adapted and simplified to use when transporting Ethernet or when transparently transporting IP/MPLS. The peering model is more adapted to use in case of “border link” with MS-PW” as there is no need for many node to perform functionalities of both IP/MPLS and MPLS-TP. We opt for a dynamic Control plane on MPLS-TP subnetwork instead of static one, due to the limitation that can present this last option in term of scalability (e.g. label space management) especially because of the dynamic characteristic of MPLS control plane (GMPLS). However, a combination of static (MPLS-TP) and dynamic (IP/MPLS) control plane can exist if some adaptations and/or modifications are made the Network Management System (NMS) role. The issue is more critical when it comes to Management Plane due to the existence of two standards (G.8113.1 supported by ITU-T and G.8113.2 supported by IETF) which are still subject of development especially regarding the IETF one. In fact, even if decision is made for one OAM solution, the backward compatibility with the management toolset of MPLS is still an open question.

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