MPLS:
Ten Years After

MPLScon 2006

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Speaker Biography

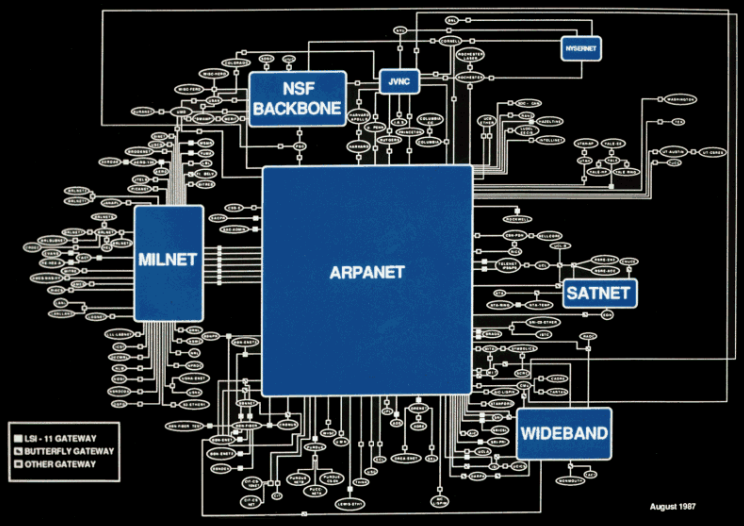
George Swallow, a Cisco Distinguished Engineer, is also a Co-Chair of the IETF's Working Group on MPLS. At Cisco, he is a member of the architecture team for label switching. He defined Cisco's architecture for applying MPLS to the problem of traffic engineering and fast reroute. Recently he has been involved in point to multi-point traffic engineering and in developing means of monitoring and diagnosing MPLS networks and MPLS based network applications.

Agenda

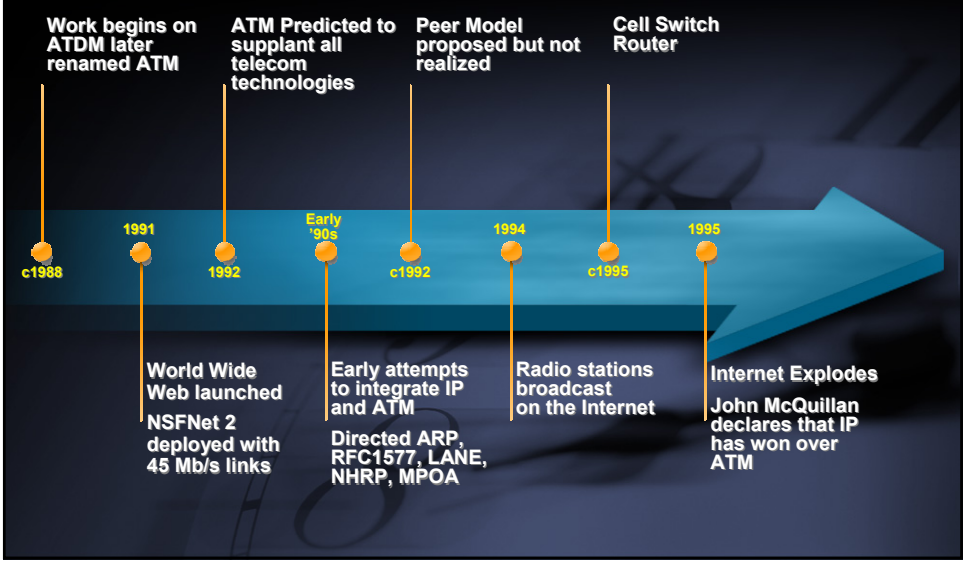
- What led to MPLS?
  - Some History
- What made MPLS successful?
  - Architecture
  - Layer Convergence
  - Service Convergence
- What's hot in MPLS?
- Where is MPLS going?
- Summary

Some History

The Internet: August 1987



Events on the road to MPLS



1996 - The Pivotal Year

35th IETF, March 4-8, Los Angeles

- Ipsilon announces their flow based Cell Switch
- Yakov Rekhter immediately reacts
  - "Great idea but make it frames, not cells; NLRI, not flows."

Spring & Summer

- Tag switching and Traffic Engineering architectures

Fall

- Tag switching BoFs held at MIT and 37th IETF

January '97

- MPLS Working Group formed

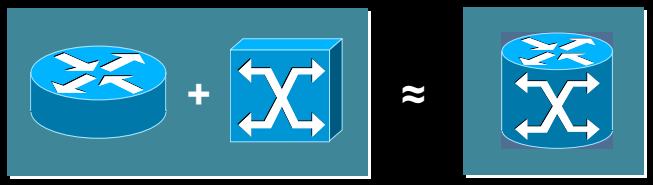
Architecture

Label Switching Motivation

- Simplify integration of ATM and IP
- Offer both ATM & native IP services in a single network
- Offer benefits of traditionally found only in Level 2 networks directly to IP

  Traffic Engineering, VPNs (Light--weight tunnels)
- Address major network scalability challenges
- Permit graceful evolution of routing & services

Label Switching: Fusing Routing and Switching



Router ATM Switch MPLS Router

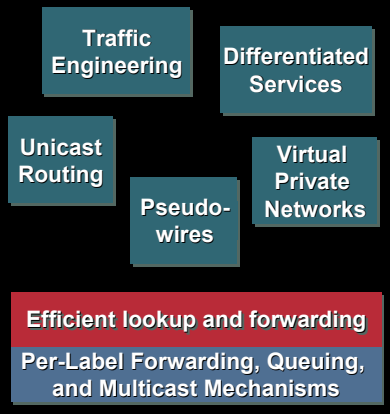
- Combining:

  Layer 3 routing - scalability and flexibility

  Layer 2 switching - high performance and traffic management

MPLS Components

- Control components
  - IP based
  - Various applications can directly manipulate label bindings
- Forwarding component
  - Simple label-swapping paradigm



- **Separation allows flexibility**

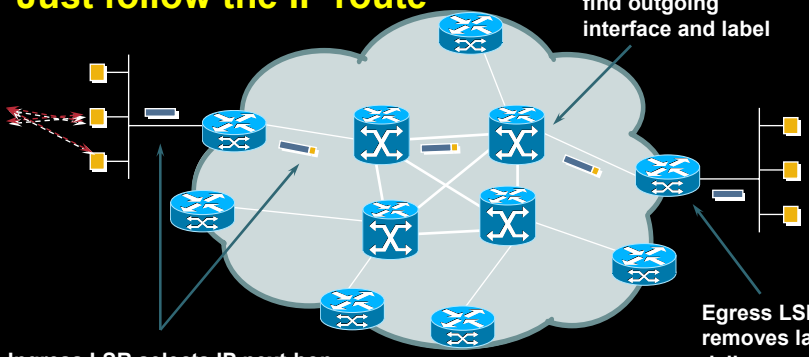
Forwarding Component

- Simple efficient forwarding
- Label lookup determines
  - Label operation
  - Queue
  - Drop priority
- **Observation:** forwarding algorithm is independent of control module

Unicast Forwarding

Keep it simple!

Just follow the IP route



Label Semantics

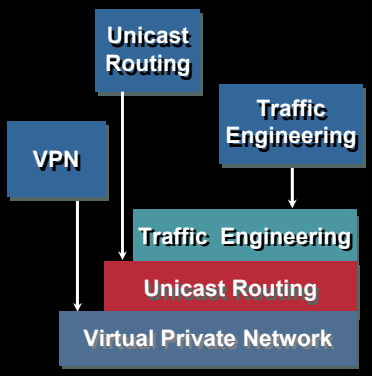
- Fine or coarse grained
- Unicast or multicast
- Explicit or implicit route
- VPN identifier

	Coarse	*Medium*	*Fine*
Implicit	Unicast Routing	Differential Sevices	RSVP
Explicit	Fast Reroute	Traffic Engineering	QoS Routing

Loose semantics create flexible control

Label Stack

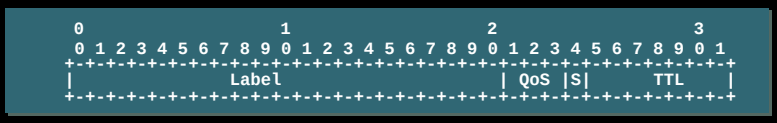
- Arbitrary number of labels
- Simple Label Stack Operations
  - Push- add a label to the stack
  - Swap - replace the top label
  - Pop - remove the top label
- Allows multiple control planes to act on a packet
- Eases the integration of applications



Media Independence / Protocol Co-existence

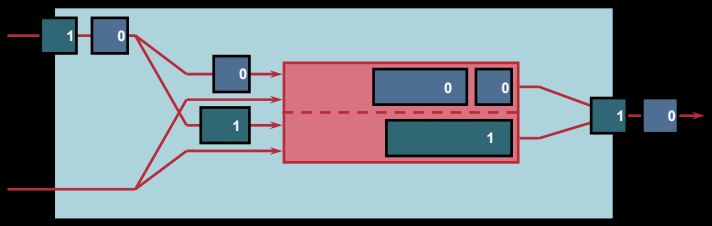
Frame Encapsulation

- POS, HDLC, Ethernet, PPP
- Other protocols (including IP) can share link
- Contains everything needed at forwarding time



QoS = Quality of Service S = Stack Bit TTL = Time to Live

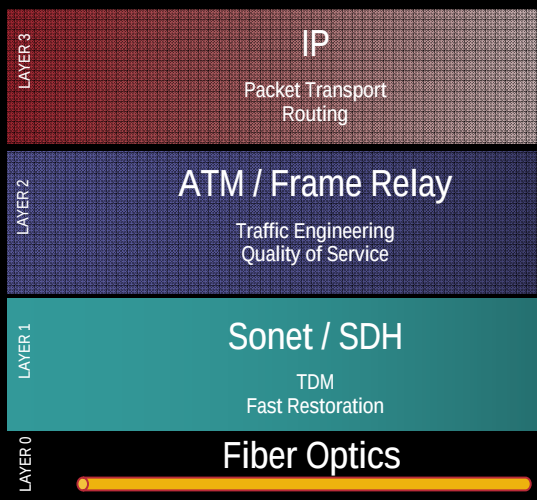
Quality of Service



- **Packets are marked with precedence:**
  - **MPLS Label plus 3 QoS bits determine queue**
- **Each class gets assigned service weight (WFQ: can be treated as a guaranteed bandwidth, or a priority)**
- **Solves the fine grained packet classification problem**
  - **Classification done once at edge of network**

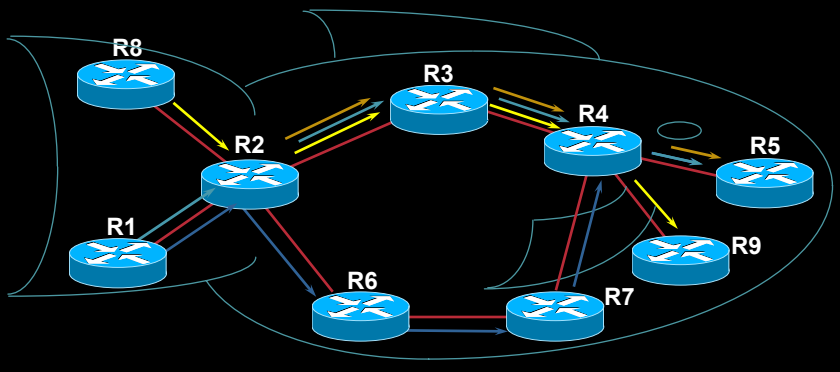
Layer Convergence

IP Service Provider Layers circa 1996



- Limited bandwidth availability
- Multiple networks
- Dedicated crafts personnel

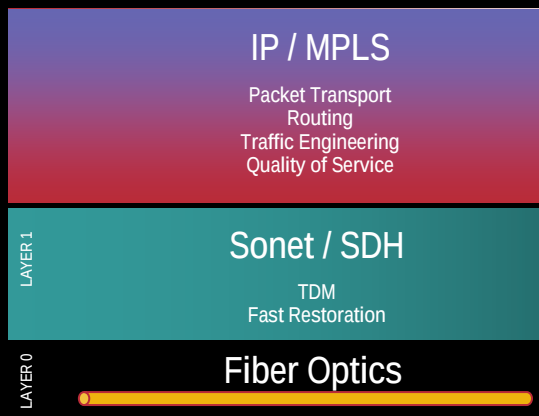
A Traffic Engineering Tunnel



Flow R8 → R9 Flow R2 → R5 Flow R1 → R5

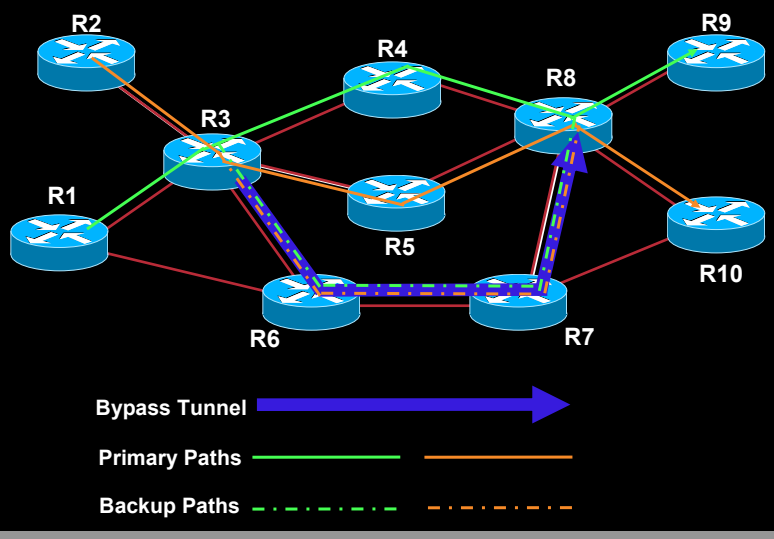
Tunneled Flow: R1 → R2 → R6 → R7 → R4 → R5

IP Service Provider Layers circa 1999

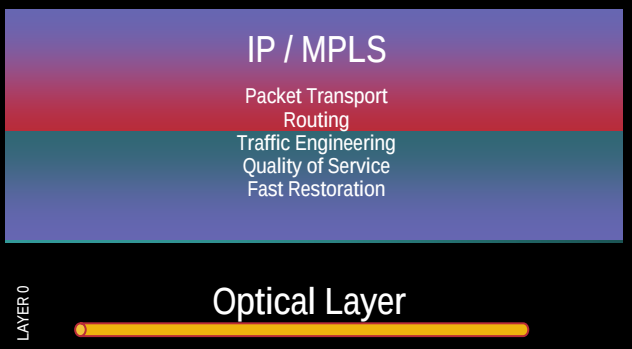


- MPLS Traffic Engineering eliminates need for a separate layer 2 network
- (Cheaper bandwidth had a lot to do with it too!)

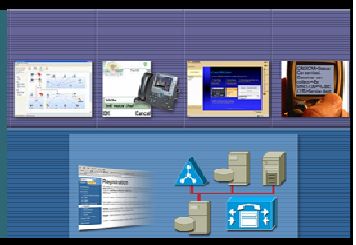
Fast Restoration



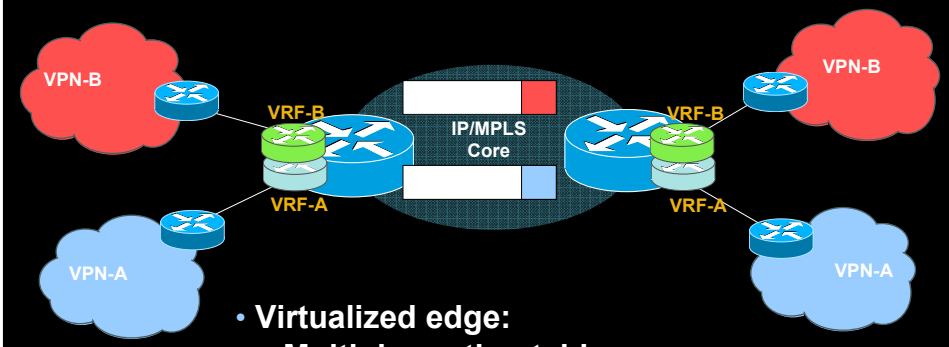
Next Generation Network Core



Service Convergence



Virtualization: MPLS VPNs

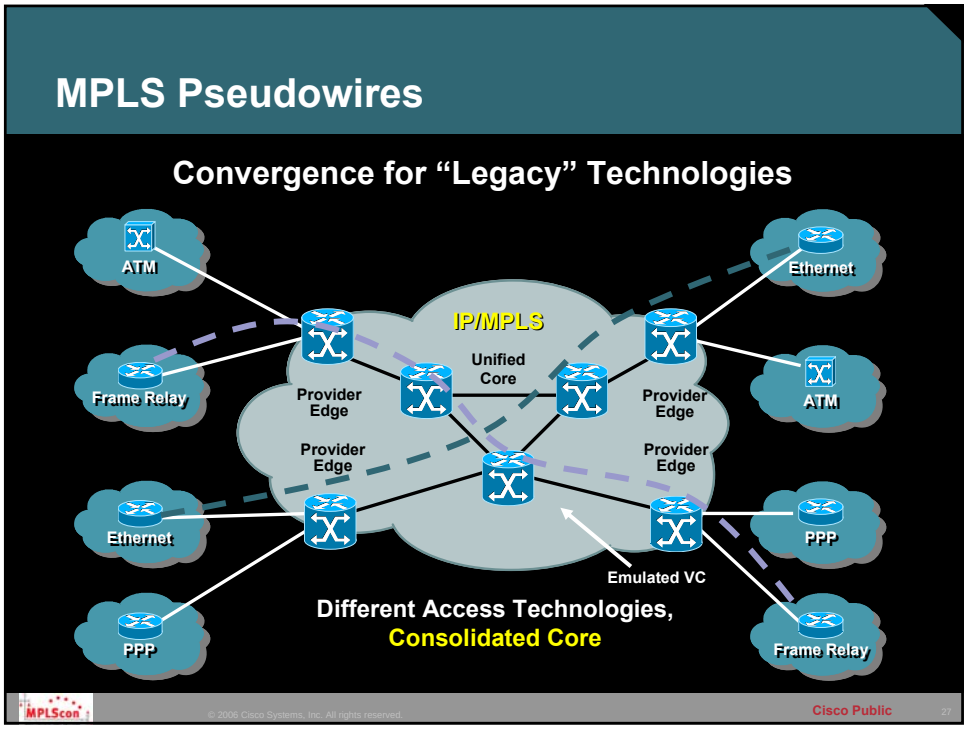


- Virtualized edge:
  - Multiple routing tables
  - Labels segregate VPN traffic
- Unified core
  - Single label for next hop

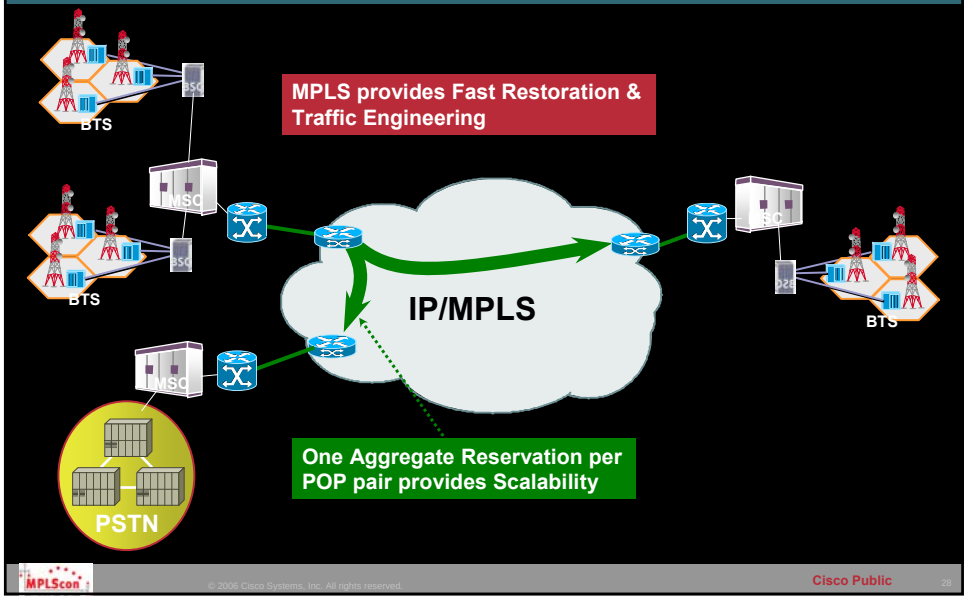
Resource Virtualization
Logically Separate, Physically Consolidated

- An Architecture that scales
- An Infrastructure that dynamically adapts
- A network that partitions and consolidates resources
- An environment which is flexible and manageable

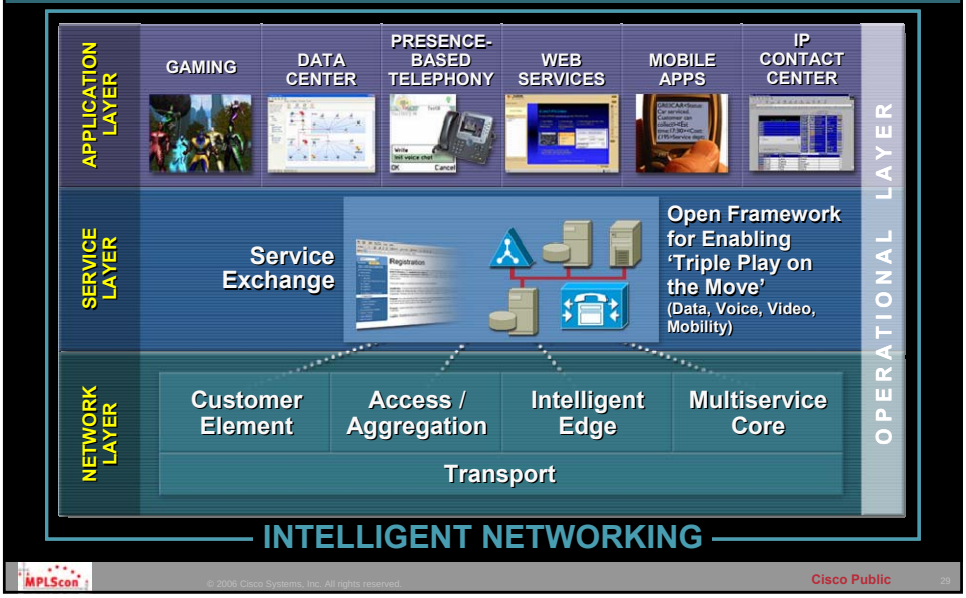
MPLS Pseudowires



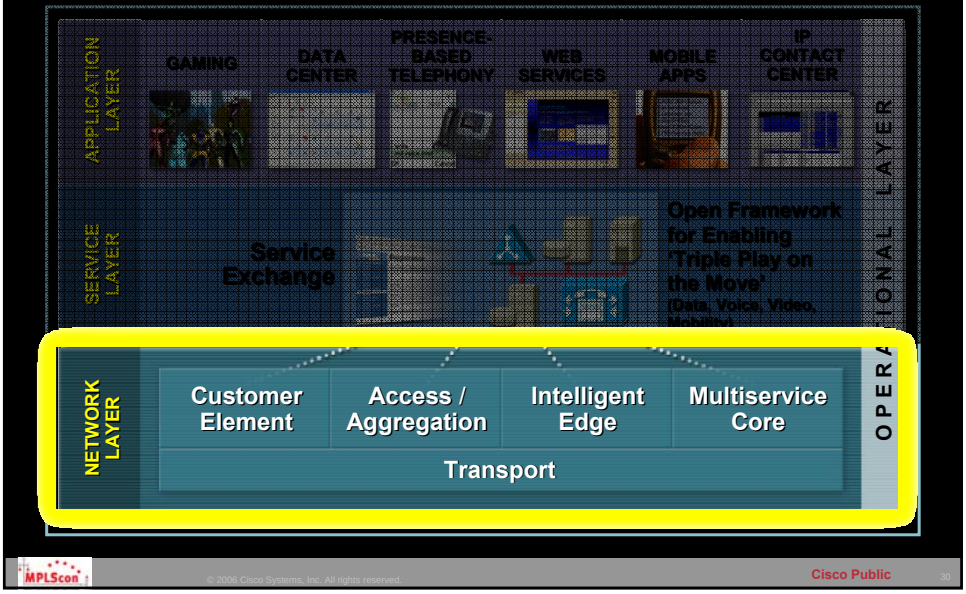
Voice Trunking



Convergence must be at multiple levels



Network Convergence



Next Generation Network Core

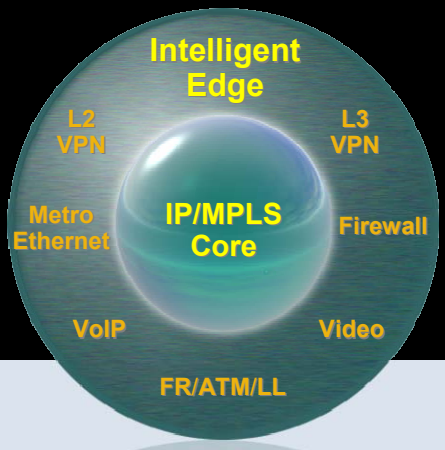
IP / MPLS

Packet Transport
Routing
Traffic Engineering
Quality of Service
Fast Restoration

LAYER 0

Optical Layer

Converge services onto one network



- Virtualization
- Service flexibility
- Scalability
- Continuous operation
- Management
- Investment protection
- Security

One Network, Many Services

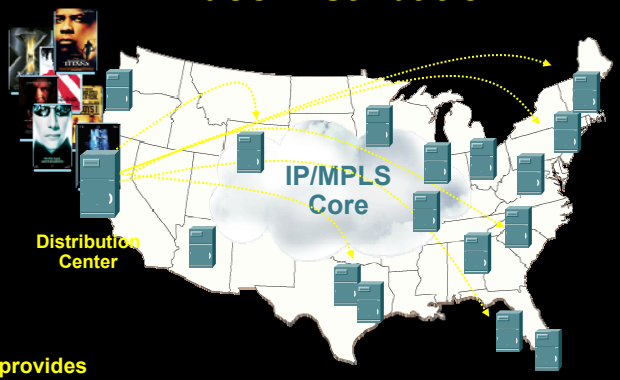
Hot Areas

Current Hot Topics

- Multicast
  - P2MP Traffic Engineering
    - Video Distribution
    - Financial Applications
  - Multicast LDP (mLDP)
    - Scalable multicast for L2 & L3 VPNs
- Operations and Maintenance (OAM)
- Re-kindled interest in GMPLS
- Access Aggregation

Multicast Traffic Engineering

Video Distribution



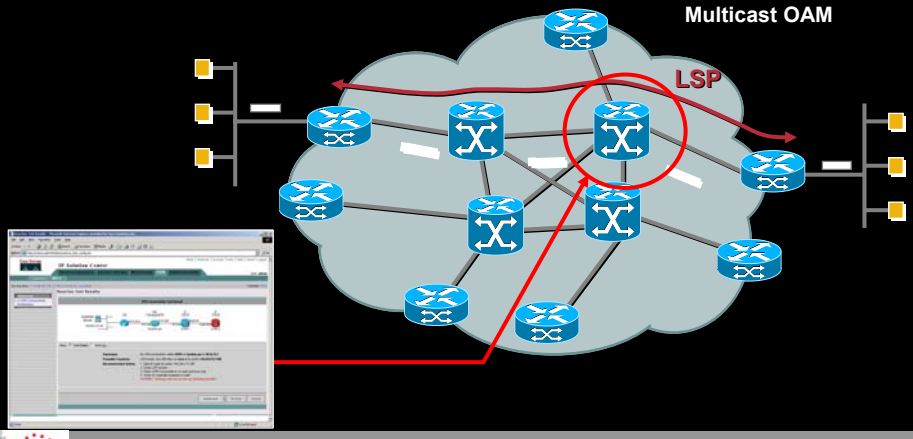
MPLS TE provides
Explicitly routed multicast
Guaranteed Bandwidth
Fast Restoration

MPLS Operations and Management

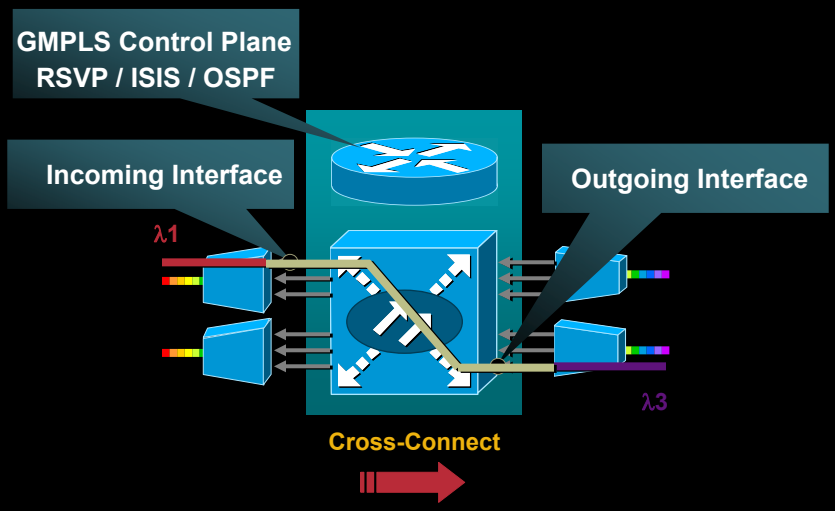
Suite of Protocols and Tools being developed

Enables rapid isolation of faults

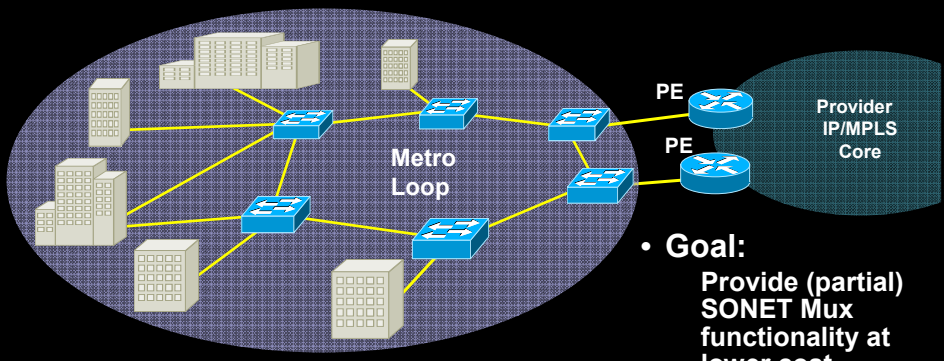
MPLS Ping / Traceroute
LSR Self-test
MPLS BFD
Multicast OAM



GMPLS: IP Based Control of Layer 1



Access Aggregation



- Goal:
  Provide (partial) SONET Mux functionality at lower cost
- Many ideas are brewing
- Some involve GMPLS, Pseudo-wires, and an ITU variant on MPLS

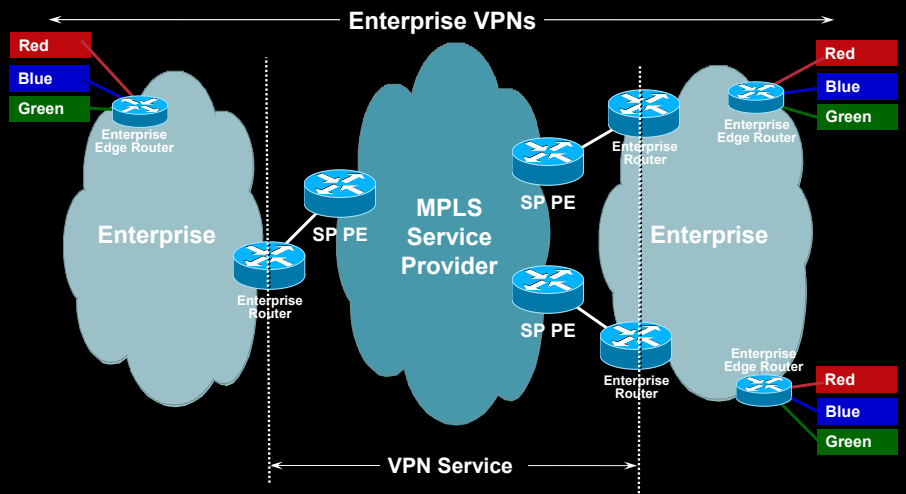
Enterprises using MPLS

- Range from very large to fairly small
- Range from one location to global presence
- Some using Traffic Engineering
  - Growing interest in FRR for VoIP
- Primary Driver is Segmentation
  - Security is the overarching theme
  - Many variations on this theme
  - MPLS VPNs seen as an enabling tool

Enterprise: Largest Growth Sector

- MPLS is no longer “bleeding edge” technology
  - Considered safe for the sophisticated enterprise
- MPLS is being “Hardened”
  - Easier to configure
  - Harder to mis-configure
  - Improved resiliency
- As it gets used, Growth accelerates
  - Industry awareness of benefits
  - Testimonials of cost savings
  - Availability of trained staff

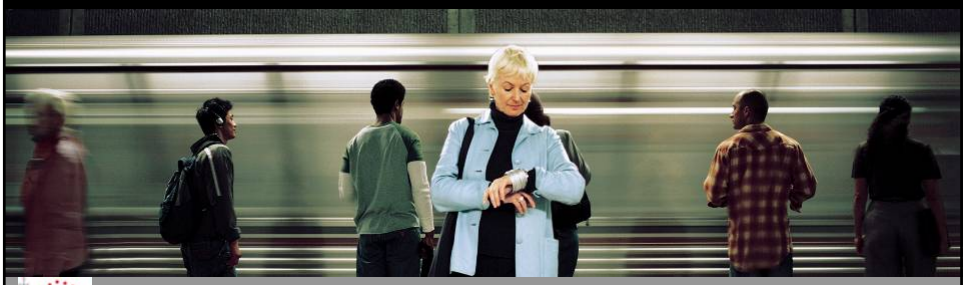
MPLS Enabled VPNs



Where is MPLS Going?

"MPLS is being deployed because it has an immediate and direct benefit to the network. The long-term impact of MPLS is difficult to anticipate because of the innovations that it enables. This is, in part, one of the indicators of an architectural change, as opposed to an evolutionary change, which would have clear, immediate, and foreseeable consequences."

Tony Li, "*MPLS and the Evolving Internet Architecture*",
IEEE Communications, December 1999



Summary

MPLS: Keys to Success

- Acknowledgement that IP won!
  - Primary applications are IP services
  - IP based Control Protocols
- Simple forwarding paradigm
- Flexibility in label semantics and stacking
- Flexible control plane tied directly to applications

MPLS Value

- Service Virtualization
- Service Convergence
- Layer Convergence
- Quality of Service
- Operation and Maintenance Tools
- All available on an IP platform

IP / MPLS Future:
The Foundation for the Next Generation

NETWORK LAYER

Customer Element	Access / Aggregation	Intelligent Edge	Multiservice Core
Transport			

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