Deploy Packet Transport with MPLS-Transport Profile

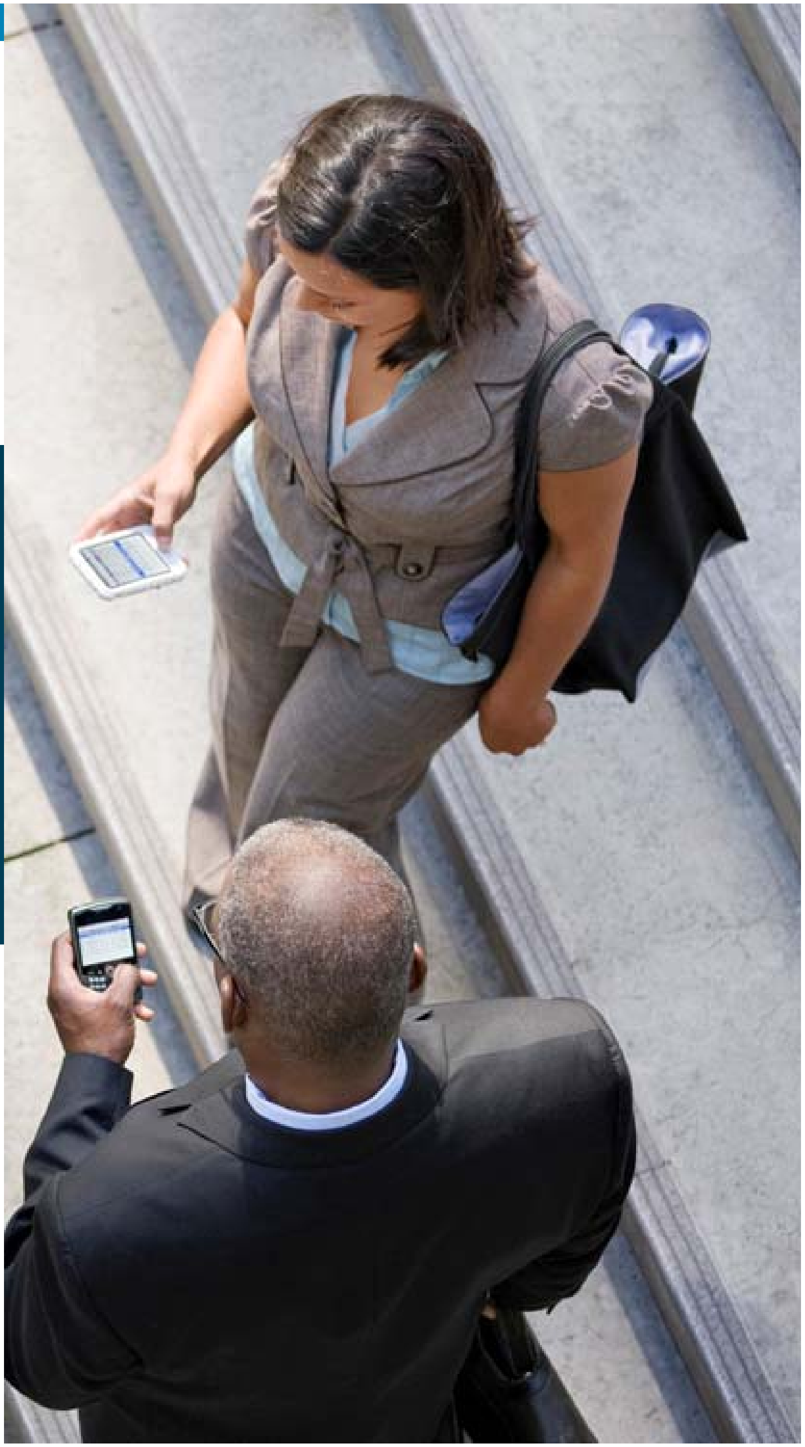
Randy Zhang

Cisco Systems Advanced Services

Agenda

- Transport Network Transformation
- Why MPLS TP?
- MPLS TP Technical Overview
- Deployment Scenarios
- MPLS TP Deployment Lifecycle

Transport Network Transformation



What is Transport Network?

A network to provide a reliable aggregation and transport infrastructure for any client traffic type

Oh um, please do it at the lowest cost per bit…

Specifically

Multi-service

Cost effective

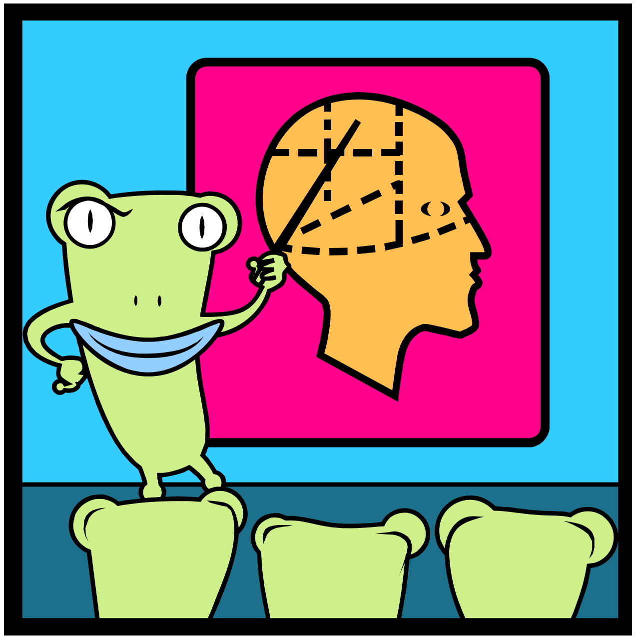
Quality of service

Scalable

Transport Network

Where Have We Been?

- Looking back in our memory for the past several decades on network events that affected the transport network



Networks in the 1980s

- 1981: first IBM PC
- 1983: Novell, ISO OSI model, ARPANET runs on TCP/IP
- 1984: IBM PC AT system, Cisco Systems
- 1985: Standardization of Ethernet 10Base2, Sun Micro NFS, IBM Token Ring
- 1987: Standardization of SONET, 10BaseT
- 1988: ATM cell format standardized

Top shows on TV were Dallas and The Cosby Show

Networks in the 1990s

- 1991: LAN switches
- 1992: Public frame relay service,100 Mbps Ethernet, Windows 3.1
- 1994: GPS
- 1995: Cable modem, VOIP software
- 1997: Standardization of full duplex Ethernet
- 1998: Standardization of Gigabit Ethernet

Top shows on TV were Seinfeld, ER

Transport Network Layers: 1980s – 1990s

Optimized for voice and TDM traffic

IP, Ethernet, ATM, Frame Relay

SONET/SDH, DSx

Important Network Issues around 2000

- TDM was the primary transport
- Business dominated bandwidth
- Client-server was the computing model
- Internet-based voice applications began to be widespread

Significant Developments 2000 - Today

- 2001: standardization of G.709
- 2002: standardization of 10 GigE
- 2009: standardization of MPLS TP
- 2010: standardization of 40 GigE and 100 GigE, OTU4

Transport Network Layers: 2000s

Retrofitting for Data

IP, Ethernet

SONET/SDH, DWDM, OTN

Important Network Issues around 2012

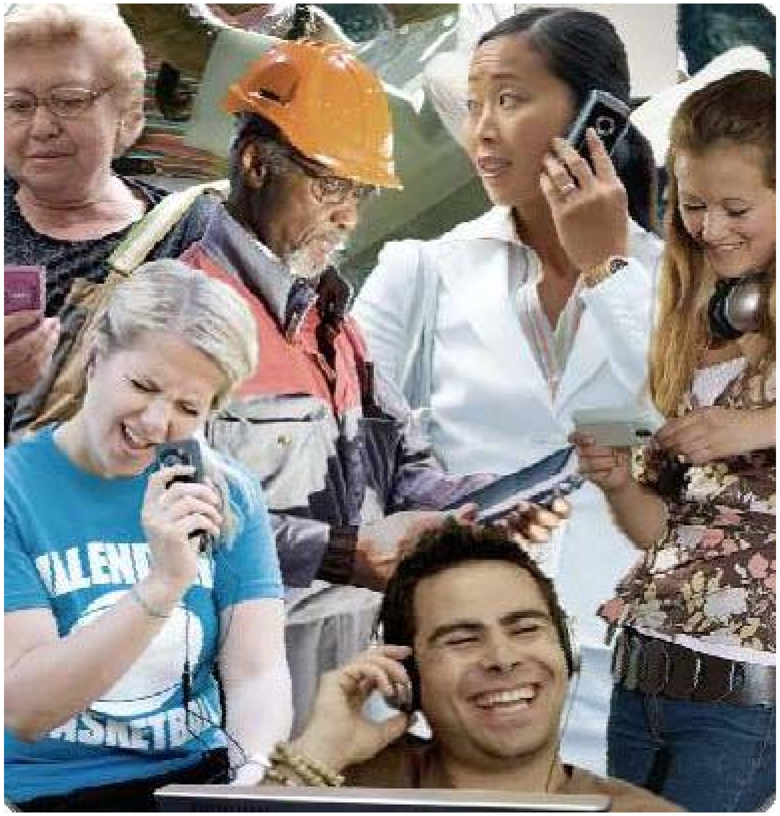
- TDM transitioning to Ethernet
- Consumer dominating bandwidth use
- Peer-to-peer computing and cloud computing as the new models
- Internet-based video applications putting demand on bandwidth

The Explosion of Bandwidth Demand

The world of Warcraft players

Cloud computing

4G mobile and wireless users

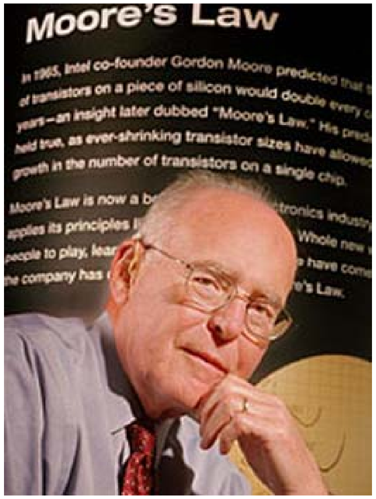


Business video

HDTV

Music and video download

Bandwidth Availability



- Moore's Law: Computing power doubles every 18 months

- Nielsen's Law: Bandwidth growth for home users doubles every 21 months

User experience remains bandwidth-bound

Why Traditional Transport Is Limited?

- Primary traffic type is now bursty data
- SONET/SDH is capped at OC-768 (40 Gbps)
- Traditional network is based on TDM
- TDM is expensive to operate
- Co-existing of multiple transport networks are costly

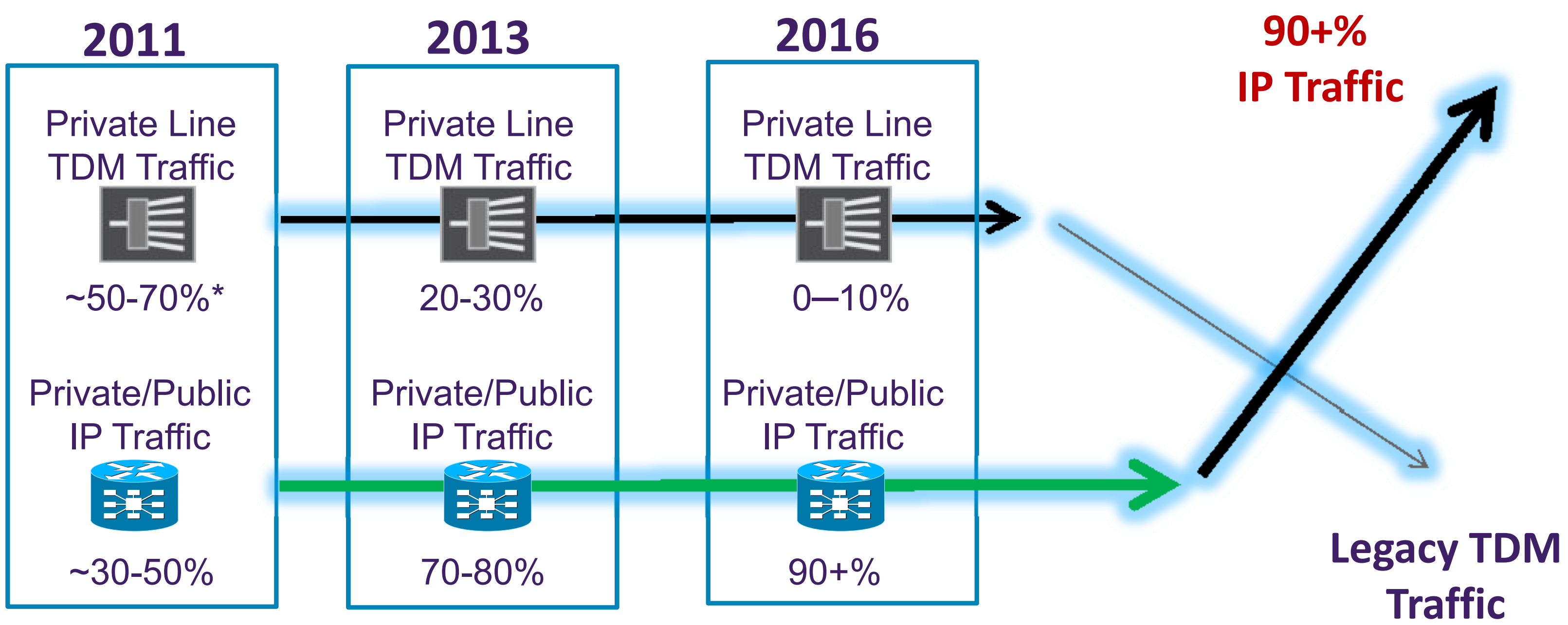
Entering the Zettabyte Era

0.2 EB to 1.2 EB per Month
6x Increase from '10 to '15

1 Exabyte = 10^9 Gigabyte
1 Zettabyte = 1000 Exabyte

Source: Cisco Visual Networking Index (VNI) Global IP Traffic Forecast, 2010–2015

Circuit to Packet Migration



- Dramatic shift in SP traffic make-up in next 5 years
- Network evolving
  - Transformation: TDM to Packet
  - Convergence: Collapse Layers; IP + Optical Convergence
- SP revenue shifting from circuits to packet services

  5 yrs → ~80% revenue derived from packet services

Source: ACG Research 2011

Summary of Transport Transformation Drivers

- Explosion of data traffic
- Convergence of multiple networks into a single transport network
- Reducing CAPEX and OPEX
- Provisioning agility and flexibility

Next Generation Transport

- Packet will be the primary traffic type
- Solutions to support packet will depend on cost
- MPLS-TP will be the predominant core transport technology
- 10/40/100 G DWDM and 10/40/100 G Ethernet on the core
- Circuit services will co-exist with packet services

Packet Optical Transport Components

- OTN: a foundation technology for any service over WDM
- Ethernet: a ubiquitous Layer 2 technology
- MPLS-TP: an emerging MPLS technology that provides carrier grade transport
- MPLS Pseudowire: A circuit emulation technology based on MPLS

Enabling Technologies

SONET/SDH
- Carrier class
- OAM&P
- QoS

Ethernet
- Lower cost
- Designed for data

The new optical packet transport network

MPLS
- Virtual circuit
- Widely deployed

OTN
- CWDM and DWDM
- G.709

A Converged Network

- A single transport network based on WDM
- OTN provides the digital wrapper
- MPLS Transport Profile (TP) provides SONET like services
- Ethernet technologies provide lower cost in CAPEX and OPEX
- Traditional TDM services and packet based services carried over a single transport network

Why MPLS TP?

Motivation for MPLS TP

- Evolution of SONET/SDH transport networks to packet switching driven by
  - Growth in packet-based services (L2/L3 VPN, IPTV, VoIP, etc)
  - Desire for bandwidth/QoS flexibility
- New packet transport networks need to retain same operational model
- MPLS TP, defined jointly between IETF and ITU-T, provides the next step

Ethernet or MPLS Transport?

- Ethernet

  Lack of scalability, traffic engineering, fast protection, circuit service support

- MPLS

  Well accepted by carrier as core IP/MPLS network

  More mature carrier-oriented packet technology.

Transport Network Characteristics

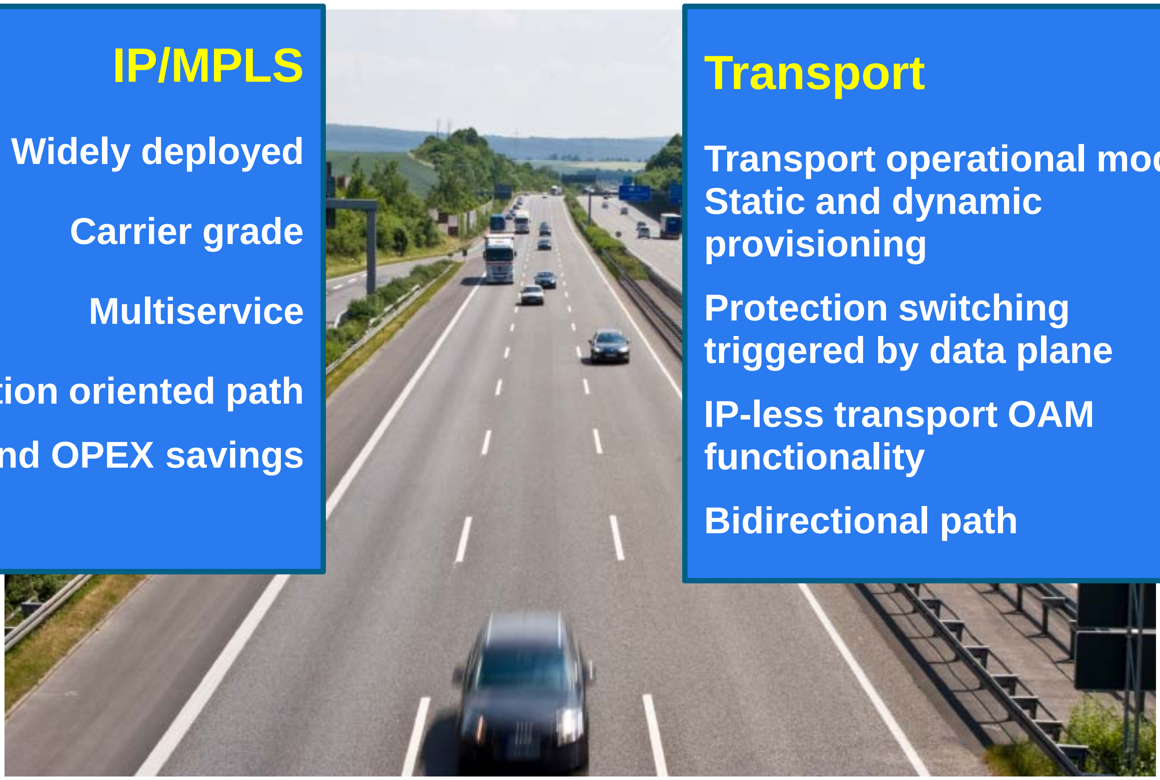
- Predetermined and long-lived connections
- Emphasis on manageability and deterministic behavior
- Fast fault detection and recovery (sub-50 ms)
- In-band OAM

MPLS Network Characteristics

- Dynamically routed label switched paths
- Traffic statistically multiplexed
- Data plane setup and torn down based on dynamic control plane
- Optimized for a packet network

Converging MPLS and Transport

MPLS Transport Profile



IP/MPLS

- Widely deployed
- Carrier grade
- Multiservice
- Connection oriented path
- CAPEX and OPEX savings

Transport

- Transport operational model
- Static and dynamic provisioning
- Protection switching triggered by data plane
- IP-less transport OAM functionality
- Bidirectional path

Objectives of MPLS-TP

- To enable MPLS to be deployed in a transport network and operated in a similar manner to existing transport technologies (SDH/SONET/OTN)
- To enable MPLS to support packet transport services with a similar degree of predictability, reliability, and OAM to that found in existing transport networks

MPLS TP is a subset of MPLS to meet transport network operational requirements plus additional functionality based on transport requirements

What is MPLS-TP?

- MPLS is bi-directional LSPs
- MPLS-TP
  - No LSP merging
  - No ECMP (Equal-cost multi-path routing)
  - Does not support connectionless mode
  - Simple in scope, less complex in operation
- OAM/Data Fate sharing with congruent paths
  - Traffic and OAM must be congruent, achieved by MPLS-TP GAL, and generic ACH to carry OAM packets and enable processing at intermediate nodes when required.

Summary of MPLS TP Characteristics

- Connection-oriented packet switching model
- No modifications to existing MPLS data plane
- IP or IP routing is not required for packet forwarding
- Interoperates/interworks with existing MPLS and pseudowire control and data planes

Summary of MPLS TP Characteristics

- Networks can be created and maintained using static provisioning (management plane) or a dynamic control plane
- In-band OAM (congruent)
- Protection options: 1:1, 1+1 and 1:N
- Network operation similar to existing transport networks

MPLS-TP: Transport like OAM

- In-band OAM channels
- Performance monitoring for SLA verification
- Sub-path monitoring with multi-level operation
- Alarms and AIS

MPLS-TP: Transport like Operation

- Data plane / control plane independent
- Transport path fully operational without control plane
- Traffic engineered path control

MPLS-TP: Transport like Protection

- Protection switching triggered by OAM
- Linear protection
- Ring protection
- 50 ms switchover

MPLS-TP Summary

Data Plane

MPLS Bidirectional P2P and P2MP LSPs

- No LSP merging
- PHP optional

GACh: Generic Associate Channel

GAL: Generic Associate Label

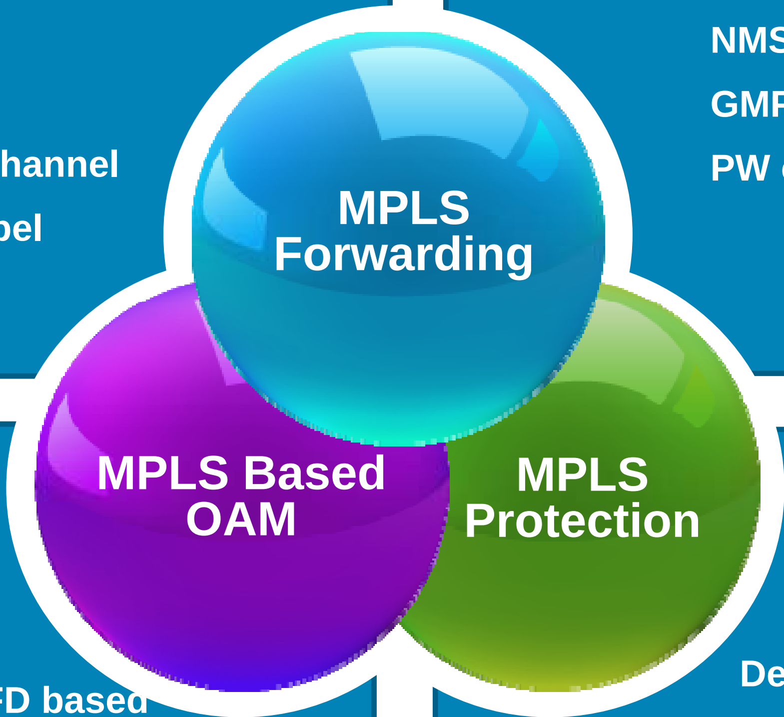
PW (SS-PW, MS-PW)

Control/Management Plane

NMS provisioning option

GMPLS control plane option

PW control plane option



OAM

In-band OAM

Fault management:

- Proactive CC/CV: BFD based
- Ping and trace: LSP ping based
- Alarm Suppression and Fault Indication
  - AIS, RDI, LDI, and CFI

Performance monitoring: Loss and Delay

Resiliency

Deterministic path protection

Sub-50ms switch over

- 1:1, 1+1, 1:N protection
- Linear protection
- Ring protection

MPLS-TP Standards

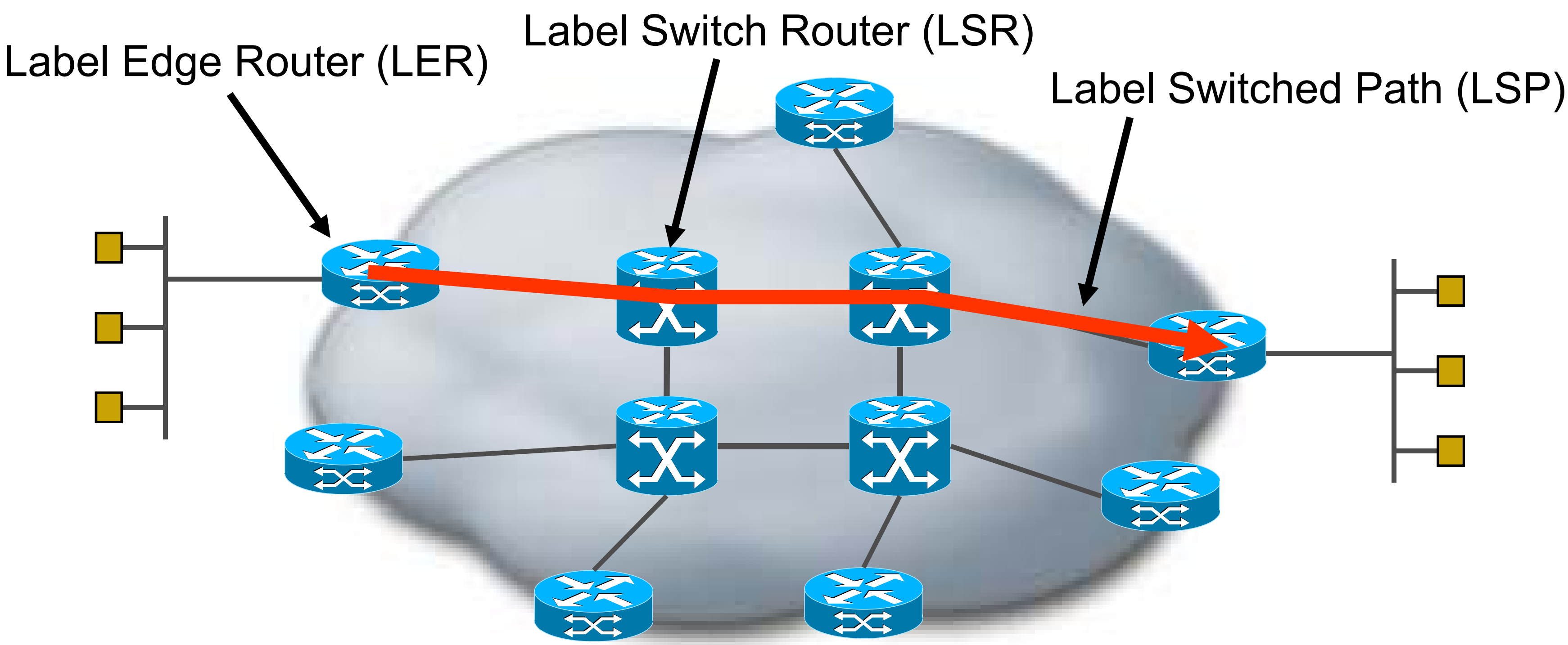
- RFC 6423: Using the Generic Associated Channel Label for Pseudowire in the MPLS Transport Profile (MPLS-TP)
- RFC 5654: Requirements of an MPLS Transport Profile
- RFC 5718: An In-Band Data Communication Network For the MPLS Transport Profile
- RFC 5860: Requirements for Operations, Administration, and Maintenance (OAM) in MPLS Transport Networks
- RFC 5951: Network Management Requirements for MPLS-based Transport Networks
- RFC 5960: MPLS Transport Profile Data Plane Architecture

MPLS-TP Standards

- RFC 6370: MPLS Transport Profile (MPLS-TP) Identifiers
- RFC 6426: MPLS On-Demand Connectivity Verification and Route Tracing
- RFC 6378: MPLS Transport Profile (MPLS-TP) Linear Protection
- RFC 6427: MPLS Fault Management Operations, Administration, and Maintenance (OAM)
- RFC 6428; Proactive Connectivity Verification, Continuity Check, and Remote Defect Indication for the MPLS Transport Profile
- RFC 6435: MPLS Transport Profile Lock Instruct and Loopback Functions

MPLS Transport Profile (TP) Technical Overview

MPLS Terminology Overview



- LSP defines the path through LSRs from ingress to egress LER
  - A collection of label pushes, swaps and Pops
  - Can be defined in many different ways : statically, dynamically through LDP, BGP, RSVP

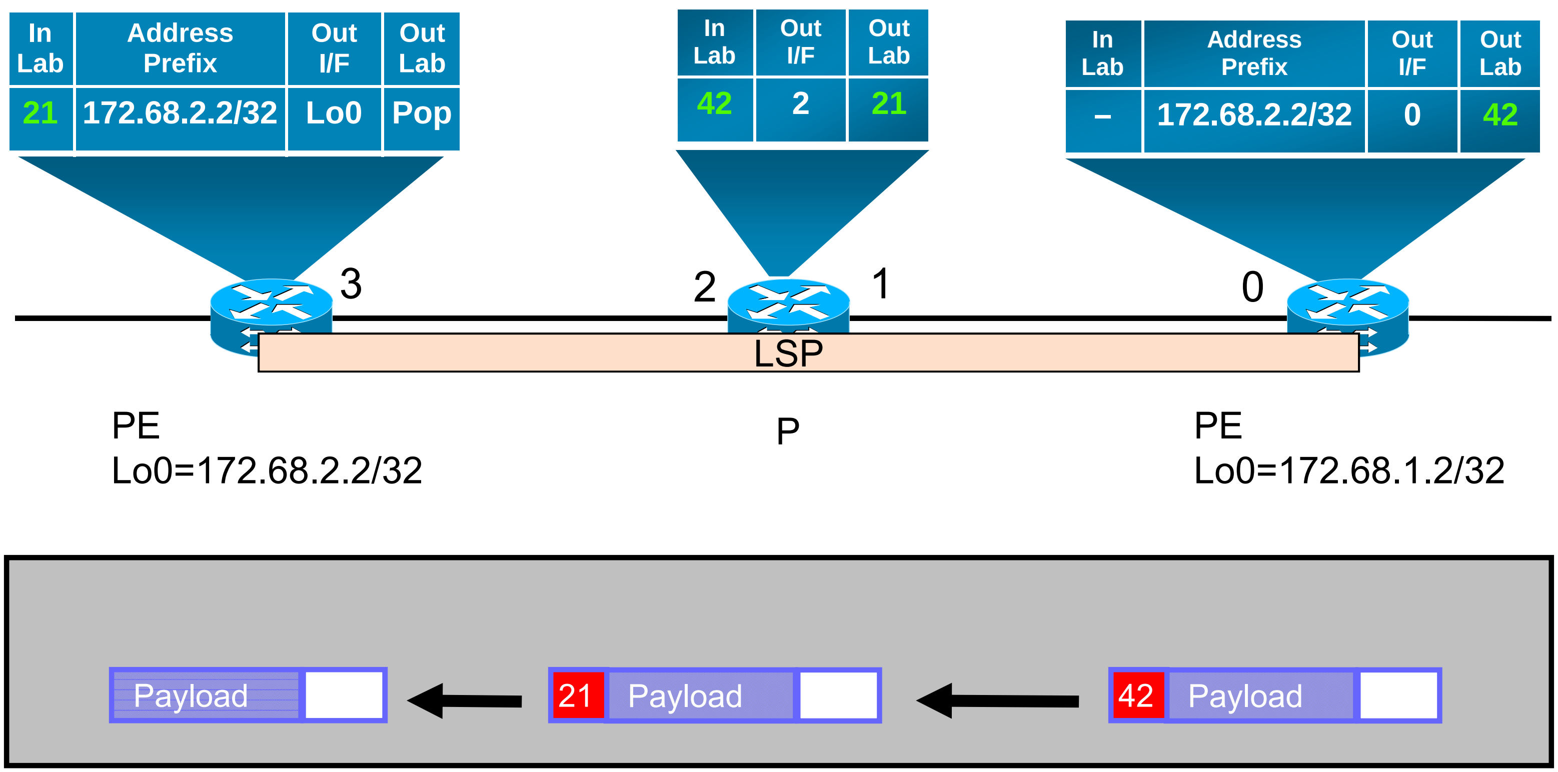
MPLS Label

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------------------------------+-----+-+---------------+
|                 Label                 | EXP |S|      TTL      |
+---------------------------------------+-----+-+---------------+
```

Label = 20 bits
EXP = Experimental bits or traffic class (TC), 3 bits
S = Bottom of Stack, 1 bit
TTL = Time to Live, 8 bits

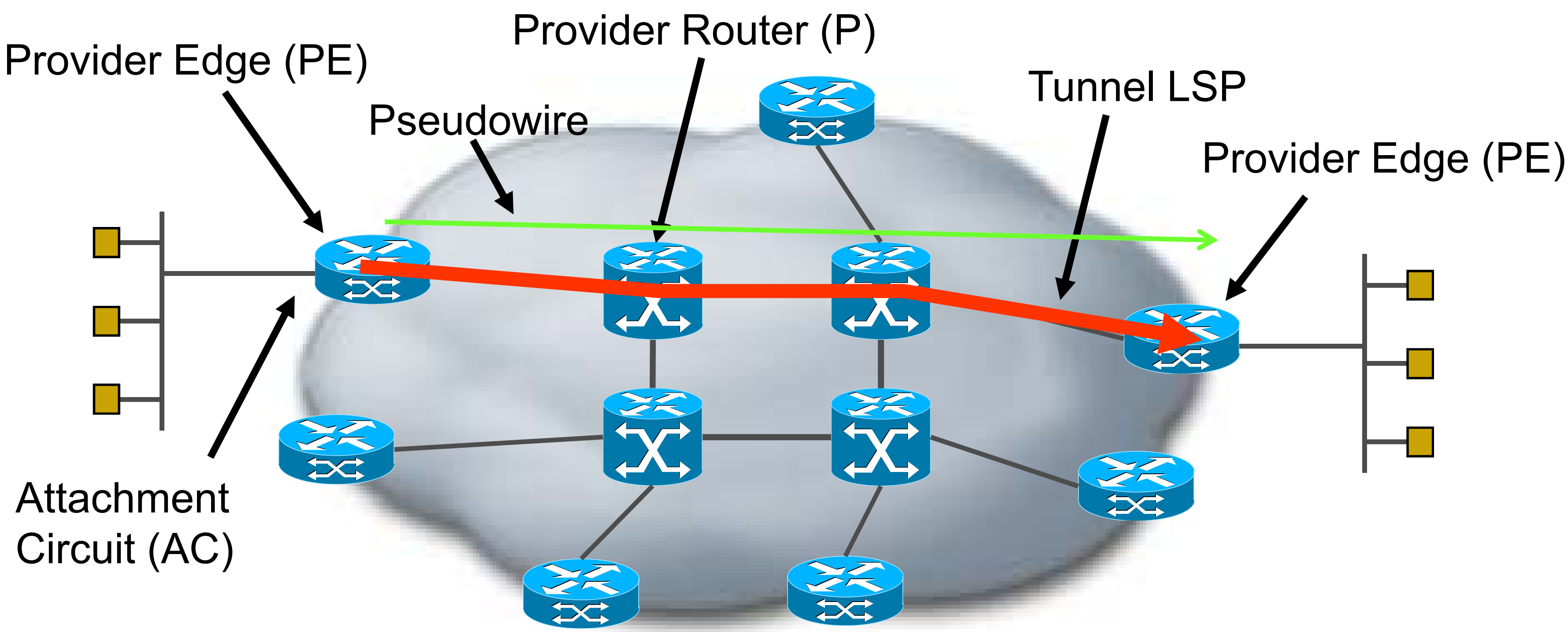
- It can be used over a variety of L2 encapsulations.
- Labels can be stacked

LSP Example



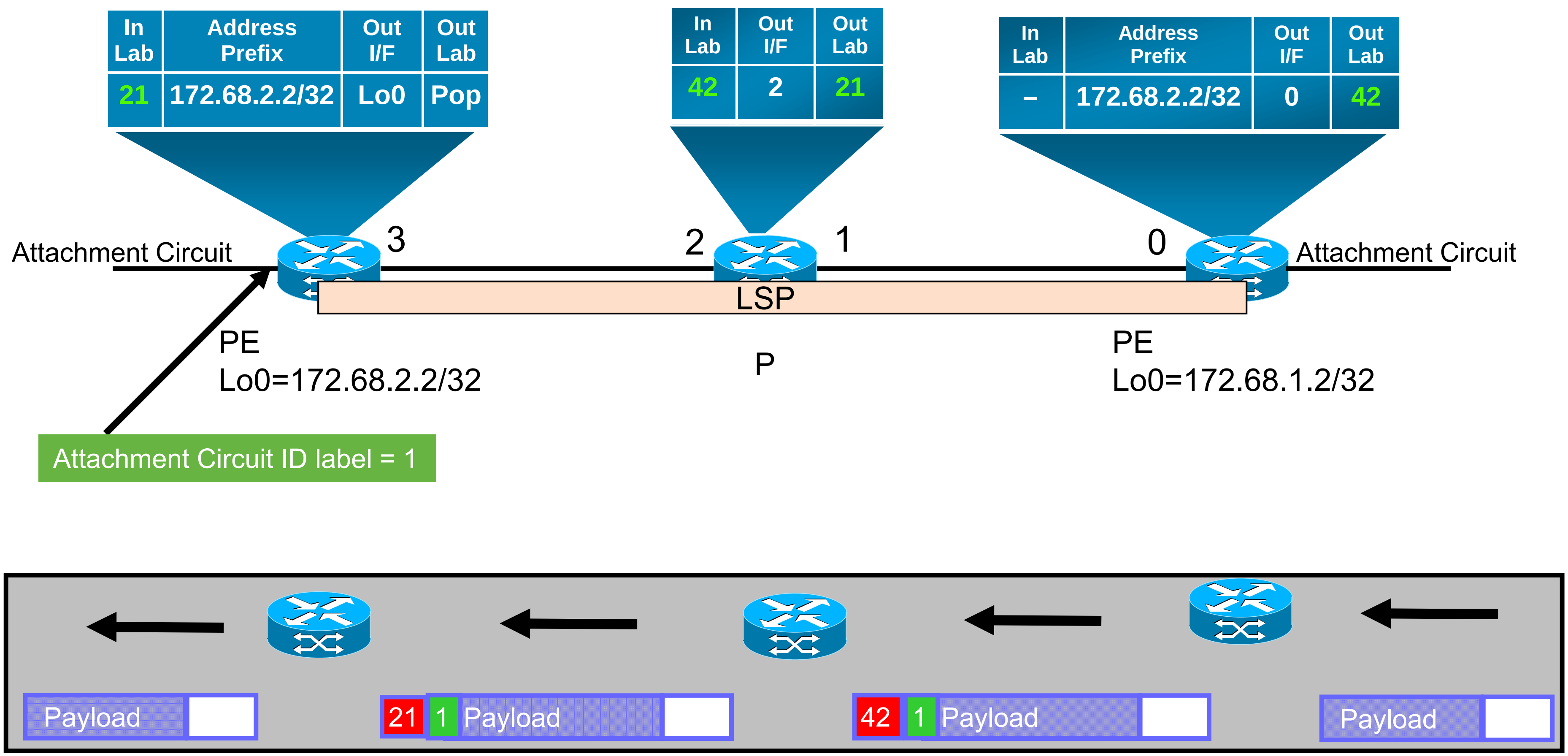
In Lab
Address Prefix
Out I/F
Out Lab
21
172.68.2.2/32
Lo0
Pop
In Lab
Out I/F
Out Lab
42
2
21
In Lab
Address Prefix
Out I/F
Out Lab
–
172.68.2.2/32
0
42
3
2
1
0
LSP
PE
Lo0=172.68.2.2/32
P
PE
Lo0=172.68.1.2/32
Payload
21
Payload
42
Payload

MPLS Pseudowire Terminology Overview

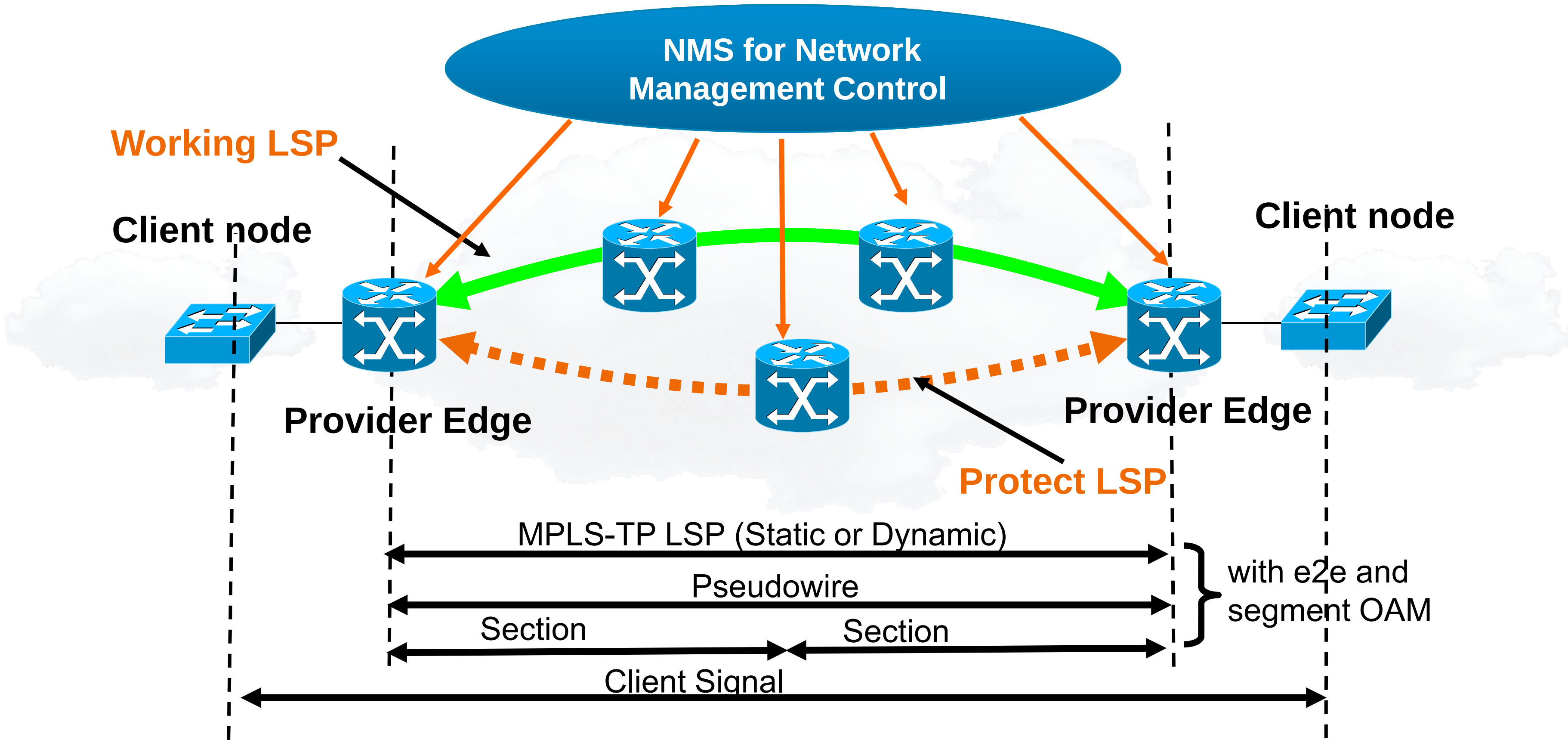


- Pseudowire used to provide a service over MPLS
- Two levels of label stacking
  - Tunnel LSP: identifying the path from PE to PE
  - Pseudowire: identifying the pseudowire services

Pseudowire Example



MPLS TP Architecture



Connection Oriented, pre-determined working path and protect path
Transport Tunnel 1:1 protection, switching triggered by in-band OAM

The Three Planes for MPLS

- Control plane
  - Routing and Signaling: label distribution and LSP setup
  - Traffic Engineering: constrain based path computation, fast reroute
- Forwarding plane
  - Also called data plane: push, pop, swap
  - Responsible for actual data packet forwarding
- Management plane
  - Configuration, provisioning, maintenance

MPLS TP Planes

- Data plane is based on MPLS label forwarding
  - Push: adding an outgoing label
  - Pop: remove an incoming label
  - Swap: replace the incoming label with an outgoing label
- Data plane bandwidth must be enforced with QoS
- Control plane is not required, with GMPLS optional
- Interoperates/interworks with existing MPLS and pseudowire control and data planes
- Labeled switched path (LSP) may be setup via the management plan

Management Plane for MPLS TP

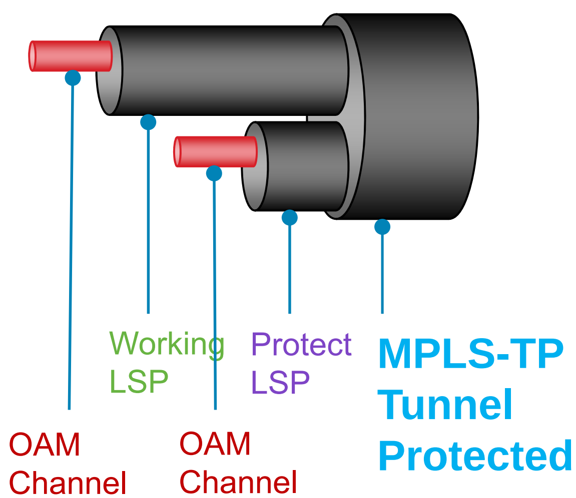
- NMS plays a central role in a transport network space
- DCN provides the critical management infrastructure
- Circuit provisioning and maintenance
  - Create and manage a LSP or PW across a network
  - LSP establishment
  - LSP maintenance
- Fault, PM reporting

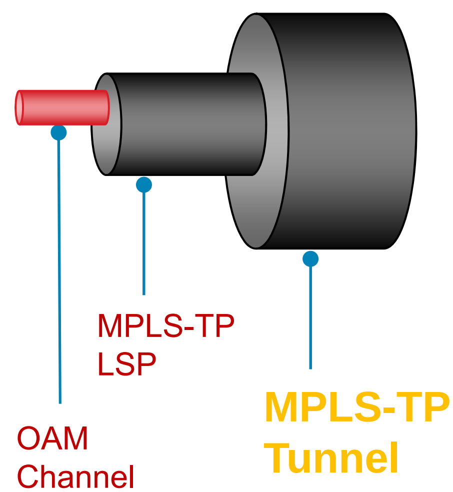
MPLS TP Control Plane

- A control plane is defined but not mandatory
- GMPLS is an optional control plane for MPLS that can dynamically set up LSPs in a transport network
- An end to end control plane is also supported
- Management and control planes may co-exist in the same MPLS TP domain

MPLS TP LSP Characteristics

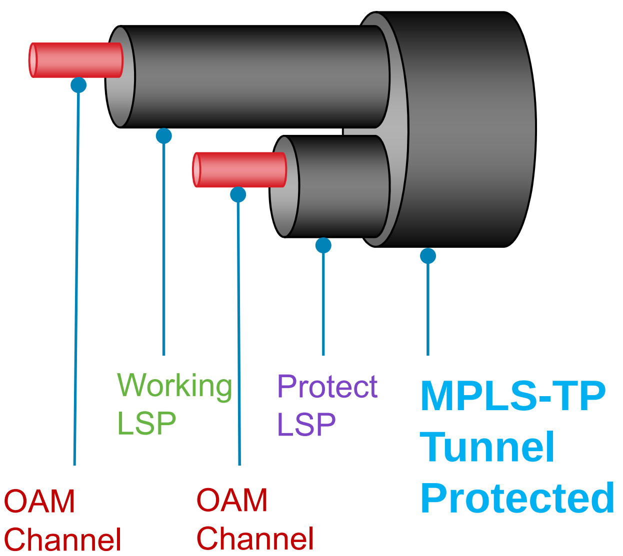
- LSP is always bidirectional
- An LSP is contained within a tunnel
- Tunnel can be protected or unprotected
- In-band OAM on each LSP





OAM

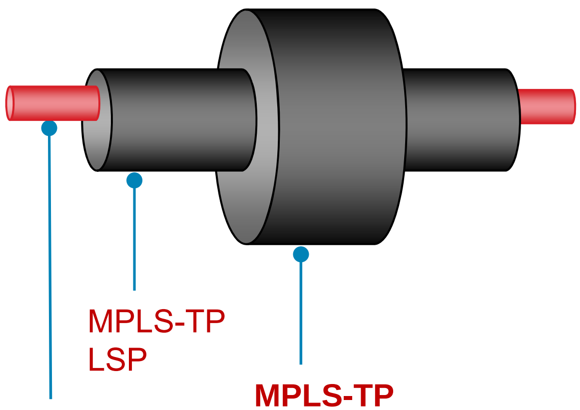
- OAM packets co-routed with data packets (in-band) to detect data plane faults
- OAM available at LSP and PW levels



Tunnel End Point

- Tunnel holds a working LSP and optionally a protect LSP
  - Working
  - Protect (optional)
- Tunnel may be configured with a bandwidth allocation
- Tunnel operationally up if at least one LSP operationally UP (and not locked out)
- LSP operationally up if OAM (Continuity Check) session operationally up

Tunnel Mid-Point



LSP Direction	Input Label	Output Label	Output Interface
Forward	323111	334111	Gi2/1
Reverse	343111	111	Gi2/4

- LSP defined using LSP ID
- Semantics of source/destination only locally significant
- Configuration of forward (from tunnel source) and reverse (from tunnel destination) LSP directions
- Configuration of label swapping (input label, output label and output interface)

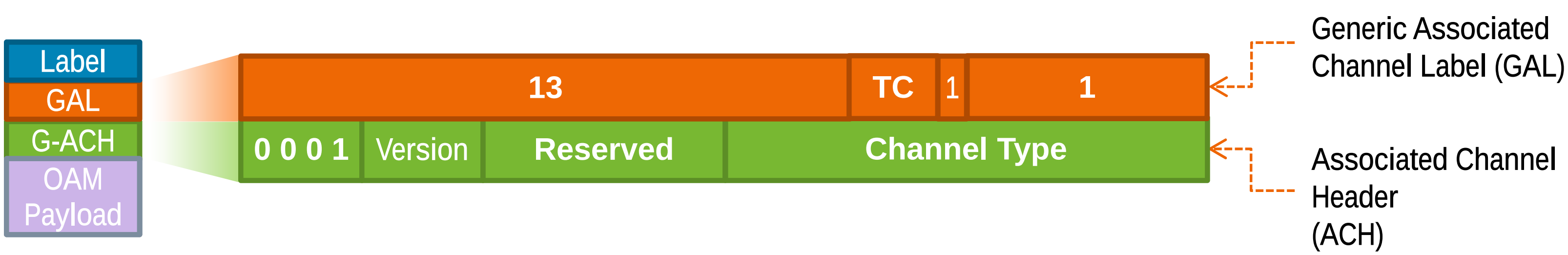
OAM Channel

- MPLS TP OAM channel is called MPLS Generic Associated Channel, or GACh
- GACh is identified by its header
- The type of channel is identified by Channel Type

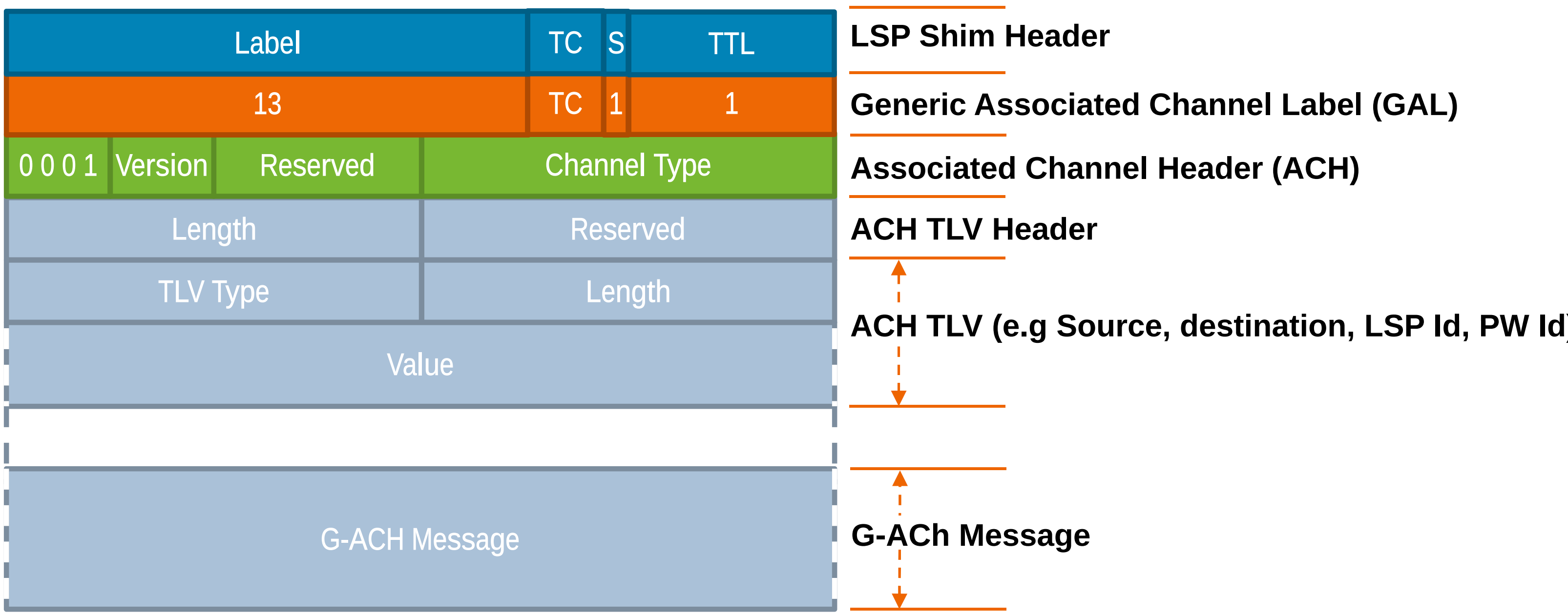
0 0 0 1	Version	Reserved	Channel Type

GACh for MPLS TP LSP

- A well-known label is assigned for GACh (13)
- A GACh Label (GAL) acts as an exception mechanism to identify OAM packets



G-ACh Packet Structure for an MPLS-TP LSP

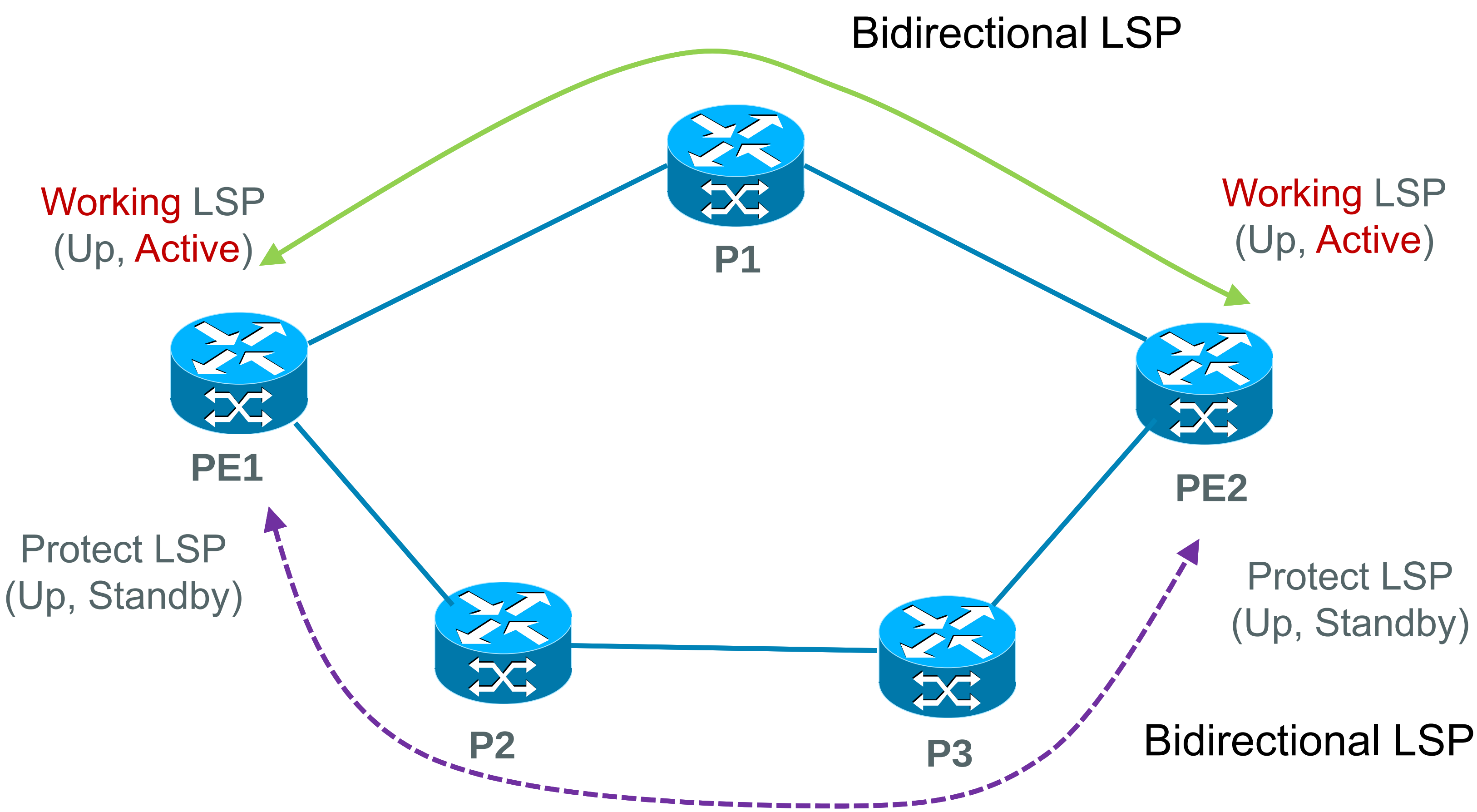


- GAL as bottom of label stack
- GAL only processed if LSP label popped or LSP TTL expires
- Same ACH structure

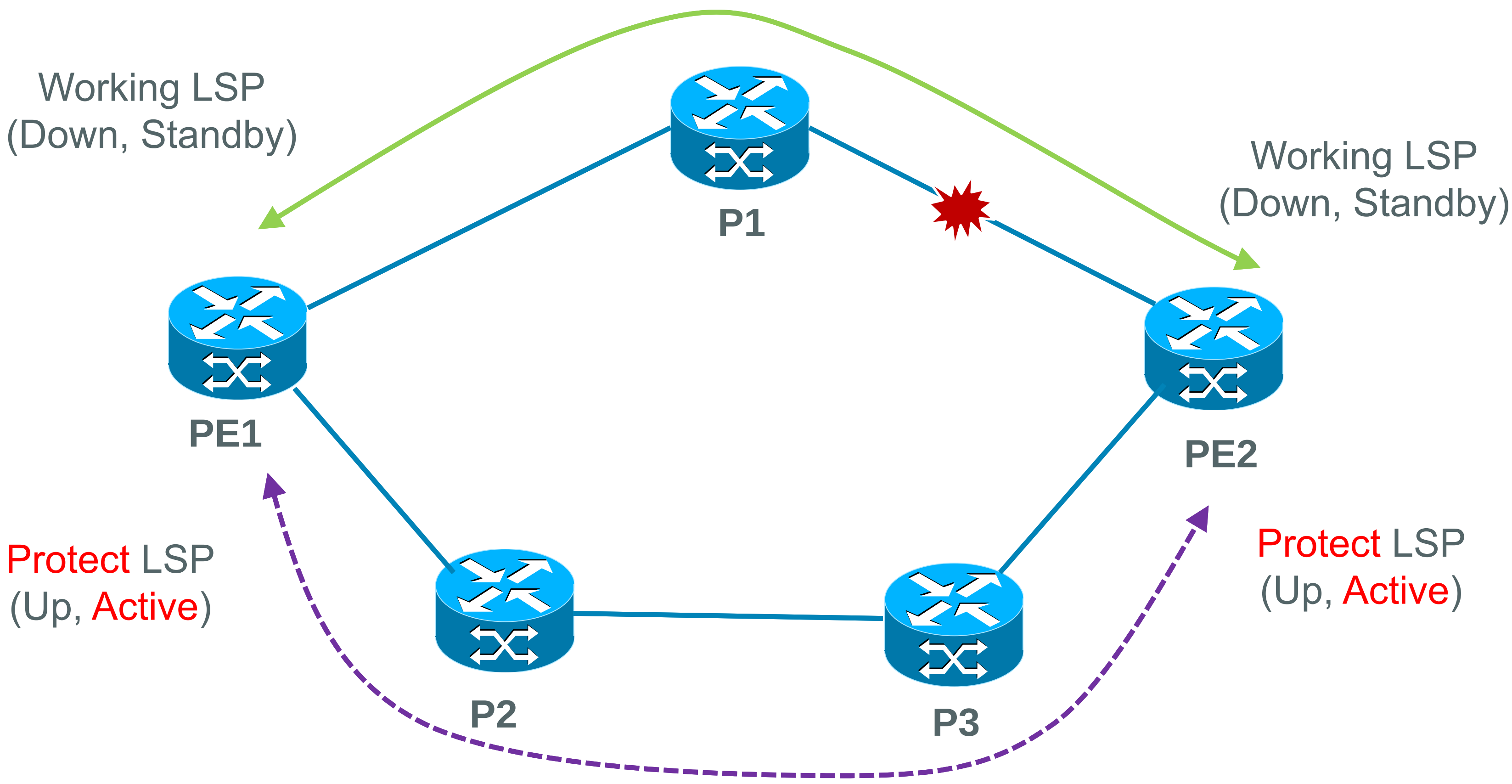
OAM Functions

Function	Description
Continuity Check	Checks ability to receive traffic
Connectivity Verification	Verifies that a packet reaches expected node
Diagnostic Tests	General diagnostic tests (e.g. looping traffic)
Route Tracing	Discovery of intermediate and end points
Lock Instruct	Instruct remote MEPs to lock path (only test/OAM traffic allowed)
Lock Reporting	Report a server-layer lock to a client-layer MEP
Alarm Reporting	Report a server-layer fault to a client-layer MEP
Remote Defect Indication	Report fault to remote MEP
Client Failure Indication	Client failure notification between MEPs
Packet Loss Measurement	Ratio of packets not received to packets sent
Packet Delay Measurement	One-way / two-way delay (first bit sent to last bit received)

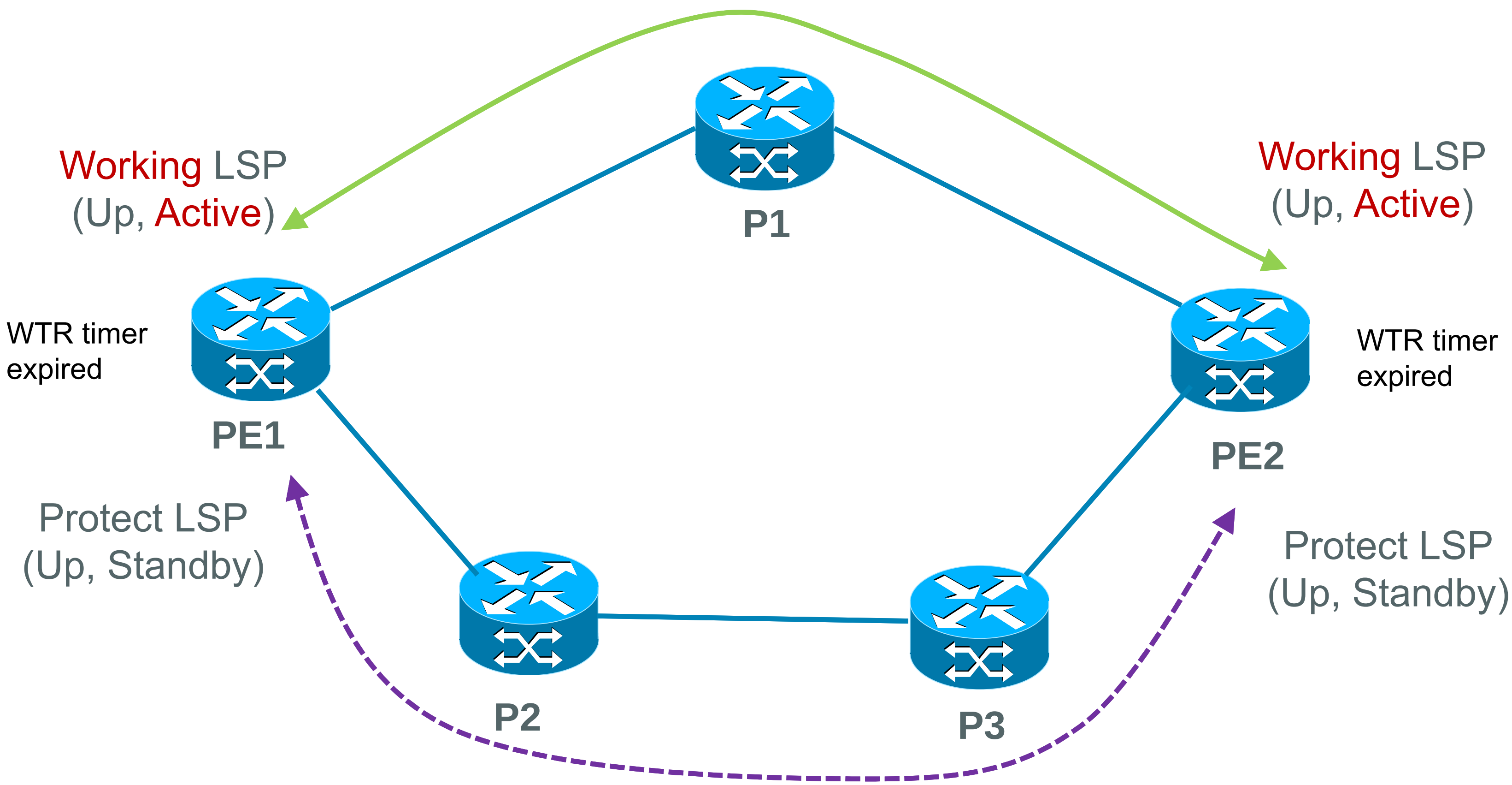
LSP 1:1 Protection



LSP Protection Switching with Fault



LSP Reversion



LSP Connectivity Check with BFD

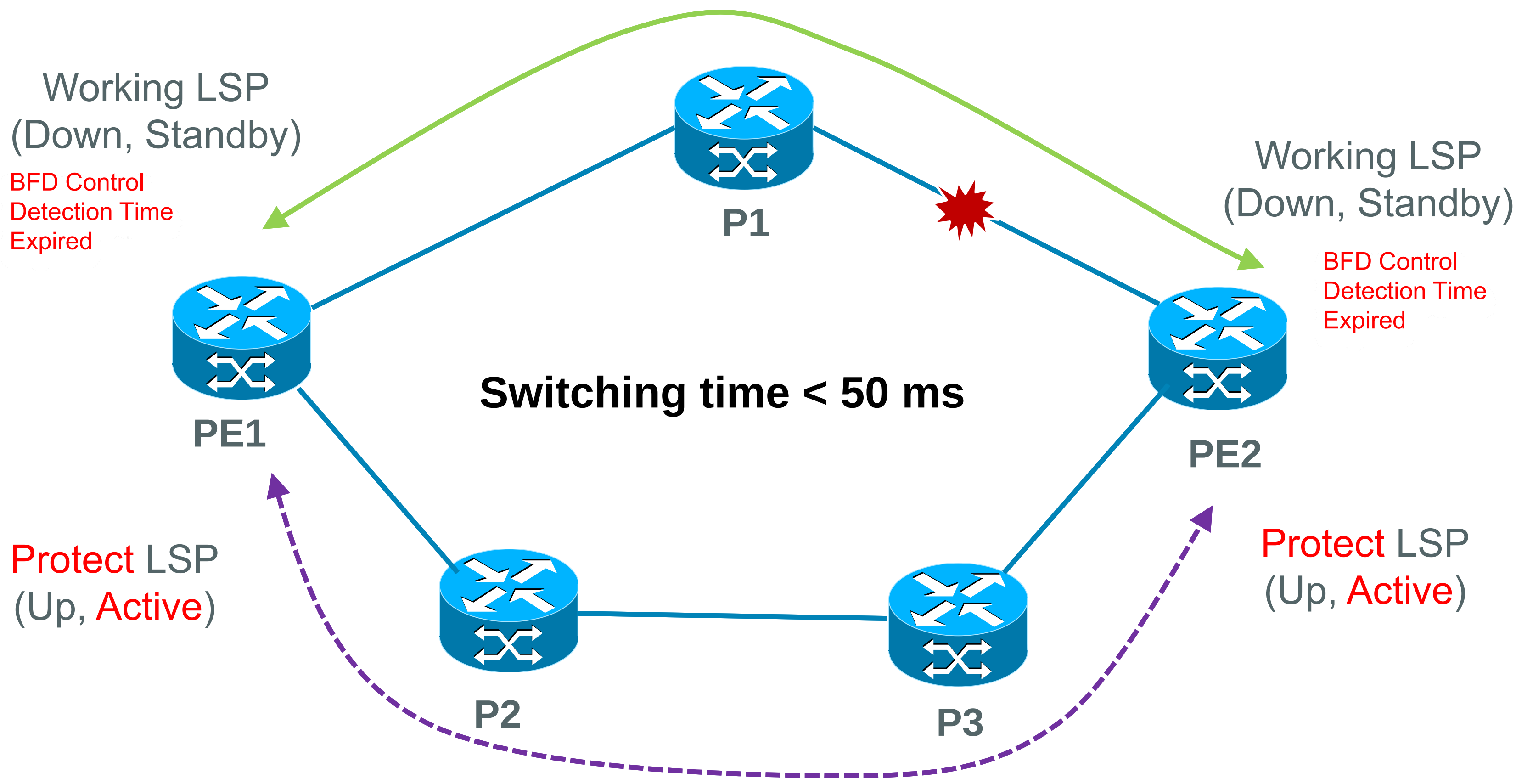
- Bidirectional Forwarding Detection (BFD) is used to actively detect LSP connectivity
- BFD relies on regularly receipt of Hello messages
- A loss of a certain (usually 3) consecutive Hello messages will trigger BFD down. For example, a 3.3 ms Hello interval will allow 10 ms fault detection
- An LSP only becomes active when BFD is configured and it is in the up state

MPLS TP BFD Encapsulation

		GACh	
Tunnel label 4 bytes	GAL 4 bytes	0001 | Ver | Resv | Channel Type	BFD header

- BFD packet label
  - GAL: 13
  - GACh header with channel type 0x7

LSP Protection Switching with BFD



LSP Fault Detection with LDI

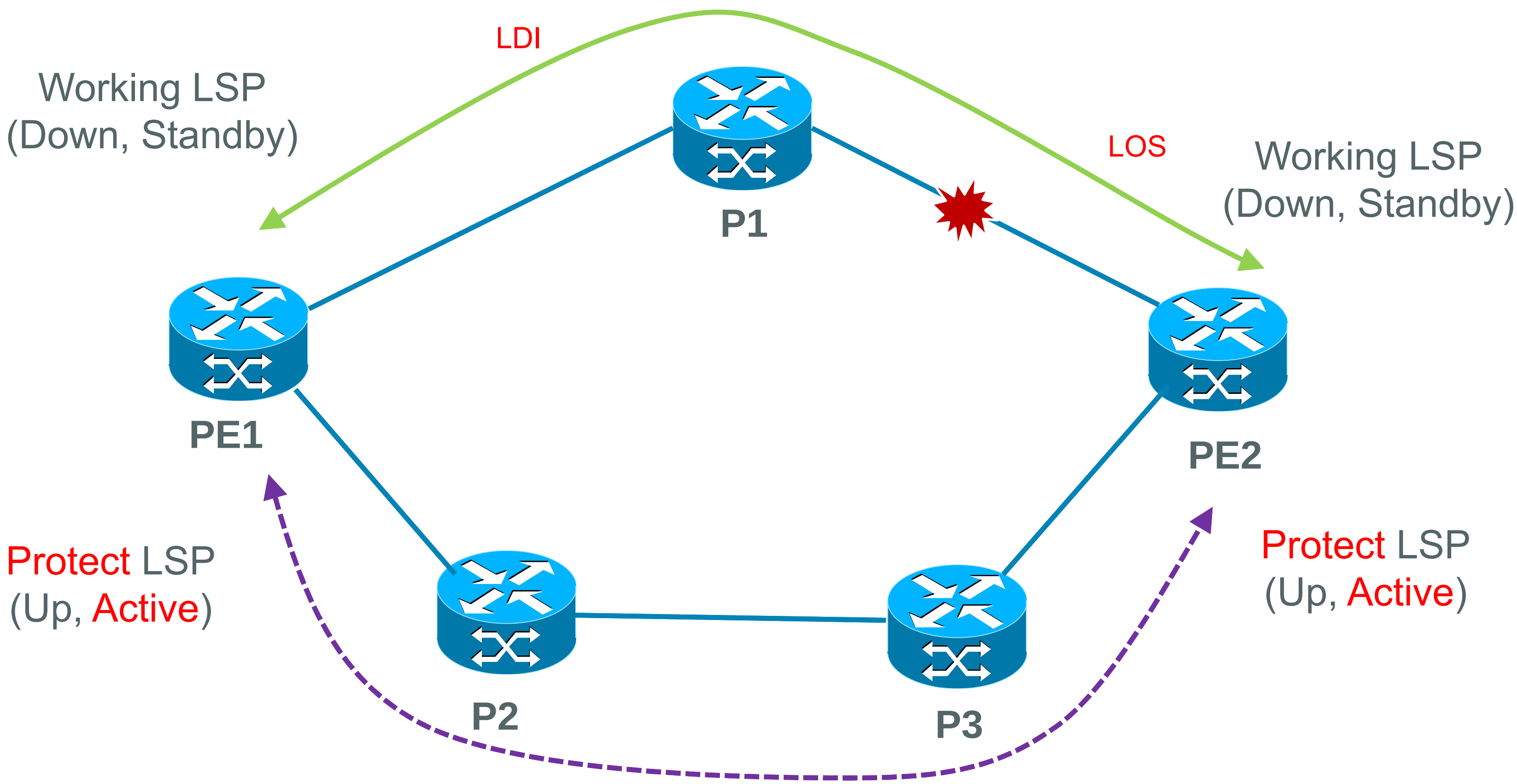
- LSP has fault detection built in
- A fault detected on any point of the LSP will cause the immediate nodes to generate LDI (Link Down Indication) messages and LOS
- LSP end points will process LDI messages and trigger LSP down action
- LSP end points will then generate RDI messages
- LSP is taken down on both directions

MPLS TP Fault OAM

		GACh	
Tunnel label 4 bytes	GAL 4 bytes	0001 | Ver | Resv | Channel Type	Fault OAM header

- Fault OAM message types:
  - AIS Alarm Indication Signal
  - LDI Link Down Indication
  - LKR Lockout
- Fault OAM packet label
  - GAL: 13
  - GACh header with channel type 0x58

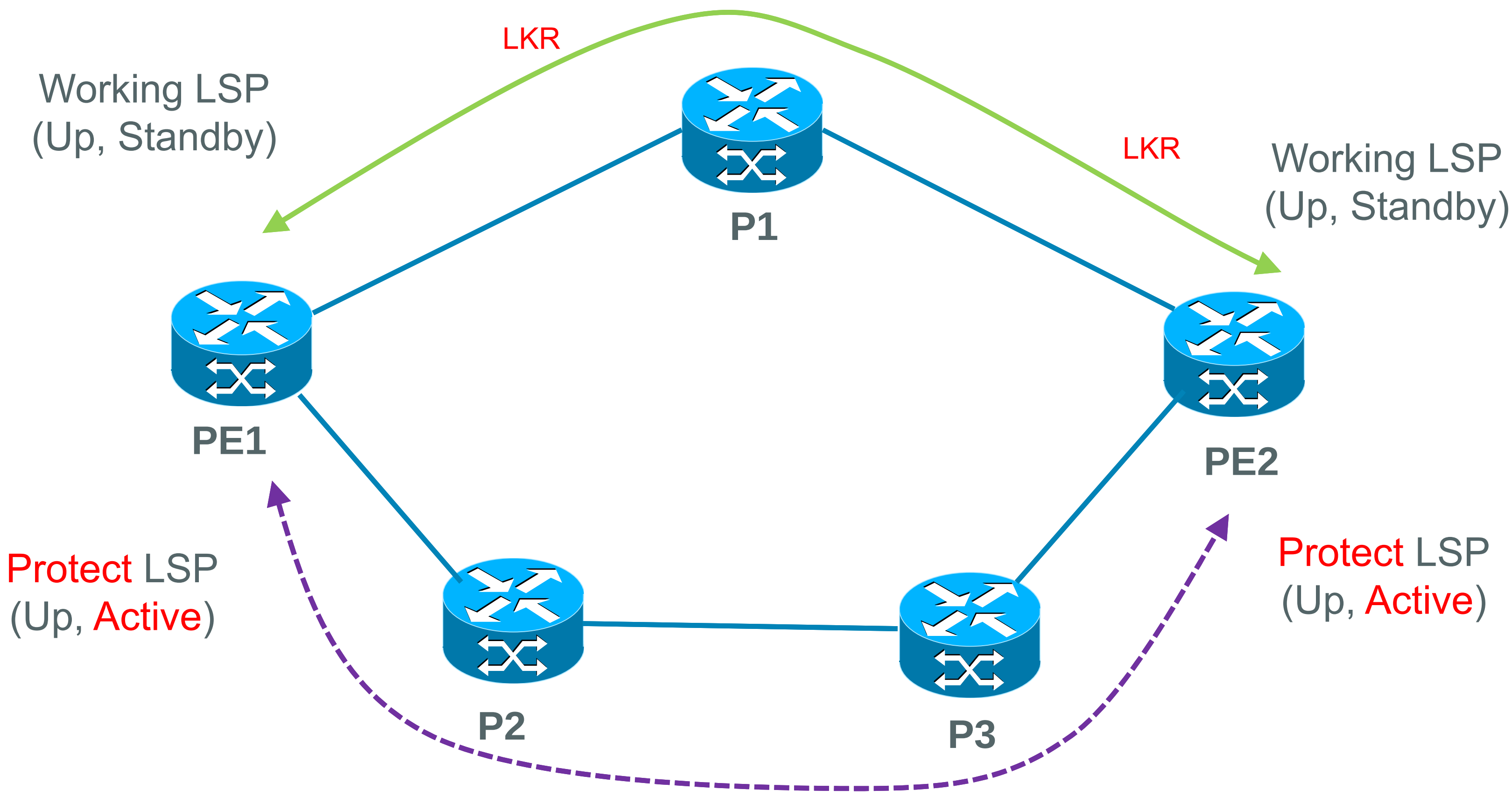
LSP Protection Switching with Fault OAM



LSP Lockout

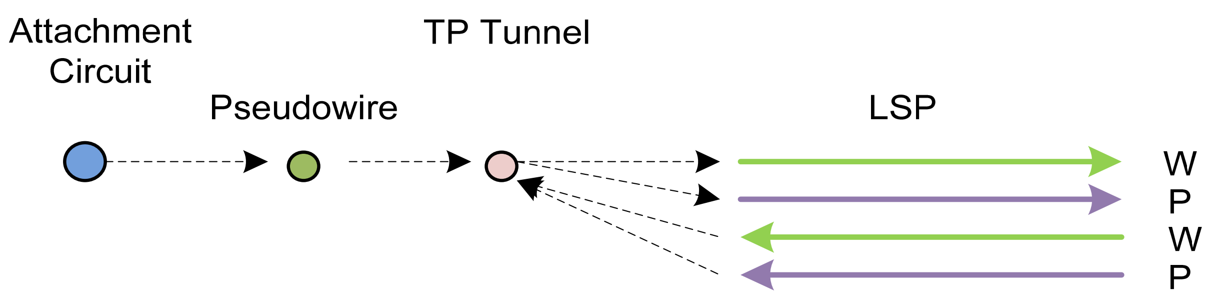
- An LSP can be administratively locked out
- A locked out LSP does not carry traffic

LSP Protection Switching with Lockout

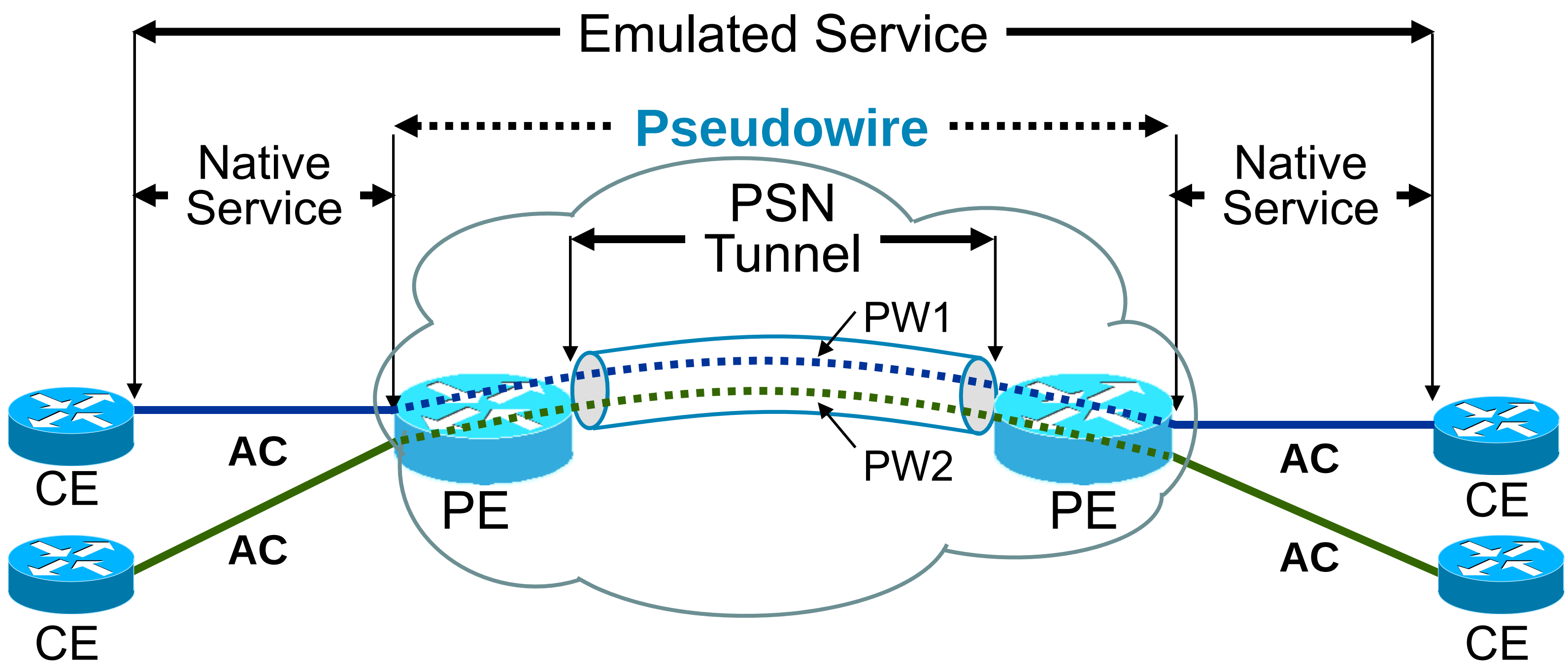


Mapping of Customer Traffic

- Customer traffic connected via an Attachment Circuit (AC)
- An AC cross connected to an MPLS virtual circuit (VC) or pseudowire
- A VC can be point to point or multipoint



Pseudowire Reference Model



- An Attachment Circuit (AC) is the physical or virtual circuit attaching a CE to a PE
- Customer Edge (CE) equipment perceives a PW as an unshared link or circuit

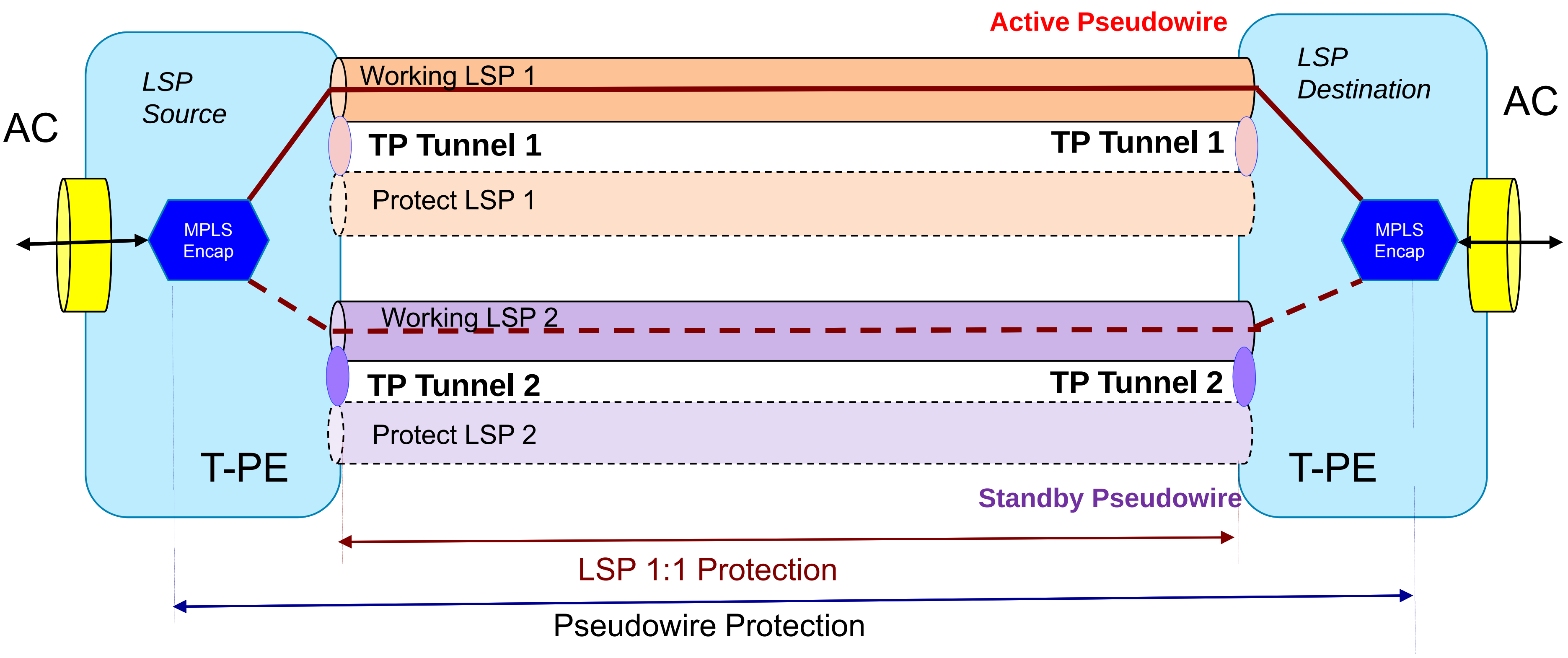
Virtual Private Wire Service (VPWS)

- A point to point circuit that emulates a line
- If Attachment Circuit (AC) is a physical port, Ethernet Private Line
- If AC is sharing the port with other ACs, Ethernet Virtual Private Line

Pseudowire Redundancy

- Second layer of redundancy in addition to MPLS-TP LSP 1:1 Protection
- Protected pseudowires are in Active/Standby states
- Standby pseudowire is down, pseudowire label is released

MPLS-TP Pseudowire Redundancy



Virtual Private LAN Service

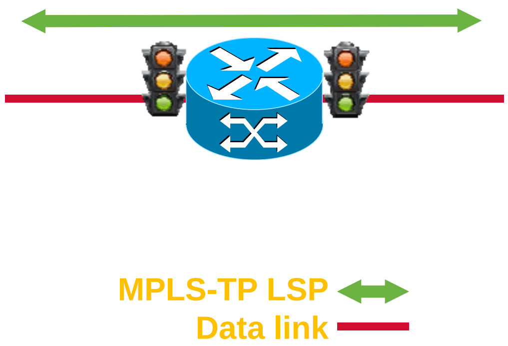
- A multipoint circuit that emulates a LAN
- If AC is a physical port, Ethernet Private LAN
- If AC is sharing the port with other ACs, Ethernet Virtual Private LAN

VPLS Redundancy

- All PEs of the same private LAN are fully meshed
- Split horizon is enabled
- A protected MPLS TP LSP makes fiber fault transparent to VPLS

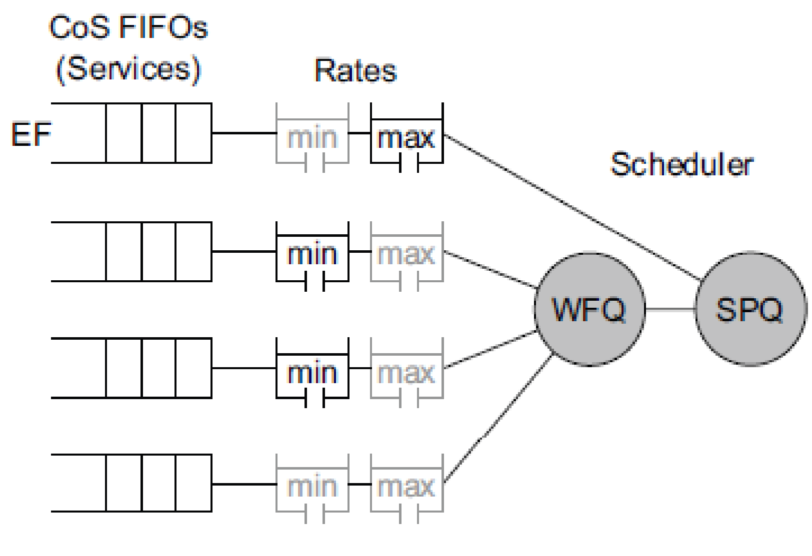
Bandwidth Management

- MPLS-TP LSPs can reserve bandwidth (for tunnel provisioning)
- LSP bandwidth reservation configured explicitly at each hop
- MPLS-TP LSPs have highest setup/hold priorities
- Data plane bandwidth enforcement requires QoS configuration



Data Plane QoS

- Traffic type classification based on CoS, IP Prec/DSCP, VLAN etc
- End-to-end bandwidth provisioning and guarantee
- Low latency queuing for delay or jitter-sensitive traffic
- Prioritizing processing of control or management-plane traffic over data-plane traffic



MPLS TP Deployment Scenarios

Common Deployment Scenarios

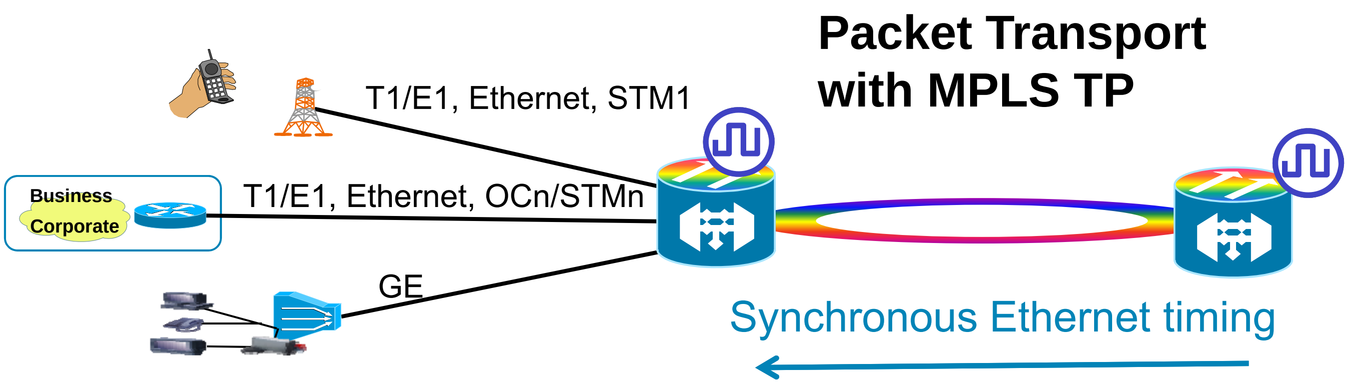
- Migration of SONET/SDH to MPLS-TP
- Consolidation into a single transport network
- Greenfield deployment that requires SONET like protection
- Multipoint LAN services over transport
- Deployment Examples:
  - Metro aggregation/access
  - Mobile back-haul

Common Deployment Practices

- LSPs are provisioned by NMS without a control plane
- BFD processed in hardware for 10 ms fault detection
- VPWS for point to point EPL or EVPL services
- Dual home pseudowires for site protection
- VPLS for multipoint services such as multicast video distribution
- Use of QoS for preferential services and oversubscription

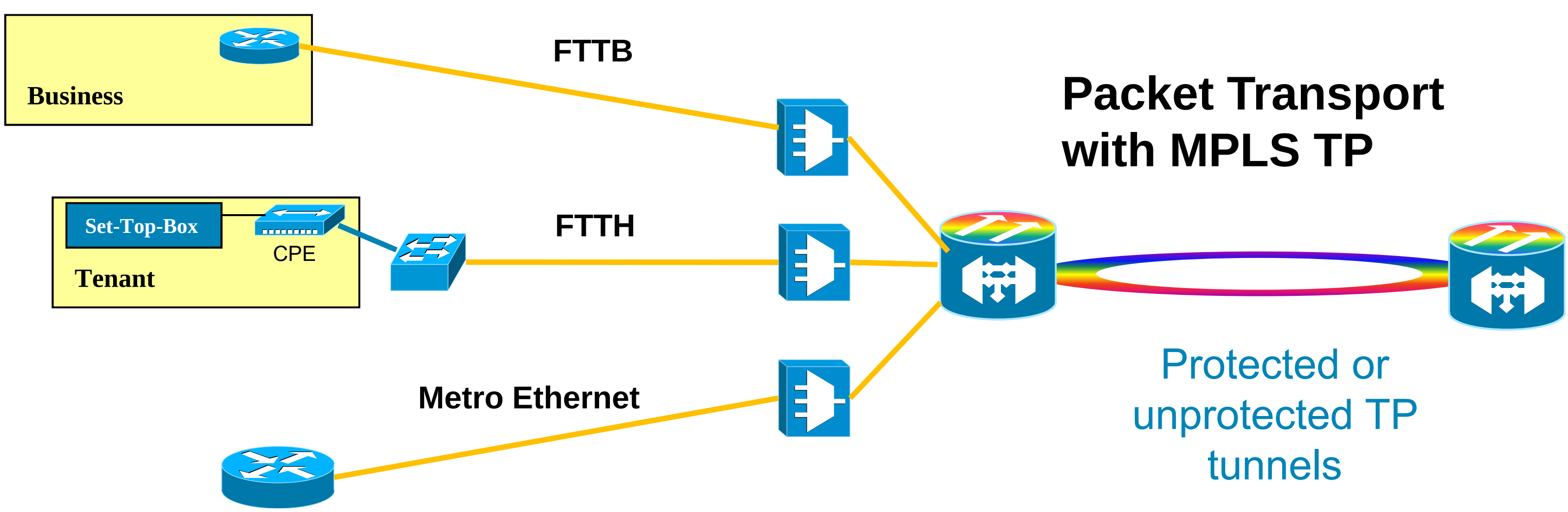
Consolidation and Simplification

- Currently multiple networks for TDM and packet
- Consolidate into a single transport network
- SONET like timing provided via Synchronous Ethernet



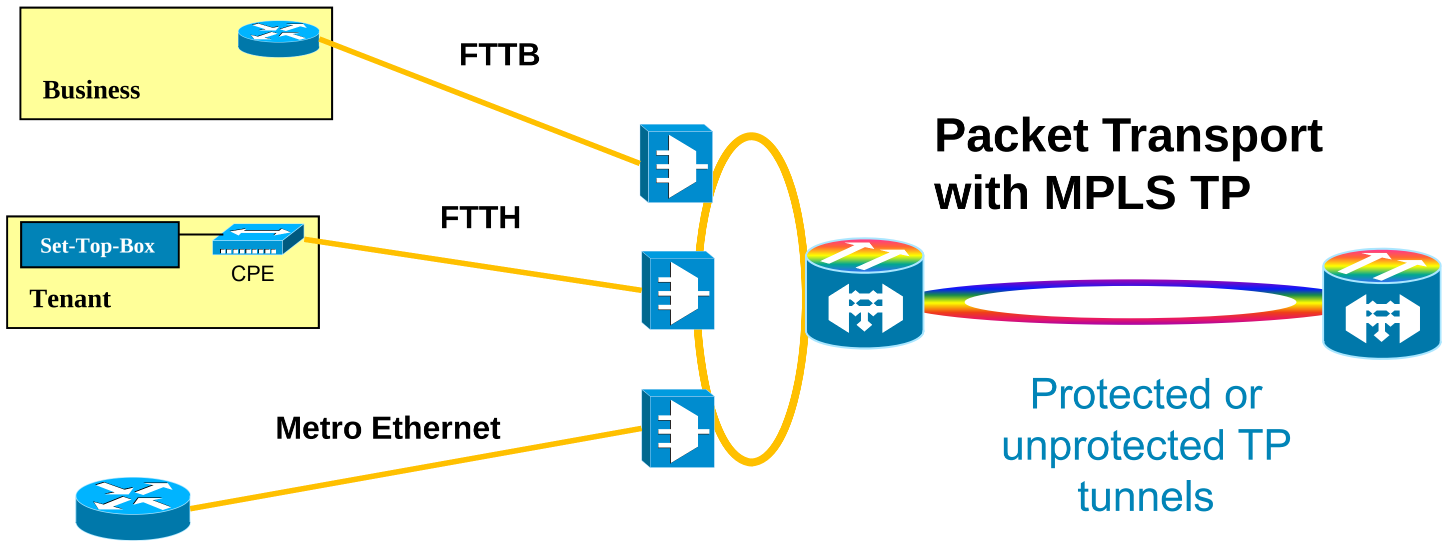
FTTx Deployment

- Aggregation of Ethernet services
- 50 ms protection for mission critical services
- QoS for preferential delivery treatment
- Use of satellite boxes to increase density and reach



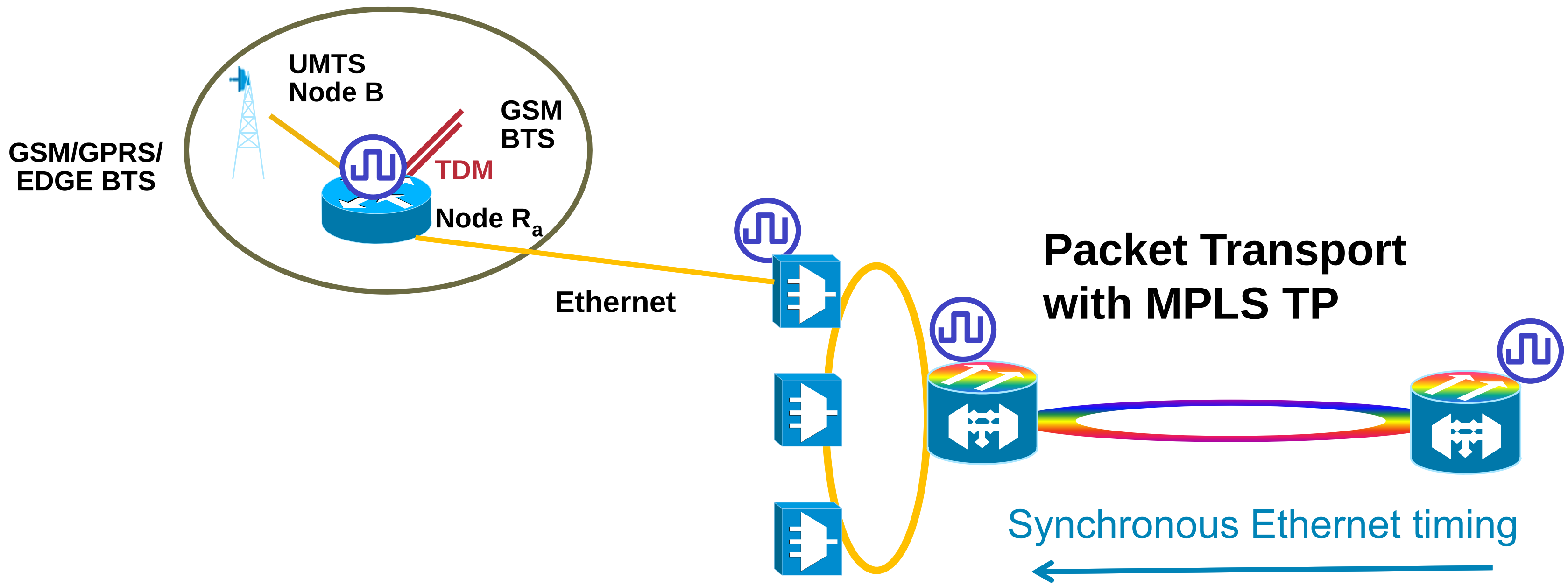
FTTx Deployment Alternate

- Use a ring of satellite boxes to reduce fiber usage



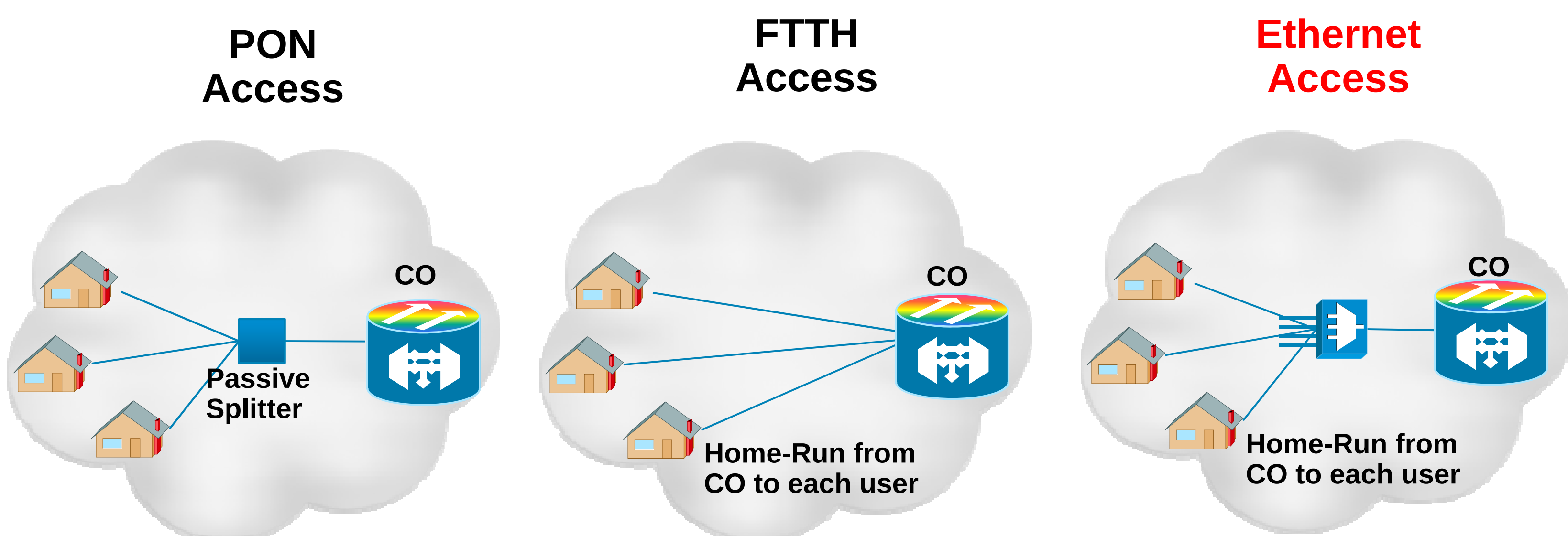
Mobile Backhaul Deployment

- Migration of TDM to packet transport
- 50 ms protection
- SONET like timing provided via Synchronous Ethernet



Central Office Fiber Management

- Use of satellite boxes to reduce fiber management at CO



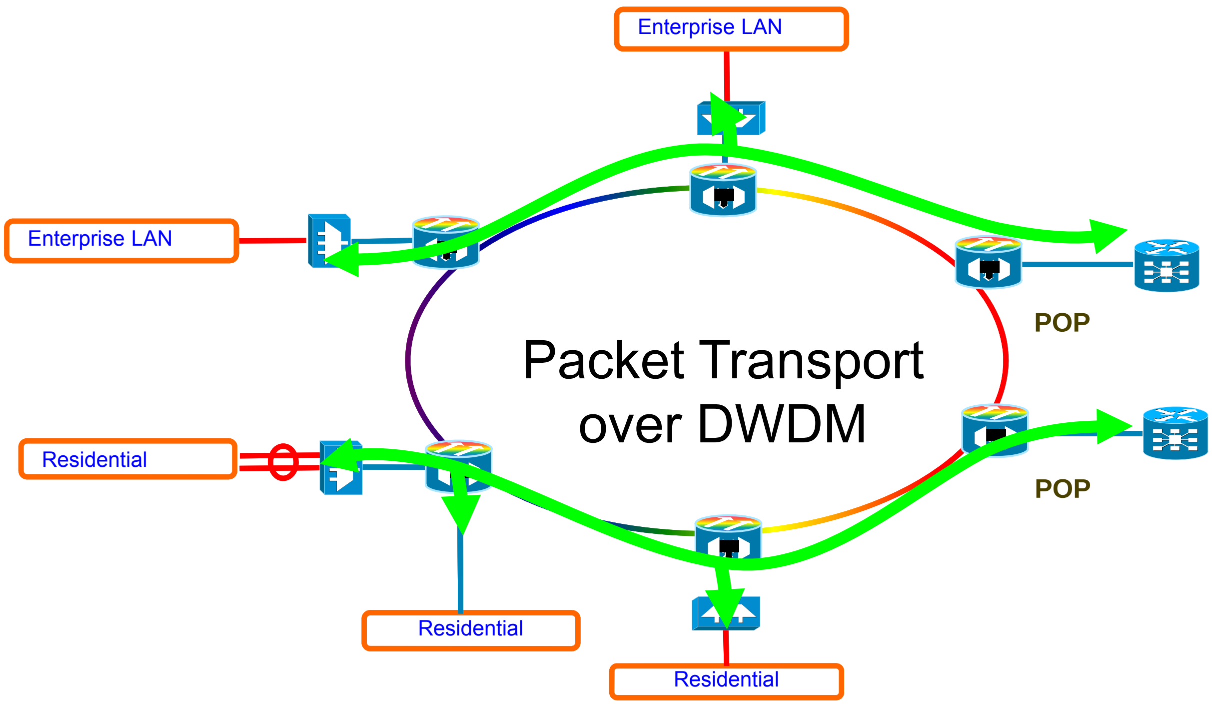
Pro: Fiber Consolidation
Con: BW Constrained

Pro: Bandwidth Scale
Con: Fiber Mgt. space overhead in CO

Pro: Fiber Consolidation
Pro : Bandwidth Scale

Multipoint LAN Services

- Virtual LAN services over MPLS TP transport
- Multicast video distribution services



MPLS-TP Deployment Lifecycle

From TDM Transport to Packet Transport

- Know the differences
- Understand the new requirements
- Proof of concept testing
- Create designs
- Performance testing
- Turn-up and provisioning

Follow a lifecycle process to ensure deployment success and timely delivery

TDM Transport vs Packet Transport

- Time division multiplexing vs statistical multiplexing
- New terminologies and technologies: LSP, pseudowire, BFD, VPWS, VPLS, QoS, policing, queuing
- Provisioned bandwidth vs data plane QoS
- Staff training

Creating Technical Requirements

- Convert business requirements into technical requirements
- Identify QoS requirements for circuit emulating traffic
- Generate topologies
- Document traffic flows
- Prioritize requirements

Proof of Concept Testing

- Convert technical requirements into a basic design
- Convert topologies into a test lab
- Validate the concept
- Focus on general functionality and mandatory requirements

Design

- Generate a high level design based on proof of concept testing
- Understand traffic flow patterns
- Identify MPLS TP parameters
- Identify MPLS virtual circuit characteristics
- Document network management
- Specify scalability limits

QoS

- Identify circuits that require SONET-like protection
- The network can support both protected and unprotected circuits
- Design QoS policies to support all types of circuits
- Identify circuits that require dual-homing

QoS Design Examples

- Traffic are classified into TDM type circuits and packet type circuits
- For TDM type circuits:
  - No oversubscription
  - Priority queue (CoS 6)
  - Timing may be required
- For packet type circuits:
  - Oversubscription allowed
  - Weighted fair queues
  - Guaranteed Bandwidth for different queues
    - High (CoS 5)
    - Medium (CoS 3)
    - Low (Cos 0)

Performance Testing

- A detailed verification of each type of traffic in the design
- Focus on protection switching and QoS
- Document test case results and solutions
- Update the design based on test results

Turn-up and Provisioning

- Equipment install and turn-up
- An intermediate staging may be useful
- Operational staff training
- Final hardware testing
- Provision the equipment based on the design

The network is ready for use

Summary

Transport Network in a Transition

- Explosion of data traffic
- Convergence of multiple networks into a single transport network
- Reducing CAPEX and OPEX
- Provisioning agility and flexibility

A Converged Transport

- A single transport network based on WDM
- OTN provides the digital wrapper
- MPLS Transport Profile (TP) provides SONET like services
- Ethernet technologies provide lower cost in CAPEX and OPEX
- Traditional TDM services and packet based services carried over a single transport network

Why MPLS Transport Profile?

- Transport like protection
- Transport like OAM
- Transport like operation
- Statistical multiplexing and oversubscription
- Interoperability with IP/MPLS

Follow the Deployment Process

- Know the differences between TDM and packet
- Understand new requirements
- Proof of concept testing
- Create designs
- Performance testing
- Turn-up and provisioning

CISCO