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

Business video

4G mobile and wireless users

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

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

- **MPLS**
  - Virtual circuit
  - Widely deployed

- **OTN**
  - CWDM and DWDM
  - G.709

The new optical packet transport network
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
**Data Plane**

MPLS Bidirectional P2P and P2MP LSPs
- No LSP merging
- PHP optional

GACCh: 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

- **Label Switch Router (LSR)**
- **Label Edge Router (LER)**
- **Label Switched Path (LSP)**

*A collection of label pushes, swaps and Pops*

Can be defined in many different ways: statically, dynamically through LDP, BGP, RSVP
MPLS Label

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

<table>
<thead>
<tr>
<th>In Lab</th>
<th>Address Prefix</th>
<th>Out I/F</th>
<th>Out Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>172.68.2.2/32</td>
<td>Lo0</td>
<td>Pop</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In Lab</th>
<th>Out I/F</th>
<th>Out Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>2</td>
<td>21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In Lab</th>
<th>Address Prefix</th>
<th>Out I/F</th>
<th>Out Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>–</td>
<td>172.68.2.2/32</td>
<td>0</td>
<td>42</td>
</tr>
</tbody>
</table>

PE
Lo0=172.68.2.2/32

P

PE
Lo0=172.68.1.2/32

Payload

21 Payload

42 Payload
MPLS Pseudowire Terminology Overview

- Provider Router (P)
- Provider Edge (PE)
- Pseudowire
  - 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

<table>
<thead>
<tr>
<th>In Lab</th>
<th>Address Prefix</th>
<th>Out I/F</th>
<th>Out Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>172.68.2.2/32</td>
<td>Lo0</td>
<td>Pop</td>
</tr>
</tbody>
</table>

Attachment Circuit ID label = 1

PE
Lo0=172.68.2.2/32

Payload
21 1 Payload

Attachment Circuit

PE
Lo0=172.68.1.2/32

Payload
42 1 Payload

© 2012 Cisco Systems, Inc. All rights reserved.
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 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)

<table>
<thead>
<tr>
<th>LSP Direction</th>
<th>Input Label</th>
<th>Output Label</th>
<th>Output Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td>323111</td>
<td>334111</td>
<td>Gi2/1</td>
</tr>
<tr>
<td>Reverse</td>
<td>343111</td>
<td>111</td>
<td>Gi2/4</td>
</tr>
</tbody>
</table>
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
GACCh for MPLS TP LSP

- A well-known label is assigned for GACCh (13)
- A GACCh Label (GAL) acts as an exception mechanism to identify OAM packets
G-ACh Packet Structure for an MPLS-TP LSP

<table>
<thead>
<tr>
<th>Label</th>
<th>TC</th>
<th>S</th>
<th>TTL</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>TC 1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Version</th>
<th>Reserved</th>
<th>Channel Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>TLV Type</td>
<td>Length</td>
<td></td>
</tr>
</tbody>
</table>

LSP Shim Header
- Generic Associated Channel Label (GAL)
- Associated Channel Header (ACH)
  - ACH TLV Header
    - ACH TLV (e.g., Source, destination, LSP Id, PW Id)
  - G-ACh Message

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

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuity Check</td>
<td>Checks ability to receive traffic</td>
</tr>
<tr>
<td>Connectivity Verification</td>
<td>Verifies that a packet reaches expected node</td>
</tr>
<tr>
<td>Diagnostic Tests</td>
<td>General diagnostic tests (e.g. looping traffic)</td>
</tr>
<tr>
<td>Route Tracing</td>
<td>Discovery of intermediate and end points</td>
</tr>
<tr>
<td>Lock Instruct</td>
<td>Instruct remote MEPs to lock path (only test/OAM traffic allowed)</td>
</tr>
<tr>
<td>Lock Reporting</td>
<td>Report a server-layer lock to a client-layer MEP</td>
</tr>
<tr>
<td>Alarm Reporting</td>
<td>Report a server-layer fault to a client-layer MEP</td>
</tr>
<tr>
<td>Remote Defect Indication</td>
<td>Report fault to remote MEP</td>
</tr>
<tr>
<td>Client Failure Indication</td>
<td>Client failure notification between MEPs</td>
</tr>
<tr>
<td>Packet Loss Measurement</td>
<td>Ratio of packets not received to packets sent</td>
</tr>
<tr>
<td>Packet Delay Measurement</td>
<td>One-way / two-way delay (first bit sent to last bit received)</td>
</tr>
</tbody>
</table>
LSP 1:1 Protection

Working LSP (Up, Active)

Protect LSP (Up, Standby)

Bidirectional LSP
LSP Protection Switching with Fault

Working LSP (Down, Standby)

Protect LSP (Up, Active)

© 2012 Cisco Systems, Inc. All rights reserved.
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

- BFD packet label
  - GAL: 13
  - GACH header with channel type 0x7
LSP Protection Switching with BFD

Working LSP (Down, Standby)
BFD Control Detection Time Expired

Switching time < 50 ms

Protect LSP (Up, Active)

PE1

P1

PE2

P2

P3
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

- Fault OAM message types:
  - AIS Alarm Indication Signal
  - LDI Link Down Indication
  - LKR Lockout

- Fault OAM packet label
  - GAL: 13
  - GACCh header with channel type 0x58
LSP Protection Switching with Fault OAM

Working LSP (Down, Standby)

Protect LSP (Up, Active)

P1

PE1

PE2

P2

P3

LDI

LOS

Working LSP (Down, Standby)
LSP Lockout

- An LSP can be administratively locked out
- A locked out LSP does not carry traffic
LSP Protection Switching with Lockout

- Working LSP (Up, Standby)
- Protect LSP (Up, Active)

PE1 → P1 → PE2
PE1 → P2
PE2 → P3
PE1 → P3

LKR
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

LSP 1:1 Protection

Pseudowire Protection

Active Pseudowire

Standby Pseudowire

Working LSP 1

Protect LSP 1

TP Tunnel 1

Working LSP 2

Protect LSP 2

TP Tunnel 2
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

Packet Transport with MPLS TP

Synchronous Ethernet timing
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

**PON Access**
- Pro: Fiber Consolidation
- Con: BW Constrained
- Passive Splitter

**FTTH Access**
- Pro: Bandwidth Scale
- Con: Fiber Mgt. space overhead in CO
- Home-Run from CO to each user

**Ethernet Access**
- Pro: Fiber Consolidation
- Pro: Bandwidth Scale
- Home-Run from CO to each user
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
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