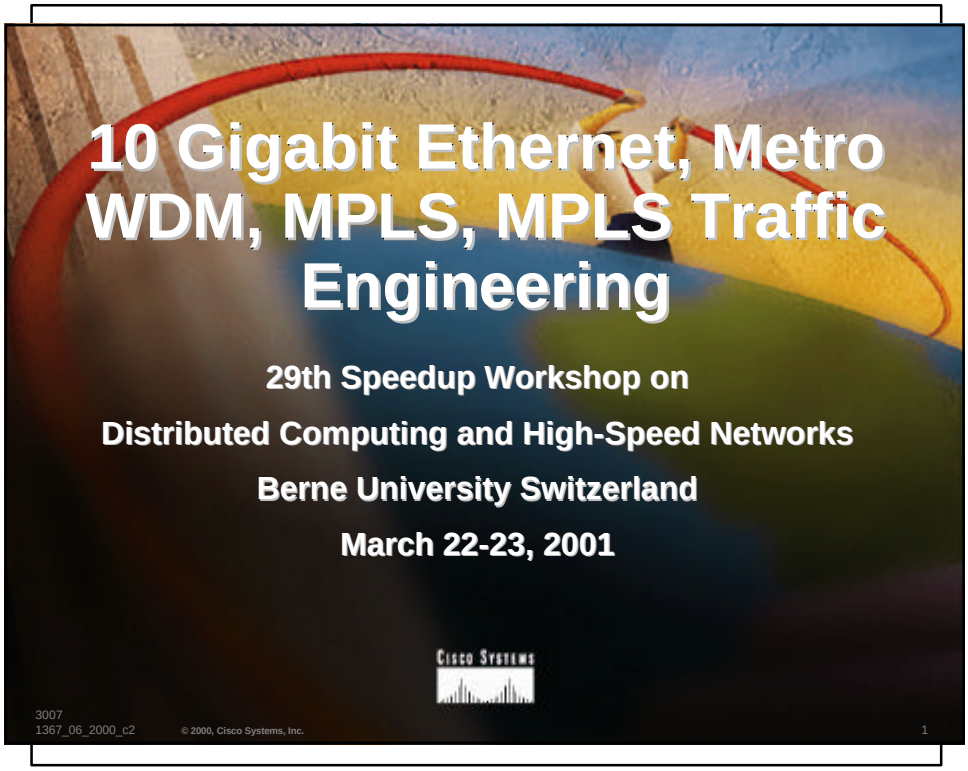


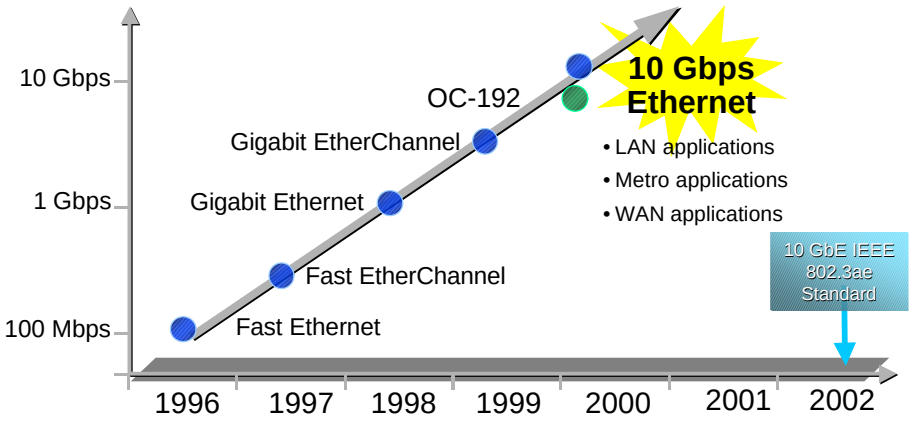
Agenda

- 10 Gigabit Ethernet
- Metro WDM, UCP (Unified Control Plane)
- MPLS, MPLS Traffic Engineering

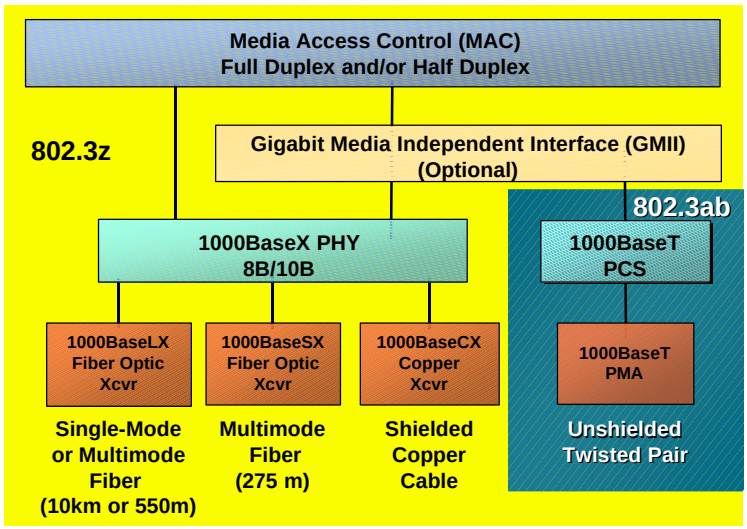
Ethernet History

- 1980's — 10 Mbps Ethernet IEEE 802.3
- 1992-95 — 100 Mbps Ethernet IEEE 802.3u
- 1995-1999 — 1000 Mbps Ethernet IEEE 802.3z, 802.3ab
- 1998-2000 — 10/100/1000 Mbps Ethernet Link Aggregation IEEE 802.3ad
- 1999-2002 — (March) 10 Gbps IEEE 802.3ae

Moving the Decimal Point: 10 GbE Performance and Scalability



Gigabit Ethernet Layer Diagram

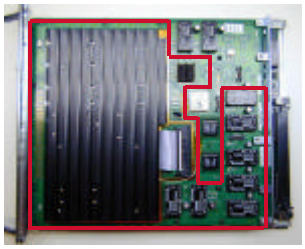


GBIC Module Flexibility

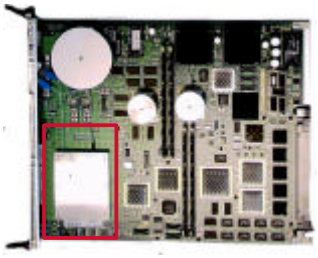
SX	Multimode only	275 meters
LX/LH	Multimode/ singlemode	550 meters/ 10 km
ZX	singlemode only	70km-100km

- Modular transceiver—'plug and play'
- Multiple suppliers
- Large volume—250K ports/month
- Low cost (compared to Ether-NOT technologies, Bob Metcalf !)

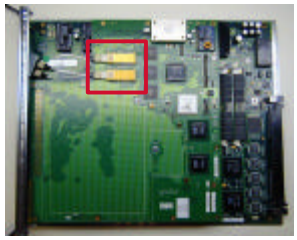
OC-192 Optics Size



First Generation



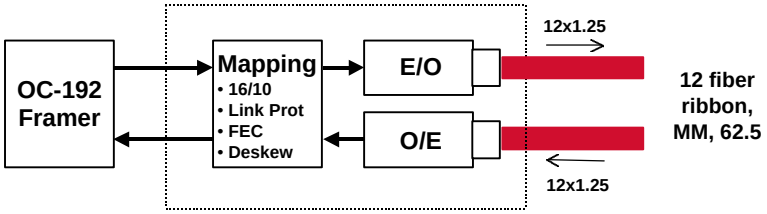
Third Generation



VSR

OC-192 Optics Circuitry

VSR (Very Short Reach) 12 x 1.25G



Features:

- 12 Tx + 12 Rx channels @ 1.25G (10 data + 2 control)
- 2 x 12 fiber ribbon (Tx and Rx)
- Protection Channel (1:10) (XOR of the 10 data channels)
- Error Detection Channel (CRC's of the other 11 channels)
- Compatible with OC-192 framer interface (OIF99.102)
- Link length up to 400m
- Leverages mature GE technology and CMOS SERDES
- OIF (Optical Internetworking Forum) Contribution OIF-99.120

Why 10 Gigabit Ethernet ?

- Aggregates Gigabit Ethernet segments
- Scales Enterprise and Service Provider LAN backbones
- Leverages installed base of 250 million Ethernet switch ports
- Supports all types of traffic and services (data, packetized voice and video, storage)
- Supports metropolitan and wide area networks
- Faster and simpler than other alternatives

10 Gigabit Ethernet Standard Status

- IEEE 802.3ae (Task Force)
- Project kicked off in March, 1999
- Project approval January 2000
- First draft September 2000
- First ballot March 2001
- Completion March, 2002

IEEE Goals for 10 Gigabit Ethernet

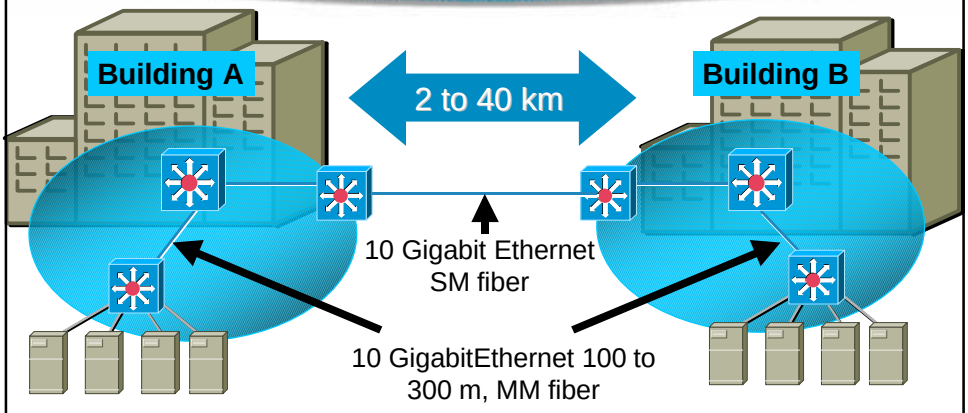
- Preserve 802.3 Ethernet frame format
- Preserve minimum and maximum frame size of current 802.3 Ethernet (No Jumbo Frames)
- Support only full duplex operation
- Support 10,000 Mbps at MAC interface
- Define two families of PHYs
  - LAN PHY operating at 10 Gbps
  - WAN PHY operating at a data rate compatible with the payload rate of OC-192c/SDH VC-4-64c

Note: Partial list

Optical Transceivers for 10 Gigabit Ethernet (802.3ae Task Force, late 2000)

PMD (Optical Transceiver)	Fiber Supported	Fiber Diameter (microns)	Fiber Bandwidth (MHz*km)	Minimum Distance (meters)
850 nm serial	Multimode	50.0	500	65
1310 nm WWDM	Multimode	62.5	160	300
	Single Mode	9.0	N.A.	10,000
1310 nm serial	Single Mode	9.0	N.A.	10,000
1550 nm serial	Single Mode	9.0	N.A.	40,000

10 Gigabit Ethernet LAN Applications



- Cost-effective bandwidth for the LAN, Switch-to-Switch
- Aggregate multiple Gigabit Ethernet segments
- 10 GigaEtherChannel will enable 20 to 80 Gbps (future)

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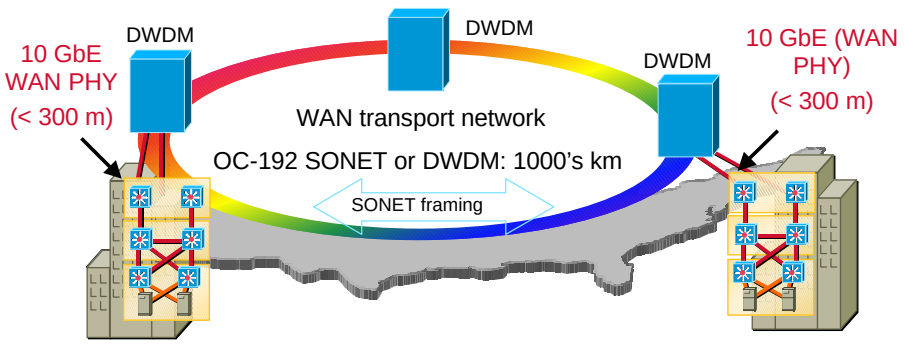
10 Gigabit Ethernet over WAN

- Attachment to the optical cloud with WAN physical layer (WAN PHY)
- Compatibility with the installed base of SONET OC-192
- No need for protocol conversion, traffic remains IP/Ethernet



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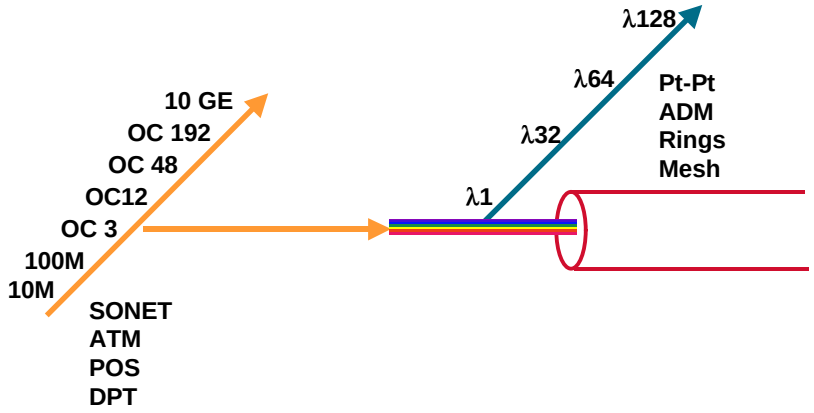
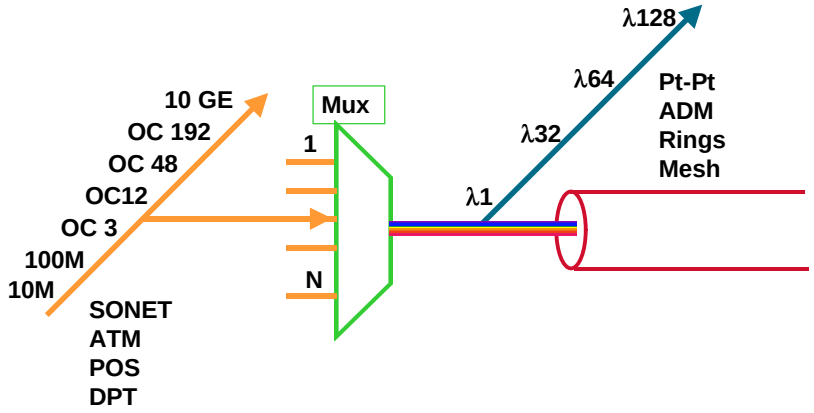
UNI PHY

- Consistent Encoding for seriel LAN PHY and SONET/SDH payload for a WAN PHY
- 64B/66B encode
- Low overhead (3%), seriel LAN PHY runs at 10.3 Gbaud
- WAN PHY solution puts 64B/66B encoded data stream into payload portion of SDH/SONET data stream

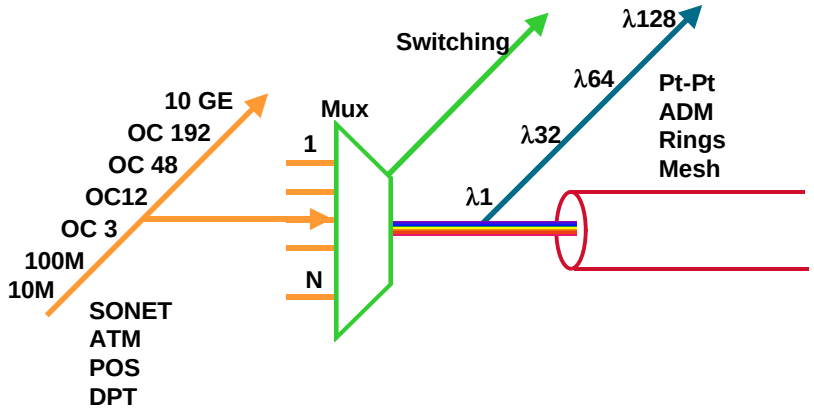
Metro DWDM Evolution



Metro DWDM Evolution

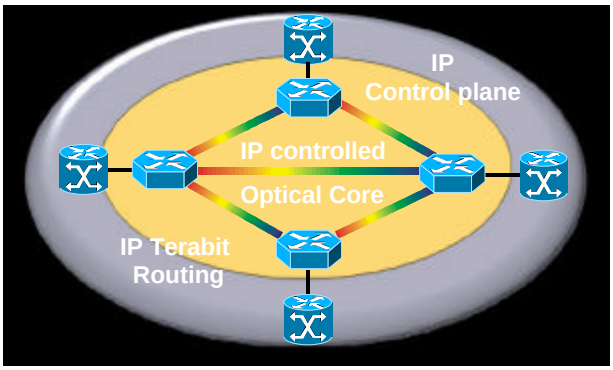


Metro DWDM Evolution



Migration to Mesh Architecture

- **Putting the "network" in optical networking**
  - **DWDM transmission**
  - **Mesh topology**
  - **A-Z provisioning**
  - **(Sub-) Wavelength switching granularity**
  - **Open protocols**
  - **Increasing distance without regeneration**



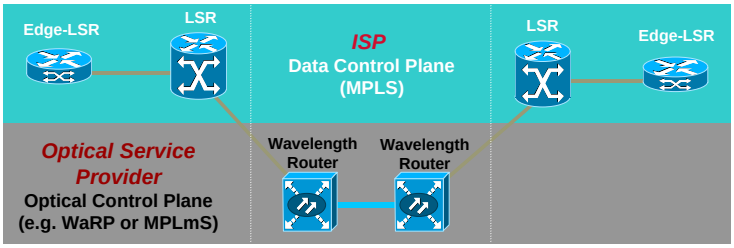
Existing Control Planes

Network Element	Standard Body	Routing	Signaling	Available
Optical Cross Connect	None	Proprietary	Proprietary	Future
ATM Switch	ATM Forum	PNNI	PNNI	Deployed
MPLS IP-LSR	IETF	Constraint Based	LDP/ RSVP	Deployed

Source: John Drake—MPLS Conference 1999

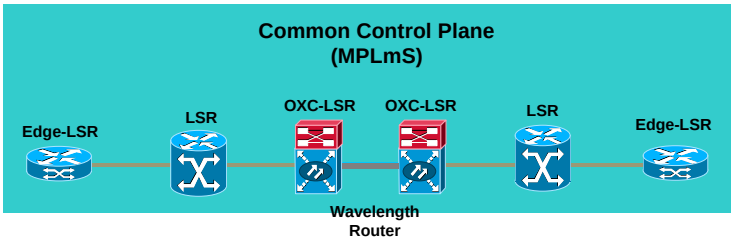
- Separate control planes exist for L1/2/3
- Limited communication creates isolation
- Results in an overlay network model

Overlay Model (O-UNI, OIF)



- Two Administrative Domains
  - Optical Transport Network
  - Internet Service Provider
- ISP requests circuits via a UNI interface
- OTN uses its own Control Plane for Provisioning

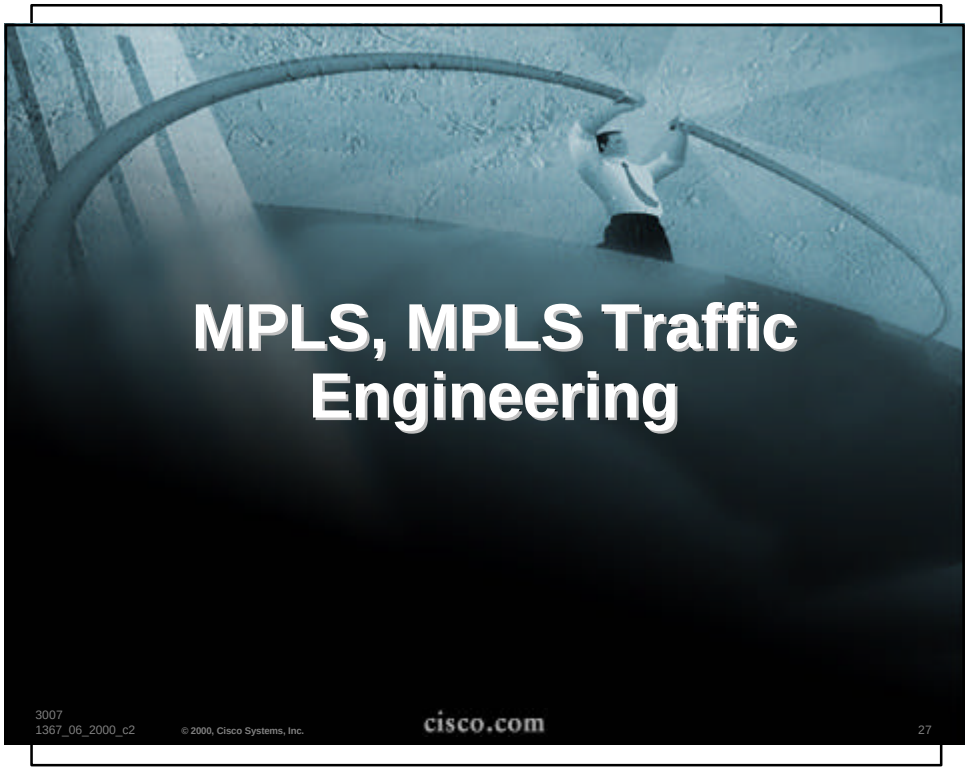
Peer Model (GMPLS, IETF)



- One Administrative Domain
- LSRs and OXC-LSR are Peers
- Common Control Plane for both L3 and OTN (full visibility of the topology at layer 3)
- reduced number of routing adjacencies

GMPLS and UNI 1.0 Comparison

	GMPLS	O-UNI	Notes
Standards Body	**IETF** (1) GMPLS based on MPLS-TE supporting peer model.	**OIF** (2) UNI 1.0 provides public UNI focused on overlay	(1) – Focus on IP control of optical networks using IP control plane (2) - Carrier driven; Transport oriented. Focus on provisioning issues.
Routing Protocol **- Intra-Domain**	**OSPF-TE** **IS-IS – TE**	**N/A** (1)	(1) – The client network routing protocol is running completely independent of the optical network routing protocol and there is no exchange of routing information at UNI
Routing Protocol **- Inter-Domain**	**O-BGP** * Very early drafts only	**N/A** (1) * Public NNI to be developed for later standard	(1) – ITU Recommendation G.709, draft 2000 Reachability information only (no topology data) is to cross the PUB-NNI.
Link Management * Including neighbor discovery, verification etc	**LMP**	**LMP** *Also includes service discovery	
Signaling Protocol	**RSVP-TE** **CR-LDP**	**RSVP-TE** **CR-LDP**	Signaling protocols used by UNI are those from RSVP, LDP and GMPLS, with extensions



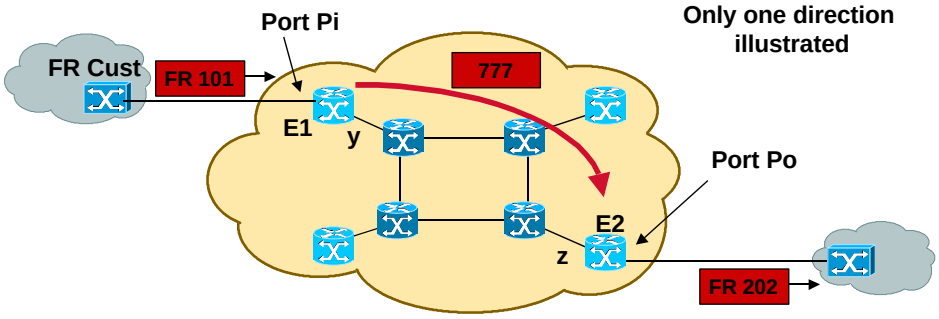
MPLS Summary

- MPLS is IETF standards based
- MPLS is accepted as a technology and products of production quality are available
- MPLS is evolving, e.g. Multicast, AToM (foo over MPLS)
- MPLS is independent of any Datalink (ATM, FR, POS, Ethernet,….)
- Not primarily implemented for reasons of performance increase
- Mainly used by Service Providers, but recently also by Enterprise customers

MPLS as Service Enabler

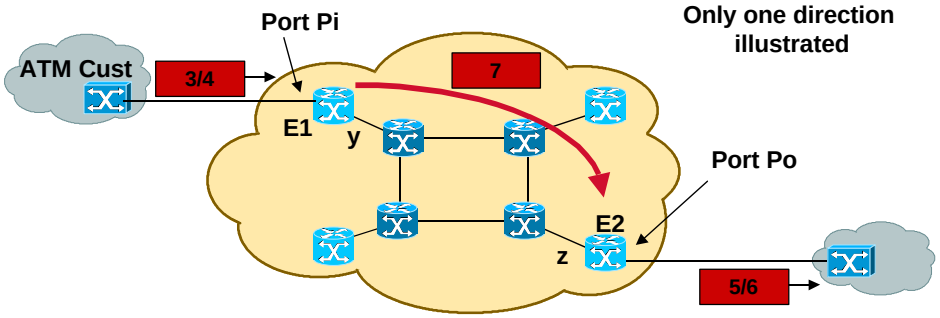
- VPN
- Traffic Engineering
- Sub-50ms Link/Node protection
- QoS
- foo over MPLS (Frame Relay, ATM, Ethernet)

FR over MPLS



DLCI	In-EdgeLSR	In-Port	Out-EdgeLSR	OutPort	Out-DLCI
101	E1	Pi	E2	Po	202

AAL5 over MPLS



vpi/vci	In-ELSR	In-Port	Out-LSR	OutPort	vpi/vci
3/4	E1	Pi	E2	Po	5/6

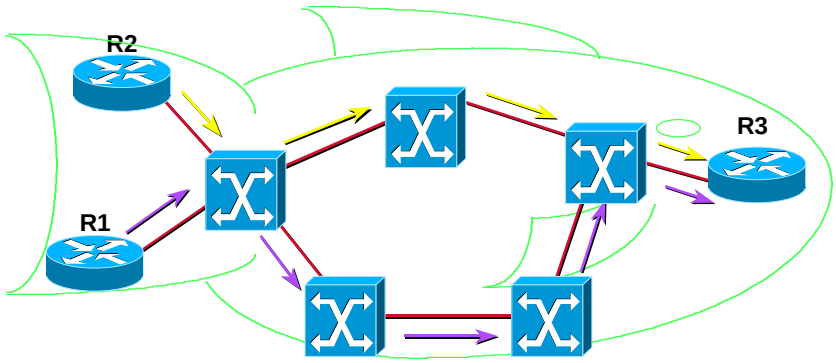
Traffic Engineering: Motivations

What is MPLS Traffic Engineering ?

MPLS TE is an optimization tool

- **Reduce the overall cost of operations by more efficient use of bandwidth resources by preventing a situation where some parts of a service provider network are over-utilized (congested), while other parts under-utilized**

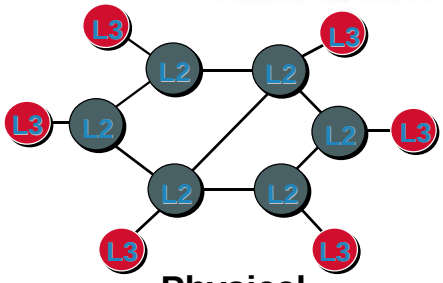
Traffic engineering with Layer 2 (e.g. ATM or Frame Relay)



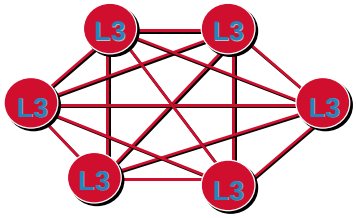
PVC for R2 to R3 traffic

PVC for R1 to R3 traffic

The "Overlay" Solution (e.g. ATM)



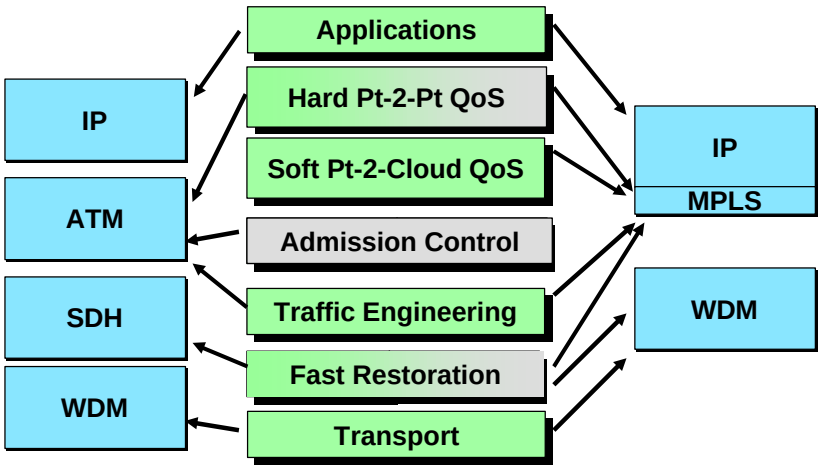
Physical



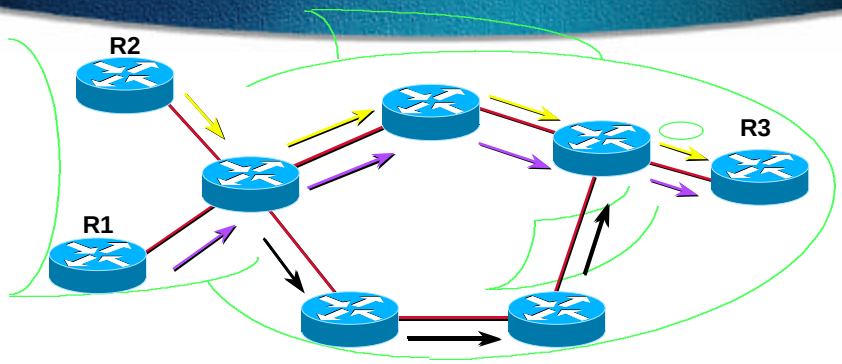
Logical

- Routing at layer 2 (ATM or FR) is used for traffic engineering
- Layer 3 sees a complete mesh. Routing at layer 3 is trivial (but poor scalability)

MPLS as the MultiService Infrastructure: Layer Collapsing



IP Traffic engineering with Layer 3



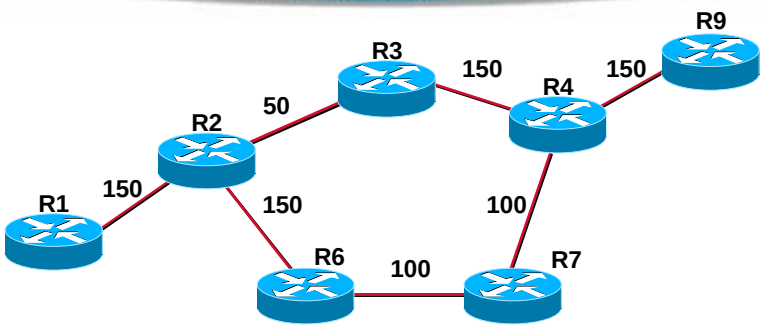
IP routing: destination-based least-cost routing

Path for R2 to R3 traffic

Path for R1 to R3 traffic

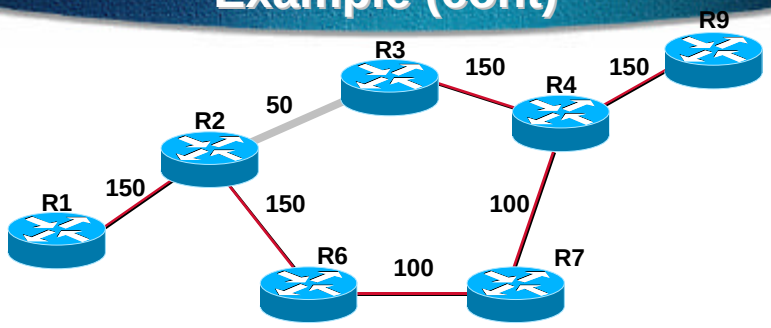
under-utilized alternate path

MPLS Traffic Engineering Example



Trying to route a trunk from R1 to R9 with bandwidth 75 Mbps

MPLS Traffic Engineering Example (cont)



Path Computation

CSPF computes paths that obey the various constraints and select the "best" one (shortest metric).

Trying to route a trunk from R1 to R9 with bandwidth 75 Mbps

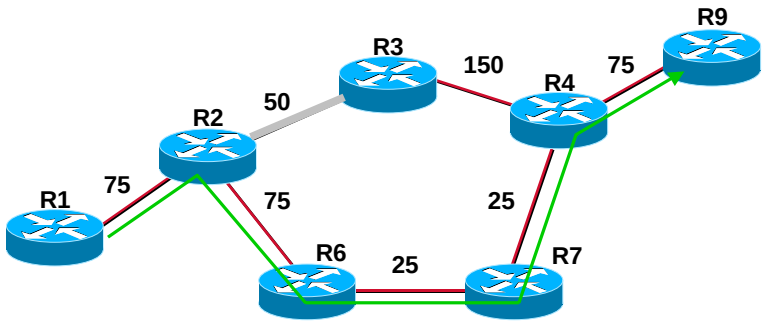
R2-R3 link violates constraint (BW ≥ 75) so prune it

Pick shortest path on remaining topology

MPLS Traffic Engineering Example (cont.)

Path Setup

establishes (explicit) routes for traffic trunks. The signaling protocol to establish the path is RSVP (with extension).



Protection/restoration in IP/MPLS networks

- **Many various protection/restoration schemes exist today:**
  - **Optical protection**
  - **Sonet/SDH (link): offering a 50ms convergence time, largely deployed and stable**
  - **IP (link & node): Convergence = O(sec)**
  - **MPLS TE Fast Reroute (link & node) 50 msec convergence.**

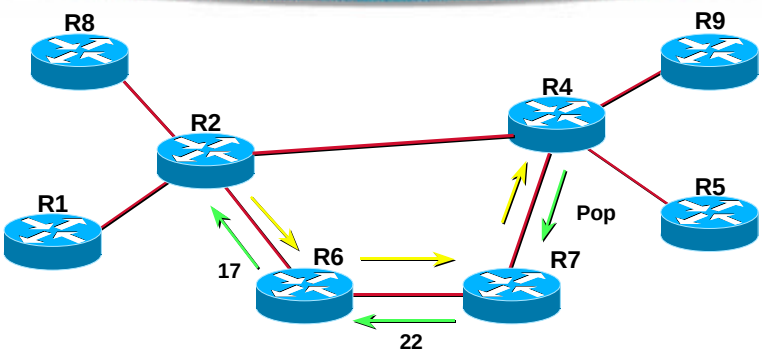
Path Protection

- Controlled by the head-end of a trunk
- Fallback to either (pre)configured or dynamically computed path
- Once the head-end has detected that the TE LSP has suffered a failure (through the IGP and/or RSVP), the TE LSP is being re signalled following the new path (if any)

MPLS TE FRR Link/Node Protection

- Controlled by the routers at ends of a failed link (know as MPLS TE Fast Reroute).
- FRR is a local protection mechanism
  - * link protection is configured on a per link basis
  - * the resilience attribute of a trunk allows to control whether link protection could be applied to the trunk which offers a fine granularity
- Uses nested LSPs (stack of labels)
  - * original LSP nested within link protection LSP

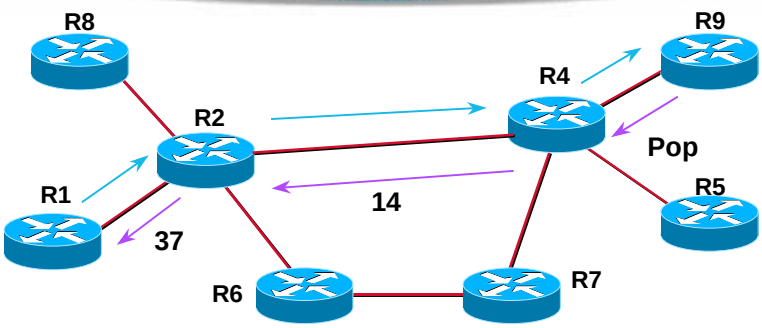
Link protection for R2-R4 link



Setup: Path (R2->R6->R7->R4)

Labels Established on Resv message

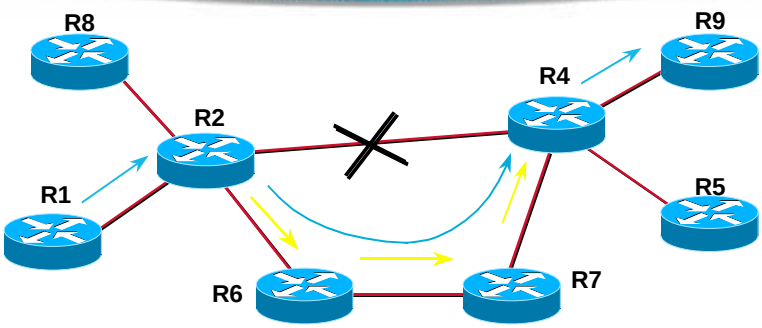
Routing prior R2-R4 link failure



Setup: Path (R1->R2->R4->R9)

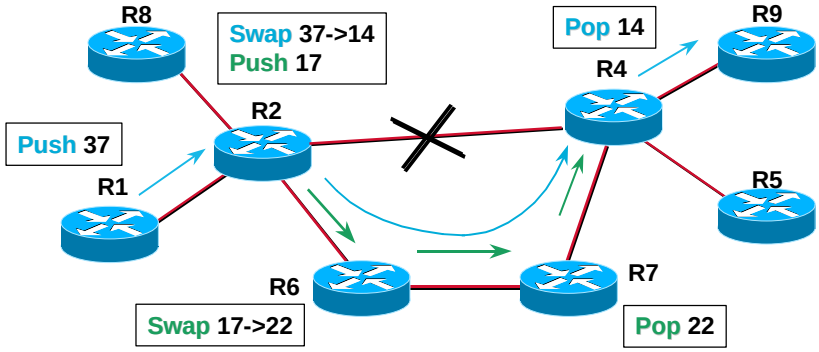
Labels Established on Resv message

Link Protection Active



On failure of link from R2 -> R4, R2 simply changes outgoing Label Stack from 14 to <17, 14>

Link Protection Active



Label Stack:	R1	R2	R6	R7	R4	R9
	37	17	22	14	None	
		14	14			

MPLS TE FRR

- FRR Link protection is available today.
- FRR Node protection is the next step.
- Tools to perform TE LSP back-up placement are under study

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