Next Generation Ethernet Transport

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April 30, 2007

Agenda

- Introduction
- Industry Dynamics
- Ethernet Trends and Convergence
- Standards Overview
- Service Mapping and Applicability
- Summary

Introduction

Introduction

- Explore dynamics around Next Generation Ethernet
  - What is happening in transport from an industry perspective
- Explore ethernet trends around the topic of convergences
- Discuss what is happening in the standards organizations like IEEE, ITU-T, IETF
- It's all about services and applications else everything is a nice theoretical discussion

Industry Dynamics

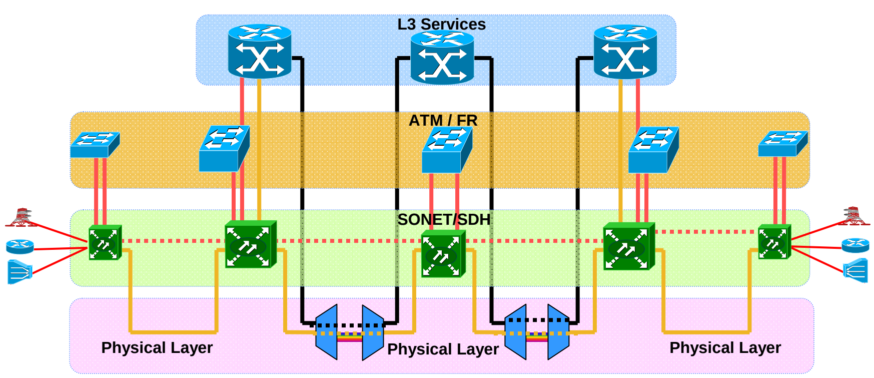
Market Trends and Focus

- Ethernet at access for service aggregation
- Require service flexible architecture
- Capex and Opex efficient
- OAM and Network management key
- High availability and resiliency
- “Adaptation” of packet switching technologies to the transport domain
- Utilization of legacy strategy where ATM technology was used both as a “transmission” and a “switching” technology
- Migration to IP/MPLS and Ethernet based core switching
- Elimination of unneeded control plane capabilities and functionalities in transmission applications
- Multiple overlay and supplemental proposals and techniques, including T-MPLS,PBB-TE, to adapt IP/MPLS and Ethernet to the transport arena

Packet Transport Market Dynamics

- Traditional circuit switched transport systems are migrating toward packet based technologies
- SDH/SONET platforms provide low speed bandwidth granularity network services and high speed long haul transmission services
- IP adoption and convergence simplifies packet transport networks in the access/aggregation and metro domains to reduce CapEx and OpEx in next generation networks

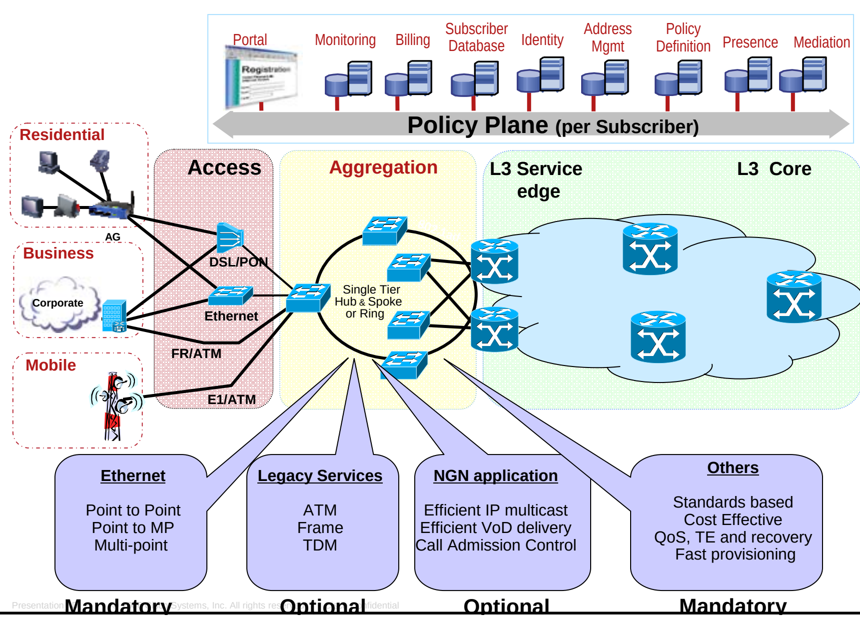
Where we are today !!



Characteristics and issues

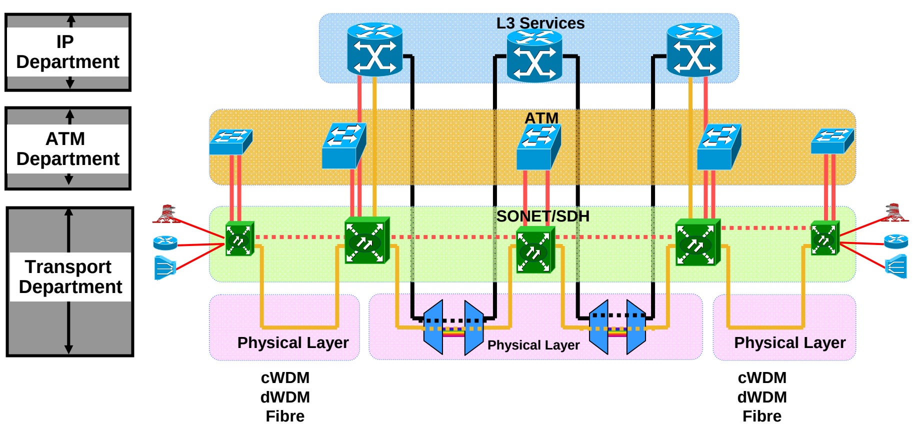
- Network centric
  - Circuit orientated
- Multiple networks
  - OPEX and CAPEX inefficiencies
  - Provisioning and service assurance complexities
  - Complexity between layers
- ATM and F/R technology is tailing off
  - Service capabilities
  - Bandwidth concerns
- NG SDH/SONET days numbered
  - TDM and circuits not well suited for packet transport
  - Acknowledged by transport vendors and SPs
  - Discussion is now about high performance packet networks
- Service capability may still be required
  - Regulation
  - Evolution may not be possible

Next Generation Transport Requirements



Ethernet Trends and Convergence

Existing roles and responsibilities



- Organisational lines drawn based on networks
- Cross charging between groups
  - Transport to ATM, Transport to IP, ATM to IP
  - Creates considerable friction
  - Can cause organisational breakdowns (IP department buys dark fibre, dwdm gear)

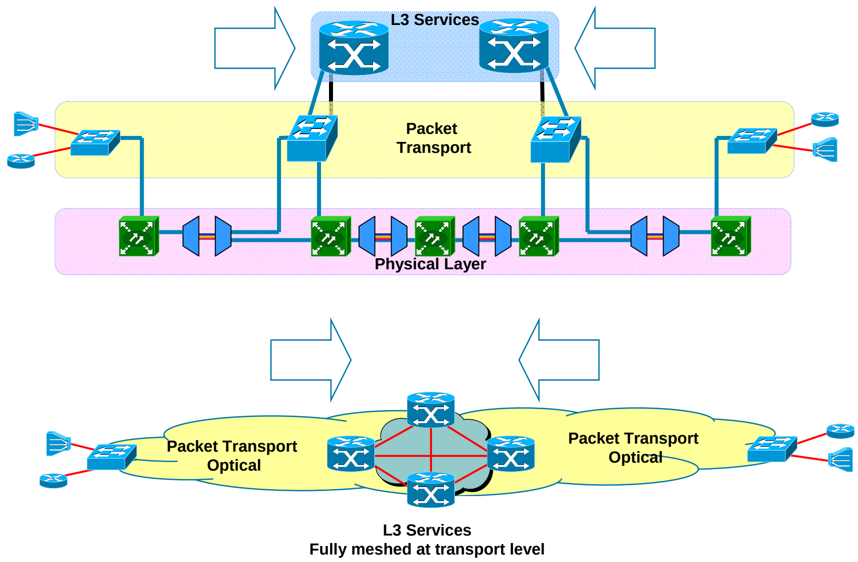
Moving forward

- IP will be an extremely important component of the NGN
  - No debate that IP is the protocol of the future
- Differing views on what an IP network is !!!
  - Routing IP packets (IP routing and optical)
  - AND / OR
  - Transporting IP packets (Ethernet and optical)
- ATM is dying rapidly
  - New services and bandwidth concerns
- SDH/SONET days numbered
  - Acknowledged by transport vendors
  - Discussion is more about high performance packet networks
  - They are moving towards :- Ethernet transport and optical

Characteristics

- Multiple networks
  - Different services, different capabilities
- Complex interaction between layers
- Layer 3 components tend to be fairly centralised in nature
- Most SPs believe the number of networks has to be rationalized
- New services are demanding more bandwidth
  - Existing transport and ATM networks will not scale
  - All see the need to build a high speed packet transport networks

Transport orientated view
Rationalise



Service Requirements

Consumer	Business	Wholesale	Evolved services
Internet Voice / Video / data Voice PSTN / Multimedia Video Over the Top Walled Garden Mobility	TDM/ATM→Ethernet L2 VPNs Pt2Pt Pt2MPt MPt2MPt L3 VPNs Connectionless Value-add Services Based on L3 visibility	TDM/ATM→ Ethernet L2 VPNs Pt2Pt Pt2MPt MPt2MPt L3 VPNs L2TP Connectionless	PSTN Migrate Mobile RAN backhaul IP transition TDM Migrate and evolve to Ethernet ATM Migrate and evolve to Ethernet F/R Evolve to Ethernet

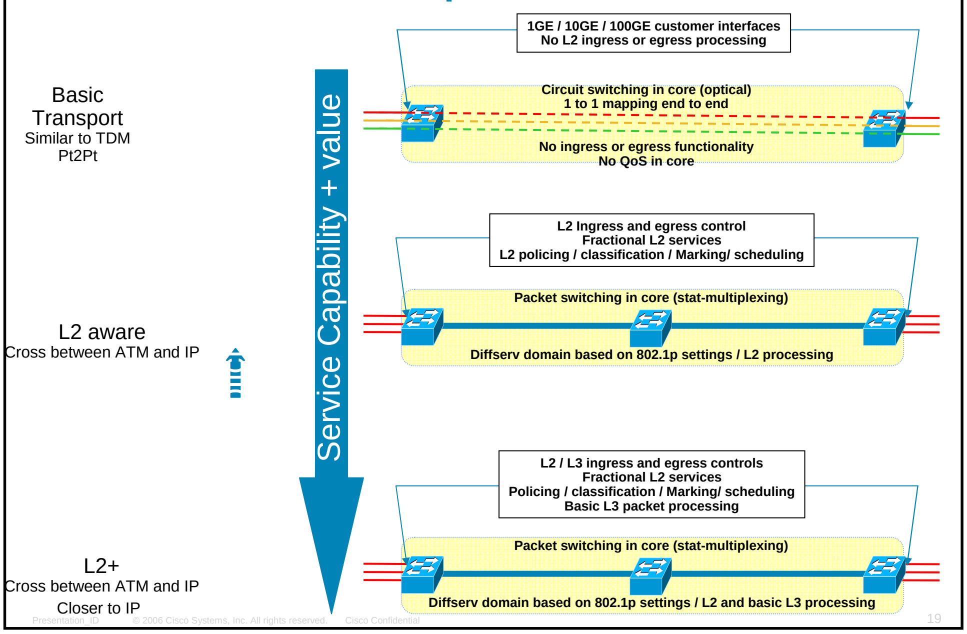
Moving forward

- Service orientated architecture
  - Functionality placed where it makes sense for optimal service delivery
  - Infrastructure and demographics
  - Traffic flows
- IP is the service protocol
  - Not Ethernet, Not optical, Not MPLS
  - Other than dumbest optical transport all NGN networks need IP disciplines
  - So do the organisations running them
- Network convergence
  - CAPEX and OPEX reduction
  - Ease of provisioning and service assurance

A service orientated architecture

- Flexible content injection
  - Centrally or distributed, or combination
- Multi-Service capability
  - IP, Ethernet, ATM, TDM services
- Connectionless Services
  - Multi-point and point to multipoint services
- Connection Orientated Services
  - Point to Point Services
- Rapid service turn up and provisioning
  - User self management
  - Minimal in-house provisioning
- Integrated into Service Control plane
  - Easily integrated with TISPAN, IMS and policy environment
- Operation and planning
  - Simple capacity planning and operational models
  - Service centric network instrumentation
- Service and Network Security

What is Packet Transport ?



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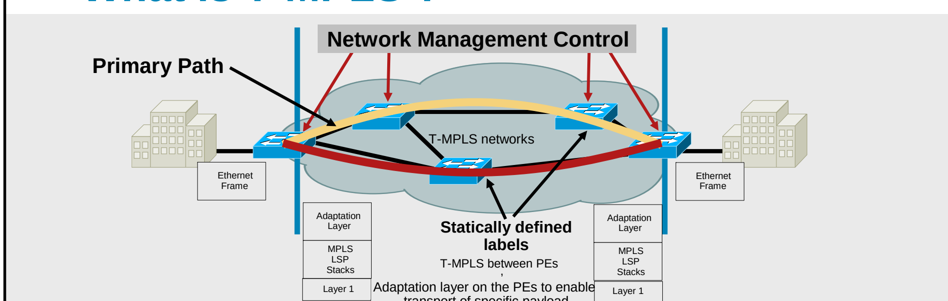
What is T-MPLS ?



- Definition: Transport MPLS
  - Forwarding Plane: MPLS labels with simplifications (bidirectional LSPs, no ECMP, no PHP)
  - Control Plane: Phase 1: static provisioning of labels using OSS/NMS
  - OAM based on Y.1711
- Services: Phase 1 : P2P connection orientated services only
- Standards:
  - ITU-T based set of standards

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What is T-MPLS ?

- Connection oriented packet switched transport over an optical transport network
  - Architecture based on ITU-T G.805
- Its main characteristics are:
  - Bidirectional trail (Point to point)
  - “Client-server” model
  - Control plane: no control plane (phase 1); GMPLS later?
  - OAM based on transport concept (i.e. AIS/RDI, CV: ITU-T Y.1711 phase 1, quality control still missing -> Y17.tom and Y.17tor)
  - Protection switching and Survivability based on ITU-T Y.1720/G.8131 (linear protection switching 1+1, 1:1, shared mesh options) and Y.mrps (ring protection switching)
  - Use same data-link protocol ID (e.g. EtherType), frame format and forwarding semantics as defined for MPLS frames
- T-MPLS is another MPLS “pseudowire” (PW) with bi-directional traffic engineered path (see GMPLS)

How is it Positioned?

- Next Generation SONET/SDH with tight integration to Metro Ethernet and Access: Transport Ethernet frames over point-to-point VCs
- Offers a transition path to SPs/Carriers who have a huge SONET/SDH infrastructure and moving toward packet
  - Re-usability of OTN networks without expensive upgrade (e.g. Introduction of control plane might require more memory or device forklift)
- Next Generation Packet Transport: Layer 2 hollow core
  - Claim: cheaper OPEX, easier to operate and deploy

T-MPLS Uses MPLS Features but…

- T-MPLS defined to use "same profile" as MPLS but:
  - Use of bidirectional LSPs
  - No Penultimate Hop Popping (PHP)
  - No LSP merging option
  - No FRR support
    - Requires LSP merge
  - No Equal Cost Multiple Path (ECMP)
- T-MPLS is a subset of MPLS but …
  - Interoperability with existing MPLS platform is a challenge

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T-MPLS and IETF MPLS

- T-MPLS supporter's claim it is a subset of IETF MPLS
  - Pseudo-wire concept, same Ethertype
  - T-MPLS simplifications are covered by the IETF MPLS RFCs
- Inter-operability will be challenging
  - Different OAM mechanisms
  - Different signaling protocols for pseudo-wires
  - Different control planes using same Ethertype (label management)
- Cisco's position on T-MPLS
  - Existing IETF RFCs and drafts cover the T-MPLS requirements and use cases
  - Why reinvent the wheel
  - Use standards already approved and implemented

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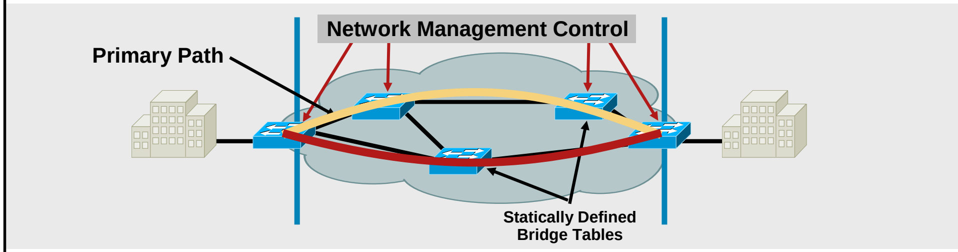
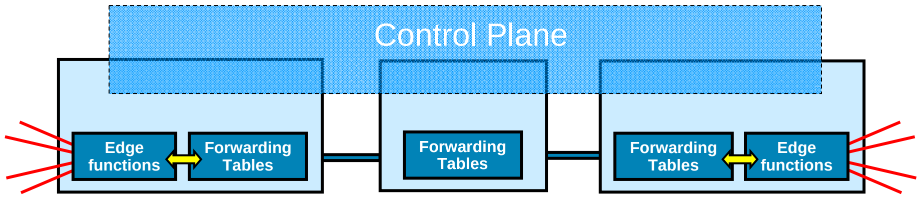
What is PBT ?



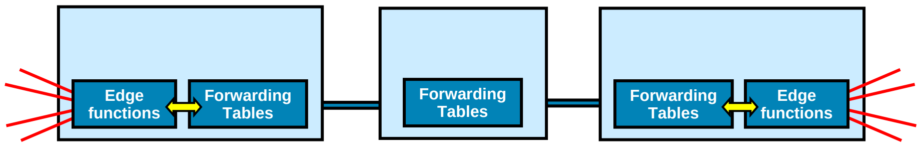
- Definition: Provider Backbone Transport (PBT)
  - Forwarding Plane: 802.1ah encapsulation from Provider Backbone Bridging
  - Control Plane: An OSS/NMS replaces IEEE control plane elements
  - OAM based on 802.1ag (with modifications)
- Services: P2P connection orientated services only
- Standards:
  - PBT is proprietary
  - PBB-TE in project approval request (PAR), has just entered the standards
    - Does not assume PBT as a base line
    - Aspiring to be more than PBT, address MP2MP services

Comparing solutions



- Edge functions
  - Conditions customer connections
  - Vital component but not part of the base transport
- Data plane
  - Encapsulation of the packets and forwarding paradigm
- Control plane
  - The set-up and control of the forwarding plane for different services

Forwarding plane Comparison

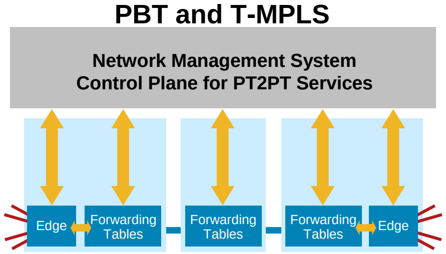


- **IP/MPLS**
  - Customer packet encapsulated in an MPLS label stack
  - Forwarding based on a label switch
- **T-MPLS**
  - Customer packet encapsulated in MPLS label
  - Forwarding based on a label switch
- **PBT**
  - Customer packet encapsulated in 802.1ah
  - Forwarding with modified Ethernet switching

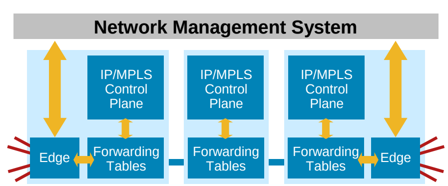
Strong similarities

Control Plane Comparison

PBT and T-MPLS



IP/MPLS



- **NMS based Control Plane**
- **Long term support integrated control plane?**
  - **PBT and T-MPLS → G-MPLS**
  - **G-MPLS – Link state Protocol, RSVP etc**
- **Single Service Control Plane**
  - **Pt2Pt Only**

- **Integrated Control Plane**
- **Multi-service Control Plane**
  - **L1, L2, L3**
  - **Pt2Pt, Multipoint**

PBT / T-MPLS : Simply moves complexity to the Network Management layer

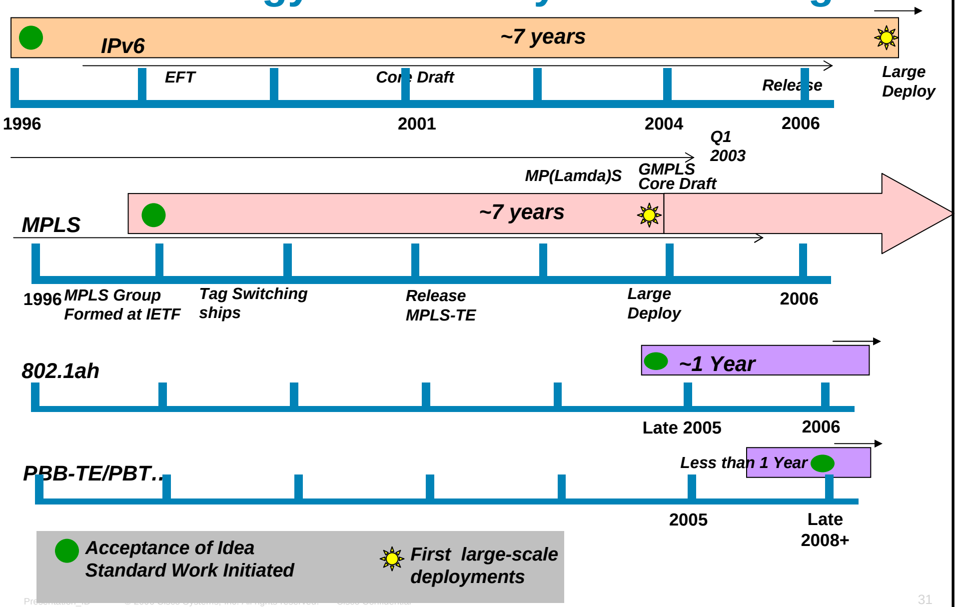
Packet Transport forwarding and control plane

- **IP/MPLS (EoMPLS and VPLS):-**
  - Lot of initial success: - but mainly sold as next generation ATM
  - Based on the encapsulation customer traffic in two or more labels
  - Label forwarding within the core based on provider label
  - IP/MPLS control plane
- **PBB-TE :-**
  - Emerging Ethernet solution
  - Based on encapsulation of customer traffic in backbone mac address
  - Ethernet forwarding within the core based on provider backbone mac address
  - NMS based control plane (discussing the use of G-MPLS)
- **PBT:-**
  - Vendor proprietary
- **T-MPLS :-**
  - Emerging
  - Based on the encapsulation customer traffic in two or more labels
  - Label forwarding within the core based on provider label
  - NMS based control plane (discussing the use of G-MPLS)
- **Arguments over which option**
  - CAPEX cost :- Ethernet and transport solutions are cheaper than IP solutions
  - Complexity of IP control plane :- OPEX associated with operating the solution

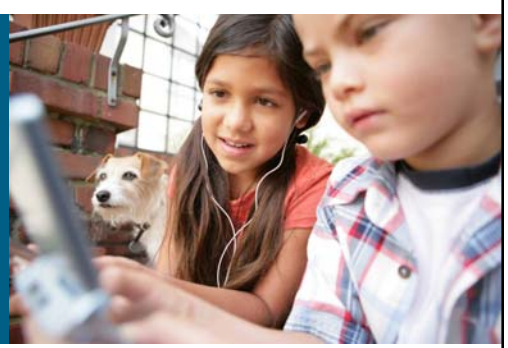
Who are the Target Customers?

- A PRIMARY target for PBT are customers with legacy SONET/SDH switching and NMS solutions
- Operators who want to offer Ethernet services over Ethernet Infrastructure –
- Existing operators who currently deploy IEEE 802.1ad (QinQ) Metro Ethernet network and want to evolve to IEEE 802.1ah/PBT network –

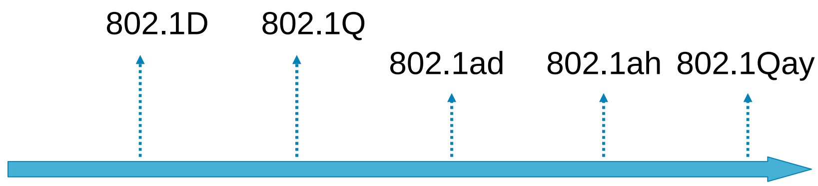
Technology Uncertainty / Forecasting



Standards Overview



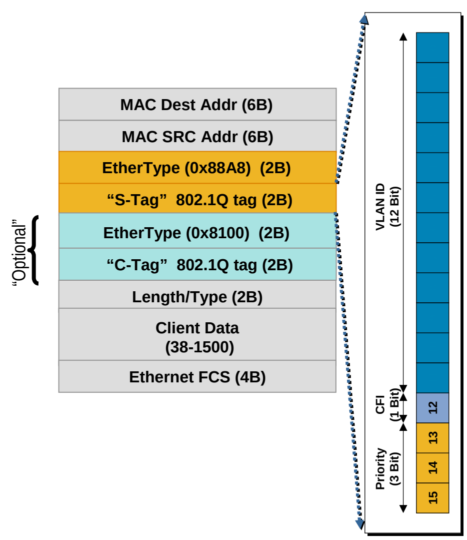
Ethernet Evolution



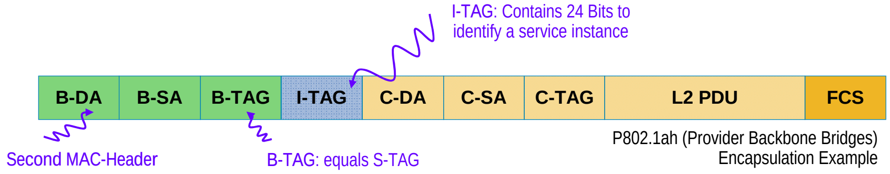
- 802.1D – Media Access Control (MAC) Bridges
  Ethernet bridging / Spanning Tree Protocol
- 802.1Q – Virtual Bridged Local Area Networks
  Tagged frame / Multiple Spanning Tree Protocol
- 802.1ad – Provider Bridges
  VLAN stacking (amendment to 802.1Q)
- 802.1ah – Provider Backbone Bridges
  MAC/VLAN stacking (amendment to 802.1Q)
- 802.1Qay – Provider Backbone Bridges Traffic Engineering
  Traffic engineering extensions based on 802.1ah

IEEE 802.1ad Provider Bridges

- Customer VLAN Transparency
  IEEE 802.1ad Provider Bridges will provide a standardized version of “QinQ” (Note: Inner .1Q tag is optional)
  Standard will include additional enhancements
- Frame Format same “QinQ”
  New Ethertype: 0x88A8
- Technically complete
  Standard approved 8th Dec 2005 (Draft 6)



IEEE 802.1ah Provider Backbone Bridges
Main Ideas/Concepts



- Service Scalability

  Define a new “Service Instance Identifier” – 24* Bits wide (taking the place of the former “VLAN”): I-TAG.

- Domain Isolation, MAC-Address Scalability

  Encapsulate Customer MAC-frames at the edge of the network into a “Provider MAC-Frame”: New MAC-Header with B-TAG.

- “Backward Compatibility” to 802.1ad

  Packet header of Provider Backbone Bridges (PBB, P802.1ah) and Provider Bridges (PB, P802.1ad) look the same

 *Note: Still under discussion, not finalized yet 35

IEEE 802.1Qay Provider Backbone Bridges Traffic Engineering

- New work item to define traffic engineering extensions for 802.1ah
- IEEE 802.1 Project Authorization Request (PAR) approved in November 2006
- Standardization expected to take at least 2-3 years
- Motivated by provider backbone transport (PBT) discussion
- How similar/different PBB-TE and PBT will look is unknown

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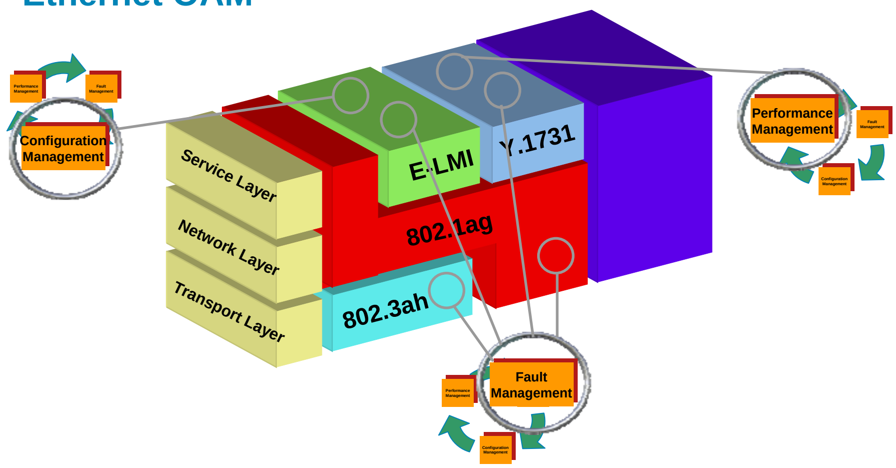
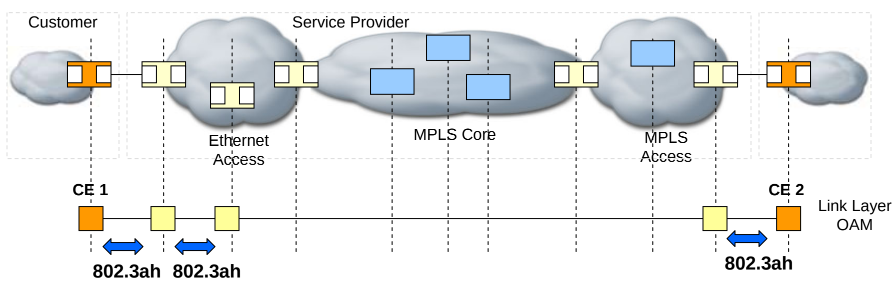
Ethernet OAM



- IEEE 802.1ag: Connectivity Fault Management (CFM)
- ITU-T Y.1731: OAM functions and mechanisms for Ethernet based networks
- IEEE 802.3ah: Ethernet Link OAM (EFM OAM)
- MEF E-LMI: Ethernet Local Management Interface
- Cisco IP SLA's: Performance Management using IP, CFM and Y.1731 Mechanisms

802.3ah



- Link Level OAM
- Operates on point-to-point link, not propagated beyond a single hop.
- Slow Protocol (Max rate of 10 frames per second)
- Functions:

  OAM discovery – Discover OAM capabilities on peer device

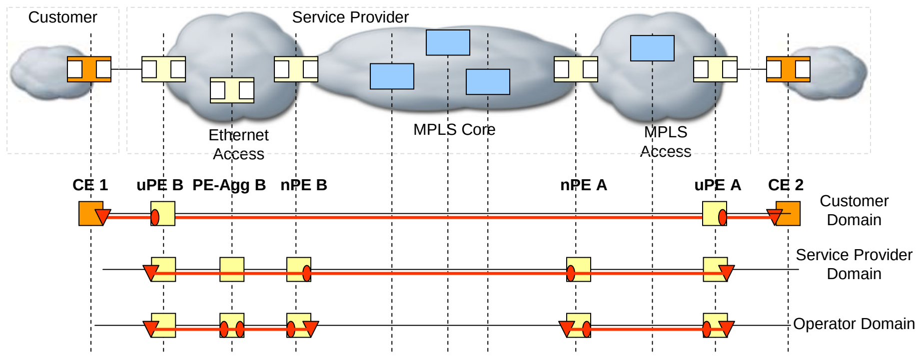
  Link monitoring – Event notification when error thresholds exceeded

  Remote MIB Variable Retrieval – Polling and response (but not writing) of 802.3ah MIB

  Remote Failure indication – Inform peer that receive path is down.

  Remote Loopback – Puts peer in (near-end) intrusive loopback state. Statistics can be collected while testing link.

802.1ag Connectivity Fault Management (CFM)

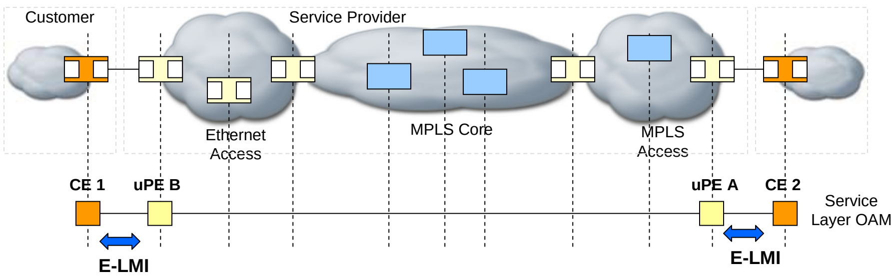


- End to End per EVC OAM
- Hierarchical Maintenance Domains
  - MEPs/MIPs
- Standard Ethernet Frames (in-band)
  - Continuity Check
  - Loopback
  - Link Trace

Y.1731

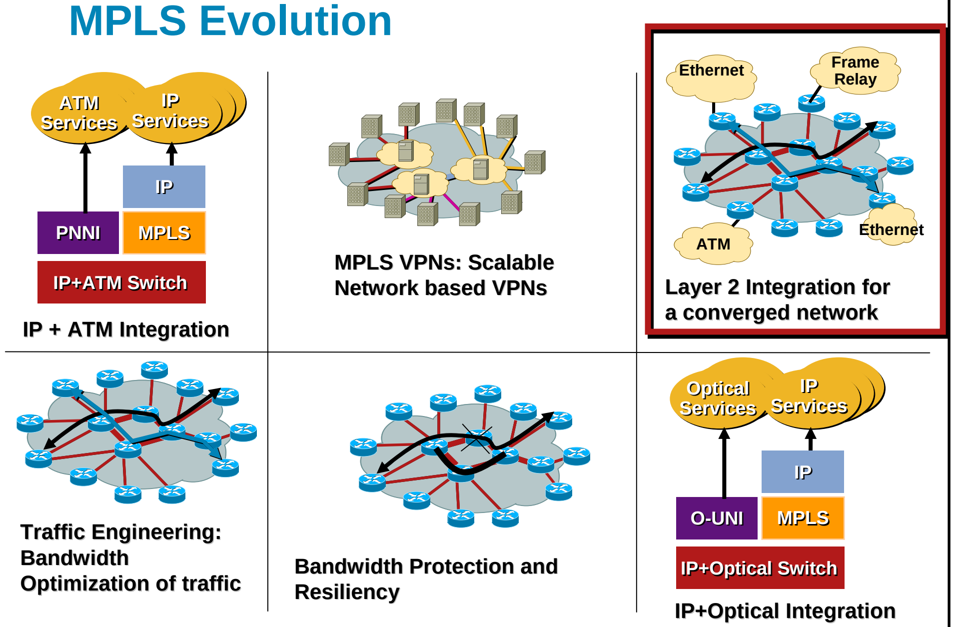
- CFM plus…
  - ETH-LCK (out of service diagnostics)
  - Multicast Loopback
  - AIS
  - TEST
  - Maintenance Communication Channel
  - Experimental OAM
  - Performance Management (Delay, Packet loss, Jitter)

E-LMI

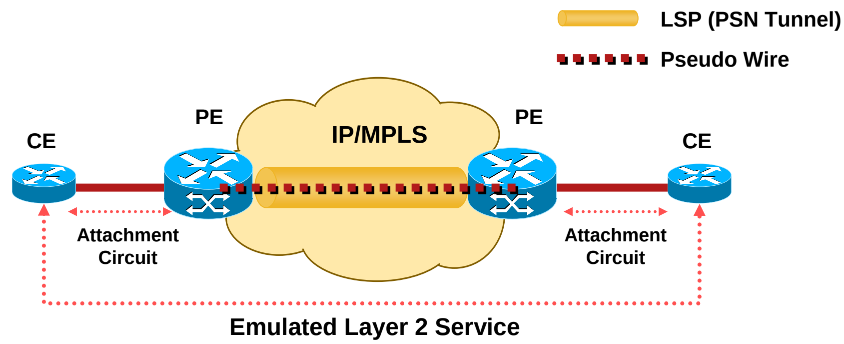


- Asymmetric protocol, applicable on UNI only (uPE to CE)
- Specifies procedures & message formats exchanged and NOT how uPE collects OAM data – relies on Service/Network OAM running uPE to uPE
- Allows uPE to communicate to CE:
  - EVC Status
  - Remote UNI Status
  - CE-VLAN to EVC Map
  - BW Profiles

MPLS Evolution



Pseudo Wire Reference Model



- A pseudowire (PW) connects native Layer 2 attachment circuits
- Establishment of PWs is signaled between PEs using LDP
- LSP ultimately carries PW traffic between PEs

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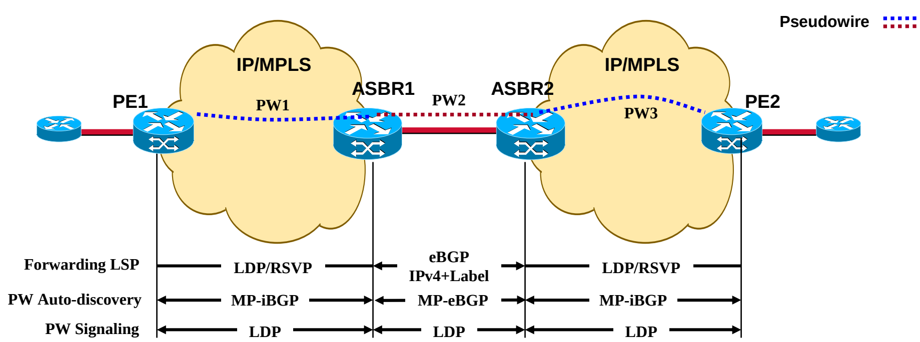
Multi-Segment Pseudowire



- Provides isolation between administrative domains
- Single (labeled) interface between ASBRs
- Single peering point (only one PW endpoint address leaked between ASs)
- PE and P devices do not learn remote PW endpoint addresses

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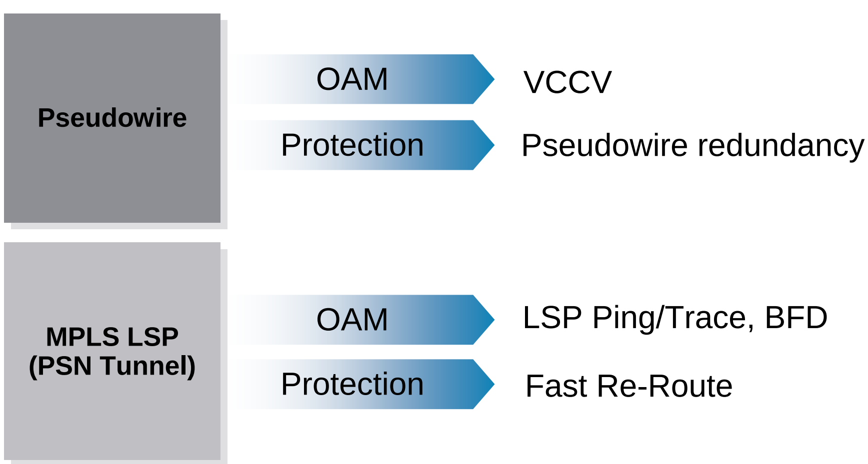
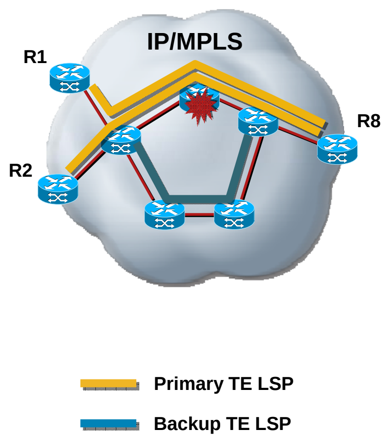
Standardization Status for Ethernet Transport over MPLS

- RFC 3985 (informational)
  PWE3 Architecture
- RFC 4447 (standards track)
  Pseudowire Setup and Maintenance using the Label Distribution Protocol (LDP)
- RFC 4448 (standards track)
  Encapsulation Methods for Transport of Ethernet Over MPLS Networks
- RFC 4385 (standards track)
  Pseudowire Emulation Edge-to-Edge (PWE3) Control Word for Use over an MPLS PSN
- draft-ietf-pwe3-segmented-pw
  Segmented Pseudo Wire
- draft-ietf-pwe3-dynamic-ms-pw
  Dynamic Placement of Multi Segment Pseudo Wires

Pseudowire OAM and Protection



MPLS TE Fast Re-Route (FRR)



- Local protection
- Subsecond recovery against node/link failures
- Scalable 1:N protection
- Greater protection granularity
- Bandwidth protection
- Supports different LSP types (P2P, P2MP, MP2P)
- BFD may help with failure detection

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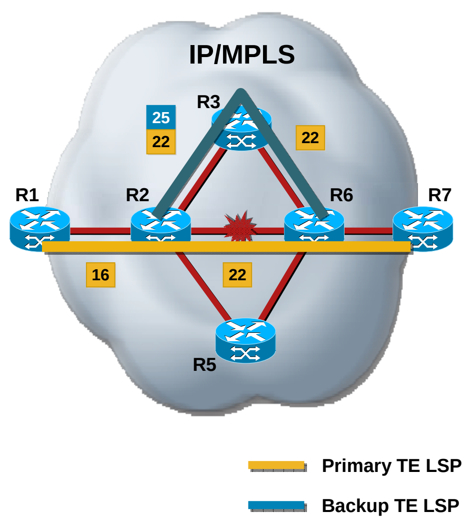
FRR Link Protection Operation

- Requires next-hop (NHOP) backup tunnel
- Point of Local Repair (PLR) swaps label and pushes backup label
- Backup terminates on Merge Point (MP) where traffic rejoins primary
- Restoration time expected under ~50 ms (local protection)



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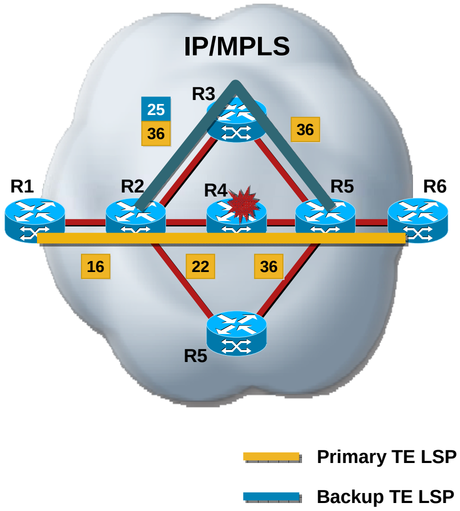
FRR Node Protection Operation

- Requires next-next-hop (NNHOP) backup tunnel
- Point of Local Repair (PLR) swaps next-hop label and pushes backup label
- Backup terminates on Merge Point (MP) where traffic rejoins primary
- Restoration time depends on failure detection time, but minimized (local protection)



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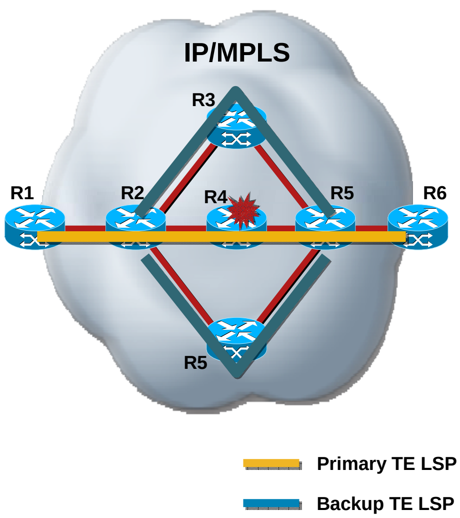
Bandwidth Protection

- Backup tunnel with associated bandwidth capacity
- Backup tunnel may or may not actually signal bandwidth
- PLR will decide best backup to protect primary (nhop/nnhop, class-type, node-protection flag)



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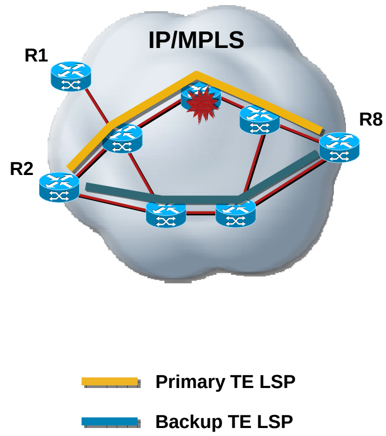
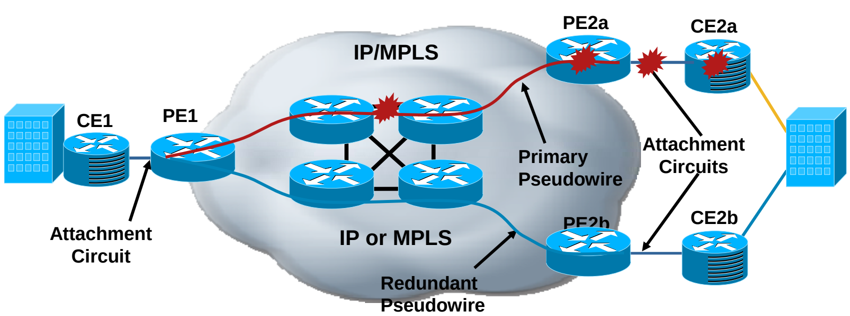
What about Path Protection?

- Primary and backup share head and tail, but diversely routed
- Expected to result in higher restoration times compared to local protection
- Doubles number of TE LSPs (1:1 protection)



Pseudowire Redundancy



- Failure notification via LDP
- Failure detection possible via VCCV+BFD
- Failures within MPLS network to be protected by MPLS FRR

Standardization Status for MPLS Protection

- RFC 4420 (Standards Track)

  RSVP-TE: Extensions to RSVP for LSP Tunnels

- RFC 4090 (Standards Track)

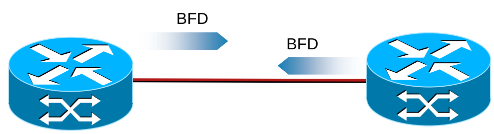
  Fast Reroute Extensions to RSVP-TE for LSP Tunnels

MPLS OAM

Fault	**Detection**	MPLS BFD
	Notification	MPLS MIBs / SNMP traps
	Verification	MPLS LSP Ping (ping mode)
	Isolation	MPLS LSP Ping (trace mode)
Performance Management		MPLS LSP Ping (ping mode)

Bidirectional Forwarding Detection (BFD)

- Simple, fixed-field, hello protocol
- Nodes transmit BFD packets periodically over respective directions of a path
- If a node stops receiving BFD packets some component of the bidirectional path is assumed to have failed
- May operation in asynchronous or demand modes



MPLS LSP Ping/Traceroute

Requirement	▪ Detect MPLS traffic black holes or misrouting ▪ Isolate MPLS faults ▪ Verify data plane against the control plane ▪ Detect MTU of MPLS LSP paths ▪ Support different LSP types (P2P, P2MP, MP2P)
Solution	• MPLS LSP ping (ICMP) for connectivity checks • MPLS LSP traceroute for hop-by-hop fault localization • MPLS LSP traceroute for path tracing
Applications	▪ IPv4 LDP prefix, VPNv4 prefix: tunnel monitoring ▪ TE tunnel ▪ L2 VPNs
RFC Standards	• RFC 4377, RFC 4378, RFC4379

Virtual Circuit Connection Verification (VCCV)

Requirement	• Ability to provide end-to-end fault detection and diagnostics for an emulated pseudowire service One tunnel can serve many pseudowires MPLS LSP ping is sufficient to monitor the PSN tunnel (PE-PE connectivity), but not VCs inside of tunnel
Solution	▪ VCCV allows sending control packets in band of pseudowires (PW) ▪ Two components Signaling component: communicate VCCV capabilities as part of VC label Switching component: cause the PW payload to be treated as a control packet Type 1: uses Protocol ID of PW Control word Type 2: use MPLS router alert label Type 3: manipulate TTL exhaust
Applications	▪ Layer 2 transport over MPLS FRoMPLS, ATMoMPLS, EoMPLS
IETF Standards	draft-ietf-pwe3-vccv-13

MPLS BFD vs. LSP Ping

Method	Data Plane Failure Detection	Control Plane Consistency	Protocol Overhead
LSP ping	YES	YES	Higher than BFD
MPLS BFD	YES	NO	Low

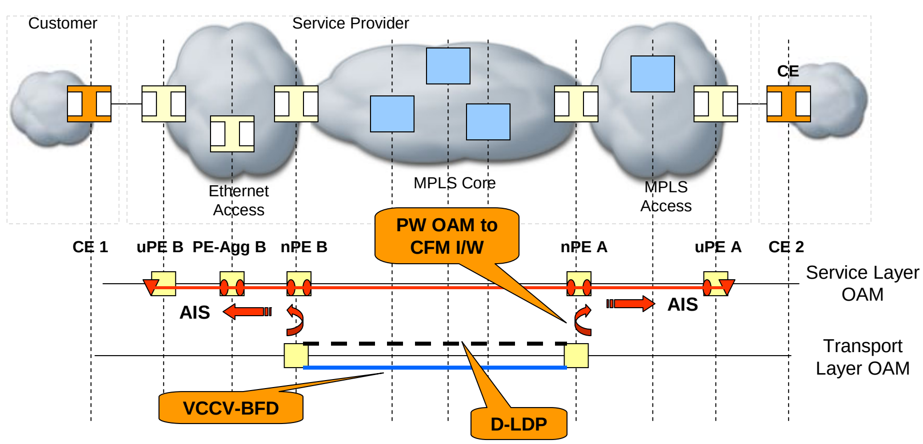
MPLS-BFD Can Complement LSP Ping to Detect a Data Plane Failure in the Forwarding Path of a MPLS LSP

Supported FECs:
RSVP IPv4/IPv6 Session, LDP IPv4/IPv6 Prefix
VPN IPv4/IPv6 Prefix, Layer 2 VPN, Layer 2 Circuit ID

MPLS Performance Management

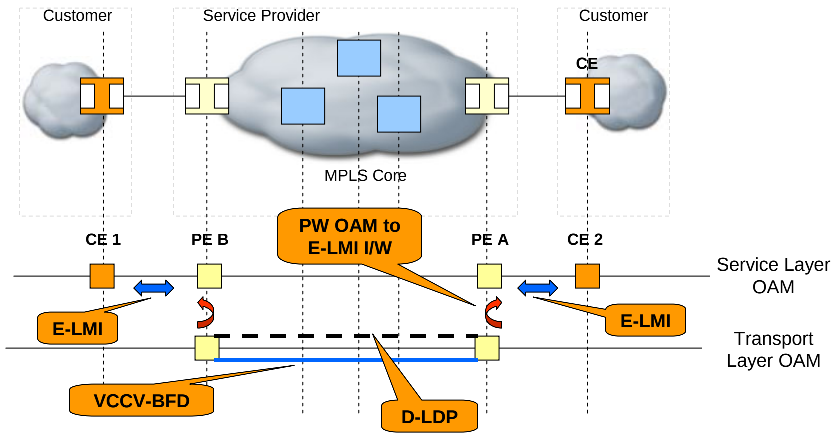
- LSP Ping includes packet timestamp
- LSP Ping can be used to measure packet delay, jitter and loss
- Applies to all different LSP types (P2P, P2MP, MP2P)
- Similar to IP performance management

Inter-working Scenarios: MPLS PW OAM to CFM



- Directed-LDP & VCCV (BFD mode) running between nPEs.
- D-LDP for defect notification, VCCV for defect detection
- 3-way I/W function at nPE
- Requires CFM AIS/RDI

Inter-working Scenarios: MPLS PW OAM to E-LMI



- Directed-LDP & VCCV (BFD mode) running between PEs.
- D-LDP for defect notification, VCCV for defect detection
- Defects detected/communicated by PW OAM are relayed to E-LMI via I/W function on PE.

Standardization Status for MPLS OAM

- draft-ietf-bfd-base
  Bidirectional Forwarding Detection
- draft-ietf-bfd-mpls
  BFD For MPLS LSPs
- RFC 4379 (Standards Track)
  Detecting Multi-Protocol Label Switched (MPLS) Data Plane Failures
- draft-ietf-pwe3-vccv (Standards Track)
  Pseudo Wire Virtual Circuit Connectivity Verification (VCCV)
- draft-ietf-mpls-p2mp-lsp-ping (Standards Track)
  Detecting Data Plane Failures in Point-to-Multipoint Multiprotocol Label Switching (MPLS) - Extensions to LSP Ping
- draft-ietf-mpls-interas-lspping (Standards Track)
  Detecting MPLS Data Plane Failures in Inter-AS and inter-provider Scenarios
- draft-ietf-mpls-mcast-cv (Standards Track)
  Connectivity Verification for Multicast Label Switched Paths

Other Packet Transport Proposals

- Provider Backbone Transport
- ITU-T Transport MPLS (T-MPLS)

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Provider Backbone Transport

- In a sentence:

  Basically using 802.1ah data-plane functionality with OSS/NMS provisioning in lieu of IEEE control protocols (MSTP, GVRP, etc.) to setup P2P VCs.

- It Consists of the following three components:

  Data-plane based on 802.1ah

  OAM based on 802.1ag

  A protection switching mechanism similar to MPLS TE Path Protection (protection path switching between two edge switches)

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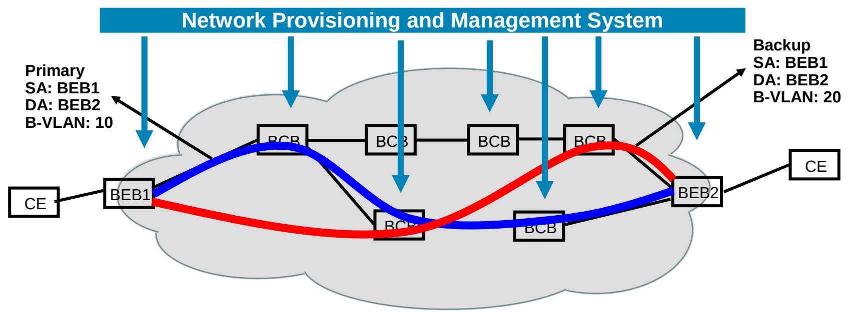
How Does It Work ?

- Use OSS to configure B-MACs and B-VLANs manually in the bridge along both primary and backup paths
- Use CFM Continuity Check Messages to monitor the primary and the backup paths
- Upon failure of the primary path, configure the edge switches (BEB1 & BEB2) to switch to the backup path



BCB: Backbone core bridge BEB: Backbone Edge bridge

How Does It Work ? (Cont'd)

- Divide the B-VID address space between conventional 802.1ah PBBN (Provider Backbone Bridge Network) B-VLANs and PBT
- Turn off learning and broadcasting on all PBT B-VIDs
- Use bridge MIB to configure the Bridge forwarding tables for PBT B-VIDs
- Each bidirectional PBT circuit is composed of a working and a protection path
- Manage co-routed bundles of PBT backbone circuits using IEEE 802.1ag

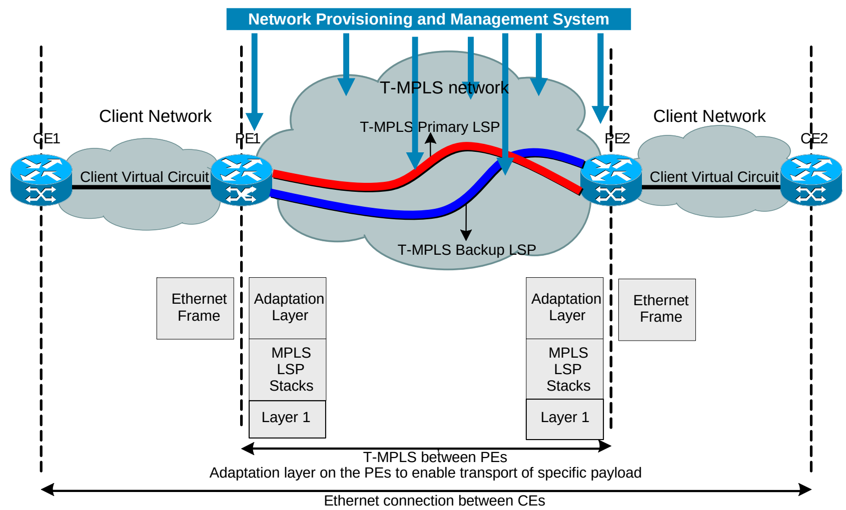
Some Pending Questions Regarding PBT

- What is the applicability?
- Does it satisfy the requirements of a wide range of services?
- If multipoint transport requires 802.1ah, what is the operational complexity of running PBB and PBT simultaneously?
- What is the protection scalability? What are the target restoration times? For how many trunks?
- What are the real benefits compared to other existing Ethernet transport alternatives?

Other Packet Transport Proposals – T-MPLS

- Connection oriented packet switched transport over an optical transport network
  - Architecture based on ITU-T G.805
- Its main characteristics are:
  - Bidirectional trail (Point to point)
  - "Client-server" model
  - Control plane: no control plane (phase 1); GMPLS later?
  - OAM based on transport concept (i.e. AIS/RDI, CV: ITU-T Y.1711 phase 1, quality control still missing -> Y17.tom and Y.17tor)
  - Protection switching and Survivability based on ITU-T Y.1720/G.8131 (linear protection switching 1+1, 1:1, shared mesh options) and Y.mrps (ring protection switching)
  - Use same data-link protocol ID (e.g. EtherType), frame format and forwarding semantics as defined for MPLS frames
- T-MPLS is another MPLS "pseudowire" (PW) with bi-directional traffic engineered path (see GMPLS)

How is it Intended to Work?

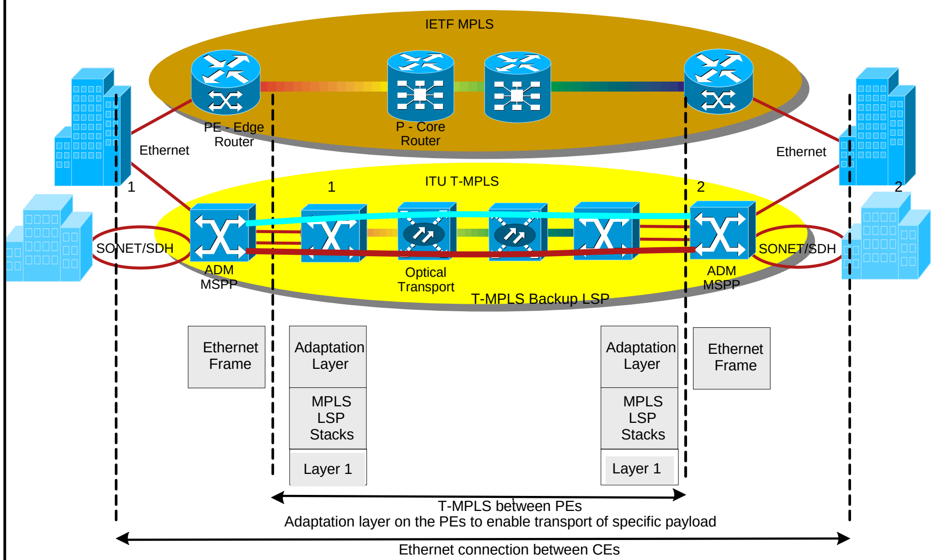


Note: Adaptation layer functions on PE define the payload to be transported into the T-MPLS LSP
It can possibly be Ethernet, MPLS, TDM…

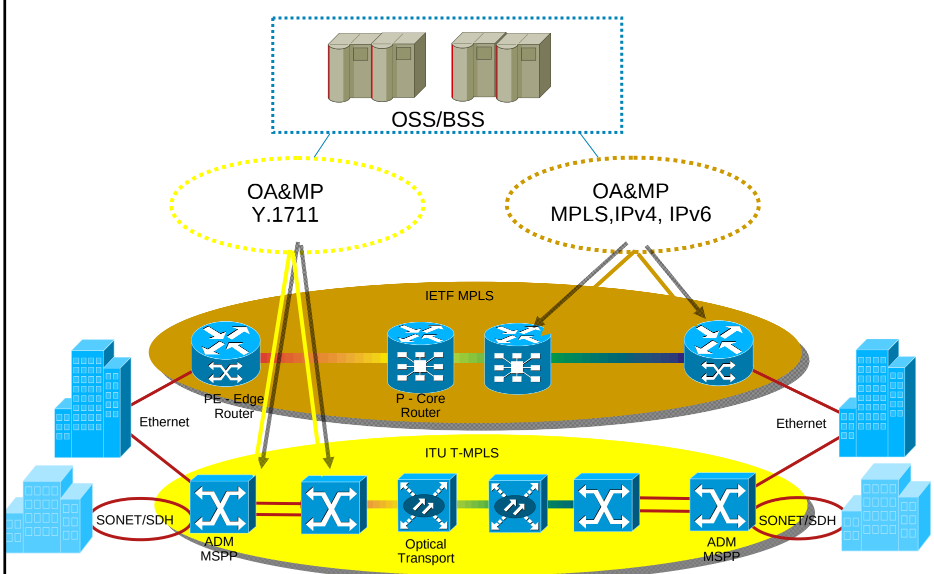
How Does it Work – as Defined Today?

- Management system (OSS) will configure primary and backup T-MPLS trail (LSP) in every NE along the path
  - As T-MPLS uses the same Ethertype as MPLS, they share the same label table
  - OSS will need to coordinate with LSRs to ensure that label management is consistent
- Y.1711 OAM CV message to monitor primary T-MPLS availability and switch traffic to backup in case of failure
- Adaptation function required at the head-end/tail-end to map client layer to T-MPLS layer trail
- Client layers: L2 (Ethernet), MPLS, TDM, etc.

ITU T-MPLS : Another Packet Aware Technology



ITU T-MPLS : Separate FCAPs & OA&M



ITU-T Standardization Status for T-MPLS

- G.8110.1
  Architecture of Transport MPLS (T-MPLS) layer network
- G.8112
  Interfaces for the Transport MPLS (T-MPLS) hierarchy
- G.8121
  Characteristics of Transport MPLS (T-MPLS) equipment functional blocks
- G.8131
  Linear protection switching for Transport MPLS (T-MPLS) networks

More than 50 items referenced "for further study"

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T-MPLS Challenges

- T-MPLS is unnecessary since existing MPLS PW has similar capabilities.
- T-MPLS has IP MPLS interoperability challenges
- T-MPLS adds an additional layer of complexity to deploying and managing converged MPLS networks

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T-MPLS – MPLS Interoperability Challenge

- T-MPLS claims to be a subset of MPLS
  - Co-existence of both equipment within the network?
  - Interoperability if T-MPLS LSP crossing an MPLS device (vice-versa)?
- Interoperability between a T-MPLS transport network and an MPLS network element
  - Matching T-MPLS options on the MPLS device
- Interoperability between T-MPLS PW and MPLS PW
  - Signaling uses different protocols - makes IW a challenge
  - Using two different OAMs additional complexity

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IETF Application of Pseudowires to Transport Networks

If a packet transport network as defined by ITU needs to be built using MPLS…

- Use a strict subset of current pseudowire specifications
- draft-bryant-pwe3-mpls-transport defines current proposal
- Based on ITU requirements
- Two VCCV profiles for OAM
  - BFD without IP/UDP headers
  - BFD with IP/UDP headers
- Two configuration methods
  - External/Static configuration
  - Dynamic control plane (GMPLS)

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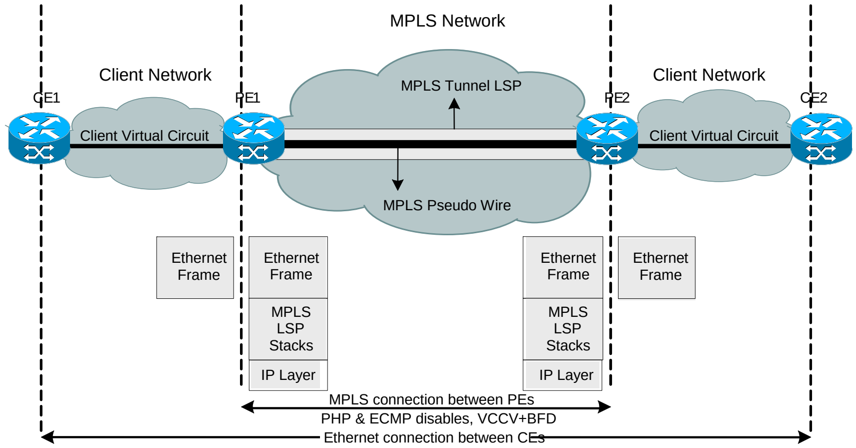
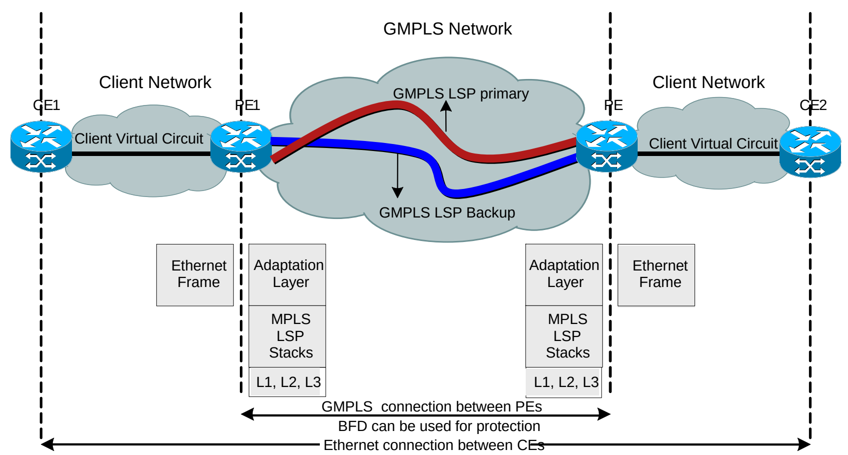
MPLS PW for Transport Networks with VCCV+BFD



draft-bryant-pwe3-mpls-transport

MPLS PW for Transport Networks with GMPLS Signaled Tunnel



Questions Regarding T-MPLS

Is T-MPLS is necessary since existing MPLS PW technology delivers similar capabilities….

Static PW combined with static LSP and VCCV+ BFD

Therefore

Reinventing the wheel ?

- Use the standard already approved
- Use the technology already deployed
- Leverage the knowledge that already exists

Recent IP/MPLS Standards Published by IETF In last 12-14 Months, Few of them..

RFC 4364	BGP/MPLS IP Virtual Private Networks (PS)	Feb-06
RFC 4665	Service Requirements for Layer 2 Provider Provisioned Virtual Private Networks	Sep-06
RFC 4664	Framework for Layer 2 Virtual Private Networks (L2VPNs)	Sep-06
RFC 4684	Constrained Route Distribution for Border Gateway Protocol/Multiprotocol Label Switching (BGP/MPLS) Internet Protocol (IP) Virtual Private Networks (VPNs)	Nov-06
RFC 4659	BGP-MPLS IP Virtual Private Network (VPN) Extension for IPv6 VPN	Sep-06
RFC 4577	OSPF as the Provider/Customer Edge Protocol for BGP/MPLS IP Virtual Private Networks (VPNs)	Jun-06
RFC 4447	Pseudowire Setup and Maintenance using the Label Distribution Protocol (LDP)	Apr-06
RFC 4385	Pseudowire Emulation Edge-to-Edge (PWE3) Control Word for Use over an MPLS PSN	Feb-06
RFC 4197	Requirements for Edge-to-Edge Emulation of Time Division Multiplexed (TDM) Circuits over Packet Switching Networks	Oct-05
RFC 4448	Encapsulation Methods for Transport of Ethernet Over MPLS Networks	Apr-06
RFC 4553	Structure-Agnostic Time Division Multiplexing (TDM) over Packet (SAToP)	Jun-06
RFC 4623	Pseudowire Emulation Edge-to-Edge (PWE3) Fragmentation and Reassembly	Apr-06
RFC 4619	Encapsulation Methods for Transport of Frame Relay Over MPLS Networks	Sep-06
RFC 4618	Encapsulation Methods for Transport of PPP/High-Level Data Link Control (HDLC) over MPLS Networks	Sep-06
RFC 4717	Encapsulation Methods for Transport of Asynchronous Transfer Mode (ATM) over MPLS Networks	Dec-06
RFC 4655	A Path Computation Element (PCE) Based Architecture	Aug-06
RFC 4657	Path Computation Element (PCE) Communication Protocol Generic Requirements	Sep-06
RFC 4674	Requirements for Path Computation Element (PCE) Discovery	Oct-06
RFC 4368	Multiprotocol Label Switching (MPLS) Label-Controlled ATM and Frame-Relay Management Interface Definition	Jan-06

Recent IP/MPLS Standards Published by IETF Continued…2

RFC 4379	Detecting Multi-Protocol Label Switched (MPLS) Data Plane Failures	Feb-06
RFC 4378	A Framework for Multi-Protocol Label Switching (MPLS) Operations and Management (OAM)	Feb-06
RFC 4377	Operations and Management (OAM) Requirements for Multi-Protocol Label Switched (MPLS) Networks	Feb-06
RFC 4420	Encoding of Attributes for Multiprotocol Label Switching (MPLS) Label Switched Path (LSP) Establishment Using Resource ReserVation Protocol-Traffic Engineering (RSVP-TE)	Feb-06
RFC 4461	Signaling Requirements for Point to Multipoint Traffic Engineered MPLS Label Switched Paths (LSPs)	Apr-06
RFC 4561	Definition of a Record Route Object (RRO) Node-Id Sub-Object	Jun-06
RFC 4687	Operations and Management (OAM) Requirements for Point-to-Multipoint MPLS Networks	Sep-06
RFC 4328	Generalized Multi-Protocol Label Switching (GMPLS) Signaling Extensions for G.709 Optical Transport Networks Control	Jan-06
RFC 4327	Link Management Protocol (LMP) Management Information Base (MIB)	Jan-06
RFC 4394	A Transport Network View of the Link Management Protocol (LMP)	Feb-06
RFC 4397	A Lexicography for the Interpretation of Generalized Multiprotocol Label Switching (GMPLS) Terminology within The Context of the ITU-T's Automatically Switched Optical Network (ASON) Architecture	Feb-06
RFC 4426	Generalized Multi-Protocol Label Switching (GMPLS) Recovery Functional Specification	Mar-06
RFC 4427	Recovery (Protection and Restoration) Terminology for Generalized Multi-Protocol Label Switching (GMPLS)	Mar-06
RFC 4428	Analysis of Generalized Multi-Protocol Label Switching (GMPLS)-based Recovery Mechanisms (including Protection and Restoration)	Mar-06
RFC 4558	Node-ID Based Resource Reservation Protocol (RSVP) Hello: A Clarification Statement	Jun-06

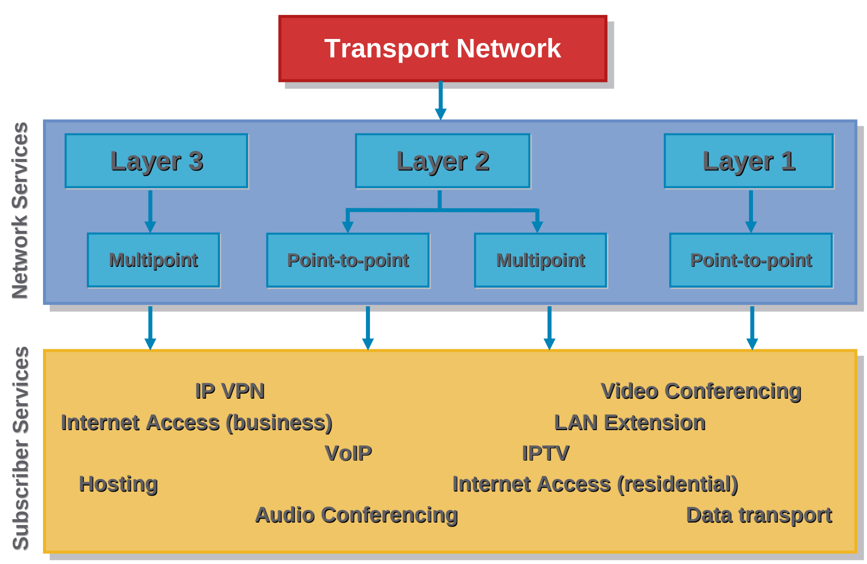
Recent IP/MPLS Standards Published by IETF Continued…3

RFC 4606	Generalized Multi-Protocol Label Switching (GMPLS) Extensions for Synchronous Optical Network (SONET) and Synchronous Digital Hierarchy (SDH) Control	Aug-06
RFC 4631	Link Management Protocol (LMP) Management Information Base (MIB)	Sep-06
RFC 4652	Evaluation of Existing Routing Protocols against Automatic Switched Optical Network (ASON) Routing Requirements	Oct-06
RFC 4736	Reoptimization of Multiprotocol Label Switching (MPLS) Traffic Engineering (TE) Loosely Routed Label Switch Path (LSP)	Nov-06
RFC 4726	A Framework for Inter-Domain Multiprotocol Label Switching Traffic Engineering	Nov-06
RFC 4783	GMPLS - Communication of Alarm Information	Dec-06
RFC 4221	MPLS Management Overview (I)	Nov-05
RFC 4216	MPLS Inter-AS TE Requirements (I)	Nov-05
RFC 4208	GMPLS User-Network Interface (UNI) (PS)	Nov-05
RFC 4206	LSP Hierarchy with GMPLS (PS)	Oct-06
RFC 4201	Link Bundling in MPLS-TE (PS)	Oct-05
RFC 4127	Russian Dolls Bandwidth Constraints Model for DS-TE (Exp)	Jun-05
RFC 4125	Maximum Allocation Bandwidth Constraints Model for DS-TE (Exp)	Jun-05
RFC 4124	Protocol Extensions for Support of DS-TE (PS)	Jun-05
RFC 4105	Requirements for Inter-Area MPLS TE (I)	Jun-05
RFC 4090	Fast Reroute Extensions to RSVP-TE for LSP Tunnels (PS)	Jun-05

Apart from this list, there are many draft standards that were published in this period which will eventually become new standards in coming months.

Service Mapping and Applicability

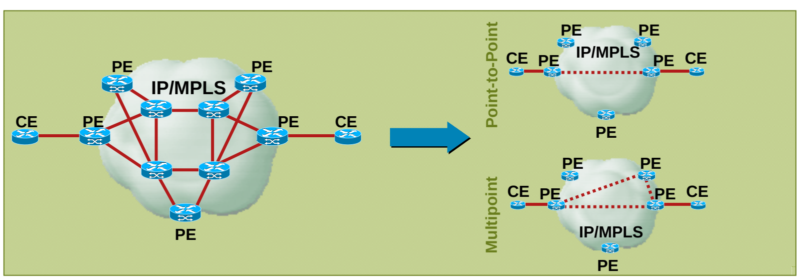
Network Service Portfolio



Building Network Services

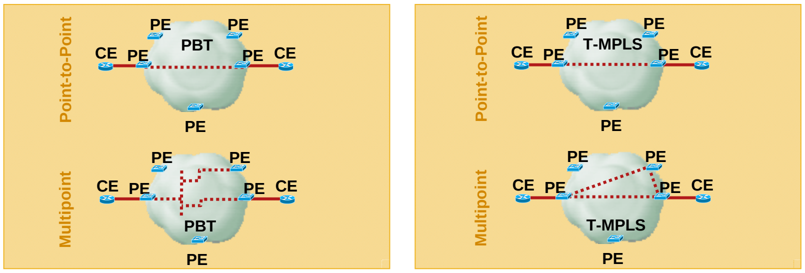
- What are the important services ?
- What are the transport requirements?
  - Point to Point Transport
  - Multipoint Transport
  - Multicast for Video Delivery
  - Legacy Integration & TDM Circuit Emulation

Ethernet Transport over MPLS Transport



- Ethernet pseudowire for point-to-point services
- VPLS for multipoint services
- Leverages protection, traffic engineering, QoS and OAM capabilities of MPLS
- Mature specifications
- Deployment experience

Ethernet over Other Packet Transport



- No native support for multipoint services
- PBT requires PBB for multipoint services
- No/partial standardization
- No support for layer-1 and other layer-2 technologies

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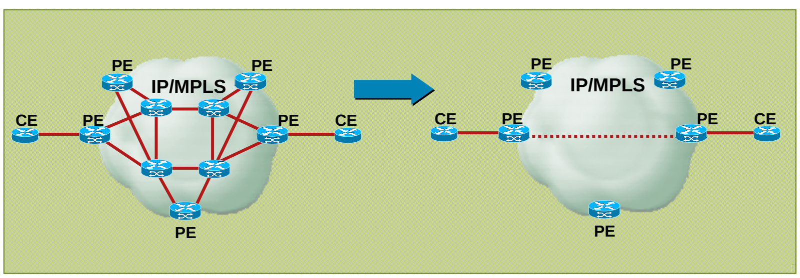
Other Layer-2 Service over MPLS Transport



- Mature specifications to transport Frame Relay, ATM, PPP/HDLC
- Leverages protection, traffic engineering, QoS and OAM capabilities of MPLS
- Deployment experience

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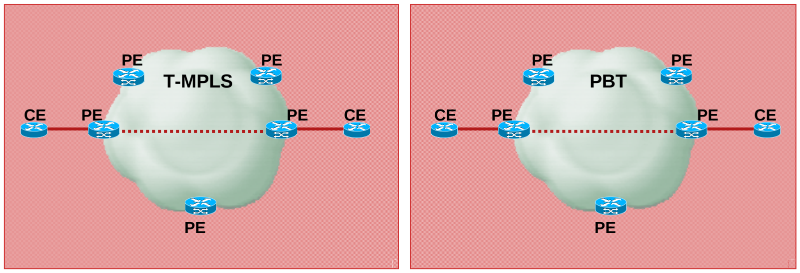
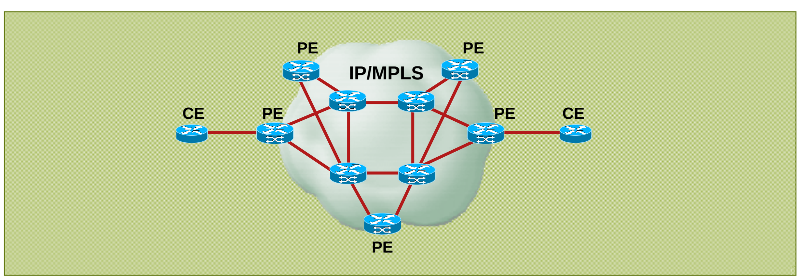
Other Layer-2 Service over Other Packet Transport



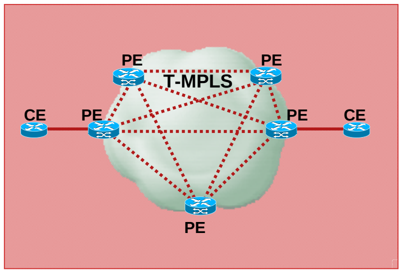
- Neither T-MPLS nor PBT are multiservice
- MPLS still required to transport ATM, FR, PPP, etc.
- Edge devices need interface and MPLS pseudowire support for other layer-2 services

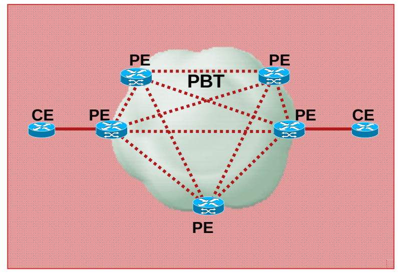
Unicast Layer-3 Service over MPLS Transport



- Optimal bandwidth use (shortest path, constraint-based routing, load balancing)
- High resiliency using MPLS TE FRR or IGP fast convergence
- Lower operational complexity on PE device
- Leverages time-proven IP scalability
- Ethernet may still be used as access technology and data-link encapsulation

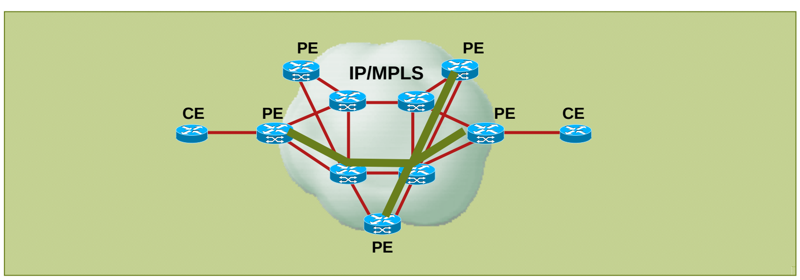
Unicast Layer-3 Service over Other Packet Transport





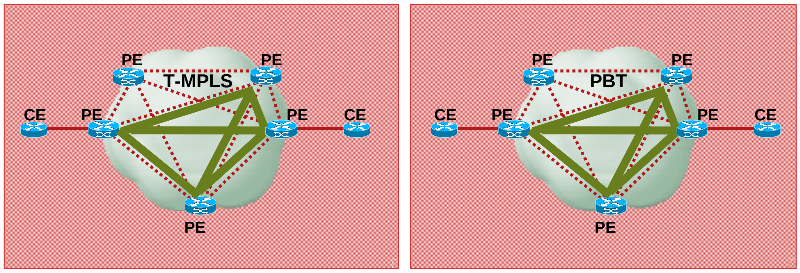
- Operational complexity in full mesh configuration (planning, management)
- Sub-optimal bandwidth use (load balancing, shortest path)
- Limited scalability (IGP adjacencies on PEs)
- Resembles challenges with IP over ATM in 90s

Multicast Layer-3 Service over MPLS Transport



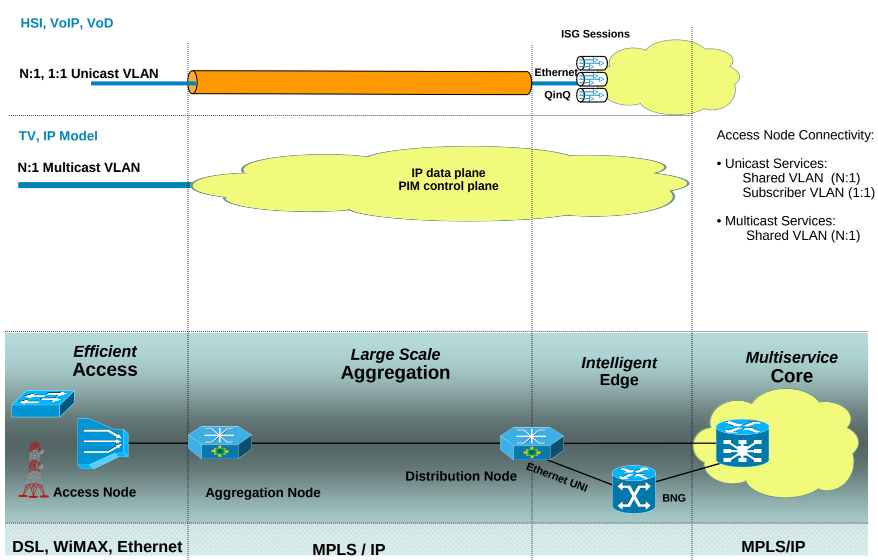
- Point-to-multipoint (mLDP/RSVP-TE) and multipoint-to-multipoint (mLDP)
- Scalable (distributed) packet replication
- Optimal bandwidth use (constraint-based routing, shortest path, load balancing)
- High resiliency using MPLS TE FRR or IGP fast convergence
- Support for receiver or sender initiated trees

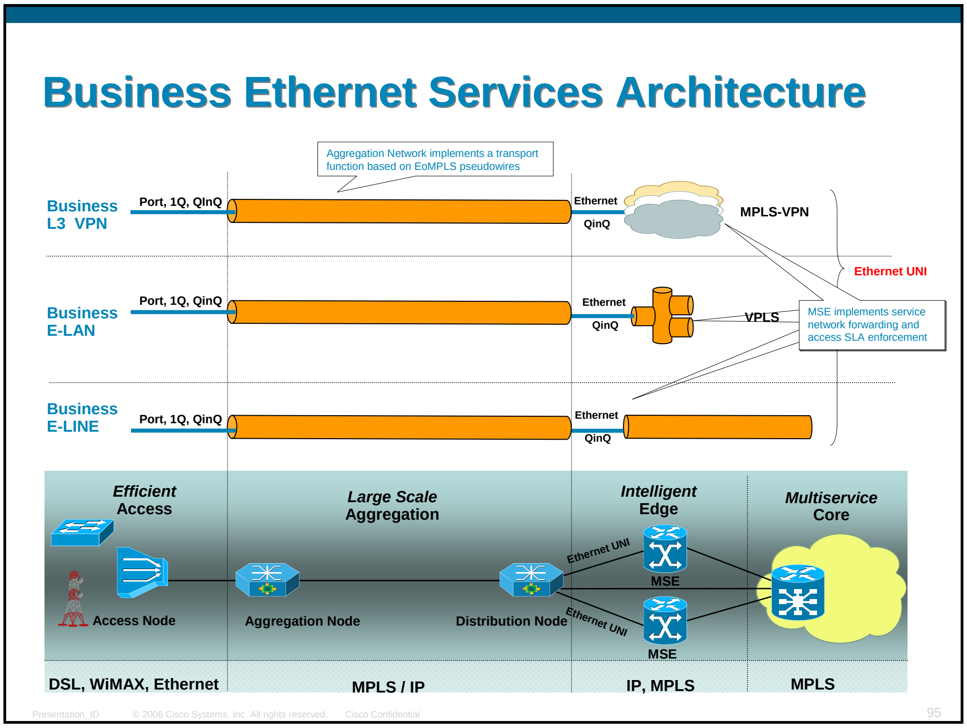
Multicast Layer-3 Service over Other Packet Transport



- Limited scalability (PE packet replication)
- Suboptimal bandwidth use (premature replication)
- Increased join/leave latency

Retail Residential Services Architecture




Business Ethernet Services Architecture
Aggregation Network implements a transport function based on EoMPLS pseudowires
Business L3 VPN
Port, 1Q, QinQ
Ethernet
QinQ
MPLS-VPN
Ethernet UNI
Business E-LAN
Port, 1Q, QinQ
Ethernet
QinQ
VPLS
MSE implements service network forwarding and access SLA enforcement
Business E-LINE
Port, 1Q, QinQ
Ethernet
QinQ
Efficient Access
Large Scale Aggregation
Intelligent Edge
Multiservice Core
Ethernet UNI
MSE
Ethernet UNI
MSE
Access Node
Aggregation Node
Distribution Node
DSL, WiMAX, Ethernet
MPLS / IP
IP, MPLS
MPLS
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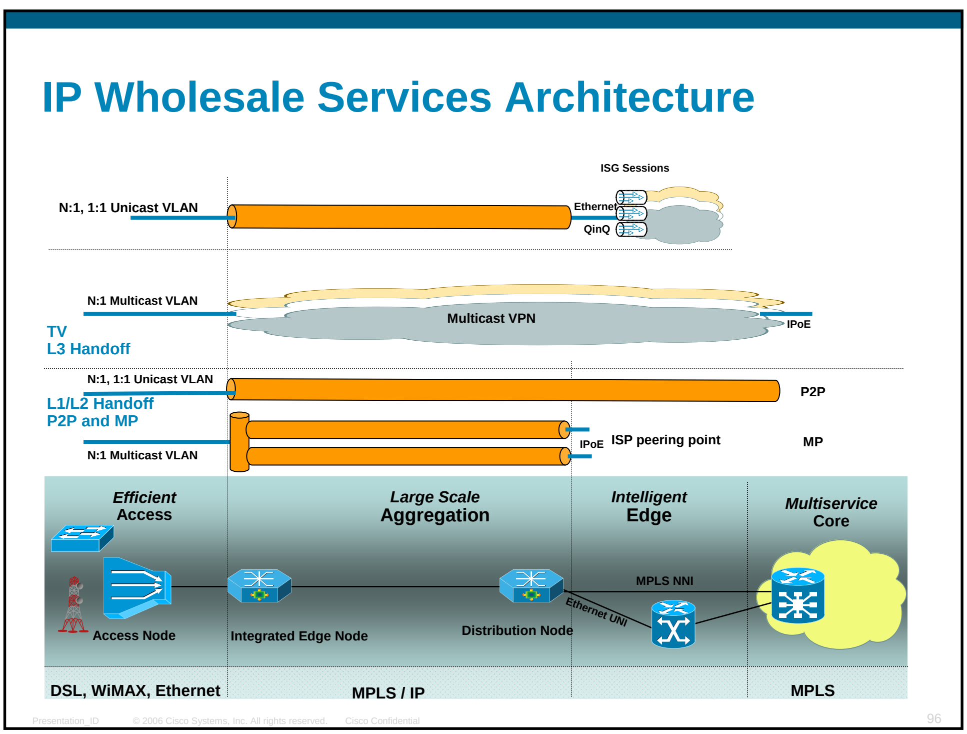
IP Wholesale Services Architecture
ISG Sessions
N:1, 1:1 Unicast VLAN
Ethernet
QinQ
N:1 Multicast VLAN
Multicast VPN
IPoE
TV L3 Handoff
N:1, 1:1 Unicast VLAN
P2P
L1/L2 Handoff P2P and MP
IPoE
ISP peering point
MP
N:1 Multicast VLAN
Efficient Access
Large Scale Aggregation
Intelligent Edge
Multiservice Core
MPLS NNI
Ethernet UNI
Access Node
Integrated Edge Node
Distribution Node
DSL, WiMAX, Ethernet
MPLS / IP
MPLS
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Multi-vendor Interoperability

- Multi-Vendor Interoperability is key to ensure
  - No Proprietary Implementation is Deployed
  - No vendor Lock-in
  - Investment protection
- Crucial to test Multi-vendor interoperability for critical services/requirements of the network to ensure right selection of technology
  - Traffic protection
  - Services : Point-to-Point, Multipoint-to-Multipoint, Multicast
  - Legacy Integration (e.g. ATM Transport)
  - Quality of Service
  - OAM

Some Historical Background of Layer 3 vs. Layer 2

- In past 10 years, there have been at least 2 major attempts to "revolutionize" networking by introducing a Layer 2 approach with arguments that Layer 3 is either unnecessary, more complex and more expensive –
  - End-to-End Pure Layer 2 Switching
  - ATM LAN Emulation
- Both failed Miserably with time!
- IP/MPLS is revolutionary in a way since it unites the benefits of both Layer 2 and Layer 3 together!

Is a Layer 2 Based Solution Cheaper than a Layer 3 Based Solution ?

Some considerations:

- Cost of overlay networks required for legacy integration
- Cost of network management system
- Cost of overlay network/intelligence required for supporting Multicast and Video
- Cost of manual provisioning & management since network doesn't have intelligent control plane
- Cost of adding Intelligence (GMPLS) to the solution that has no control plane
- Cost of important features on network elements like Hierarchical-QoS (H-QoS), ISSU etc

Summary

Summary

Key Points to Consider Before Selecting Technology for Building your Next Generation Ethernet Network

- Technology State, Standardization, Maturity, Field Proven, Future Roadmap
- Network Intelligence: Integrated Control Plane or Proprietary NMS Control Plane
- Is Selected Technology agnostic of transport protocols so that it allows you to migrate smoothly
- Are All Required Services can be offered by the Technology or basic services itself requires workarounds.
- Is technology Multi-Vendor Interoperable
- Last but not the least, its combined capital & operational cost

