

# **IP Over DWDM: Issues and Standards**

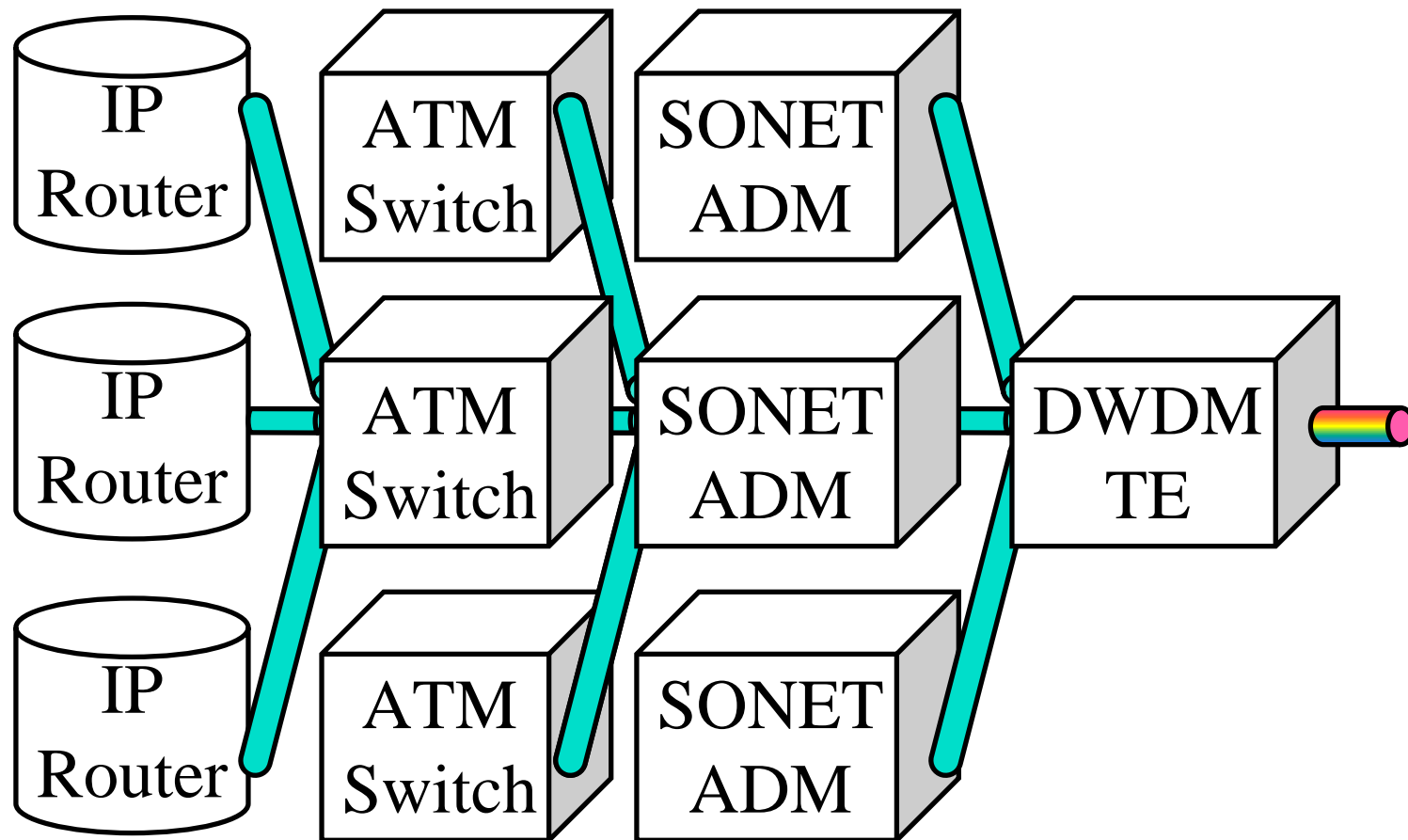
Raj Jain  
Co-Founder and CTO  
Nayna Networks  
481 Sycamore Drive  
Milpitas, CA 95035  
raj@nayna.com

These slides are available at:

<http://www.cis.ohio-state.edu/~jain/talks/itcom01.htm>

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# IP over DWDM (Past)

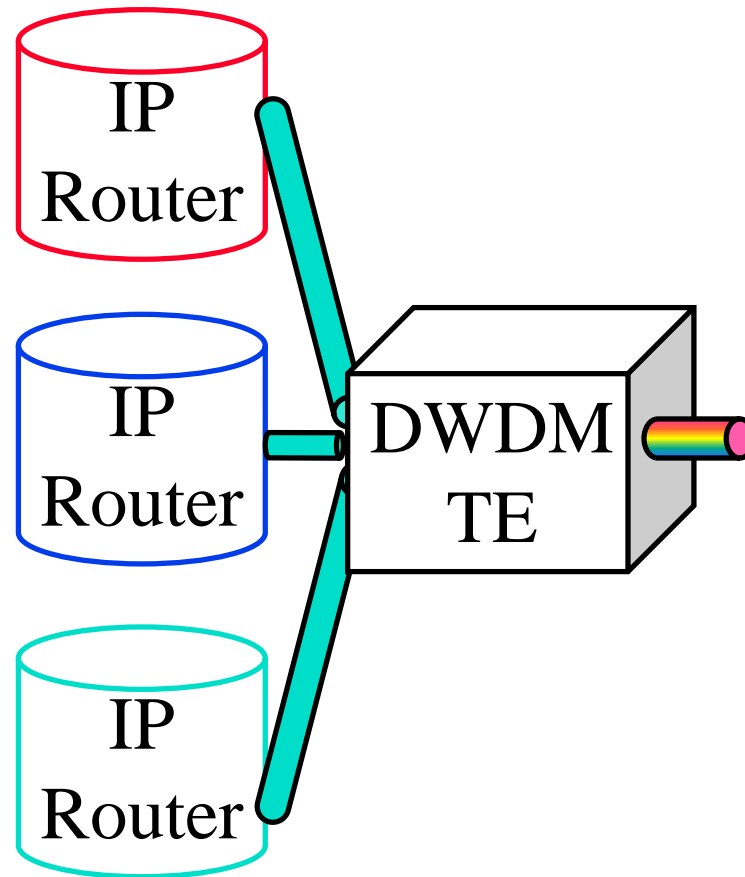


# IP over DWDM: Protocol Layers

1993	1996	1999	2001	2003
IP	IP	IP/MPλS	IP/GMPLS	IP/GMPLS
ATM	PPP	PPP	Ethernet	Ethernet
SONET	SONET	SONET Framing	SONET Framing	
DWDM	DWDM	DWDM	DWDM	DWDM
Fiber	Fiber	Fiber	Fiber	Fiber

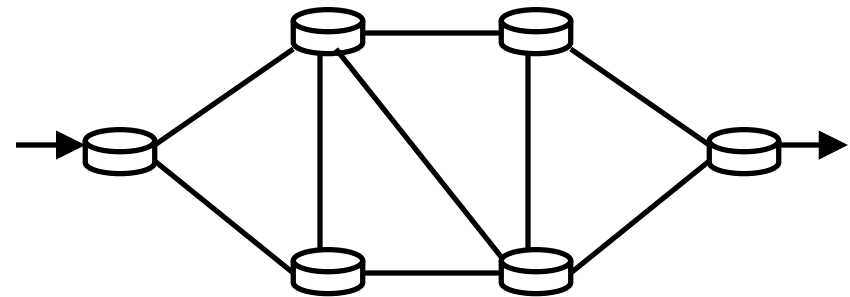
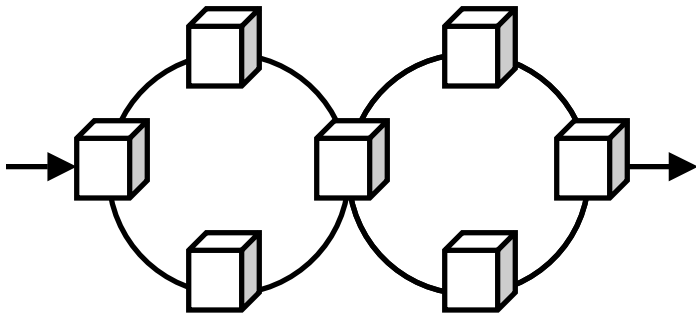
- ❑ IP is good for routing, traffic aggregation, resiliency
- ❑ ATM for multi-service integration, QoS/signaling
- ❑ SONET for traffic grooming, monitoring, protection
- ❑ DWDM for capacity
- ❑ Problem: Restoration in multiple layers, Sonet Manual  
 ⇒ Intersection of features and union of problems<sub>Raj Jain</sub>

# IP over DWDM (Future)



# Telecom vs Data Networks

	Telecom Networks	Data Networks
Topology Discovery	Manual	Automatic
Path Determination	Manual	Automatic
Circuit Provisioning	Manual	No Circuits
Transport & Control Planes	Separate	Mixed
User and Provider Trust	No	Yes
Protection	Static using Rings	No Protection

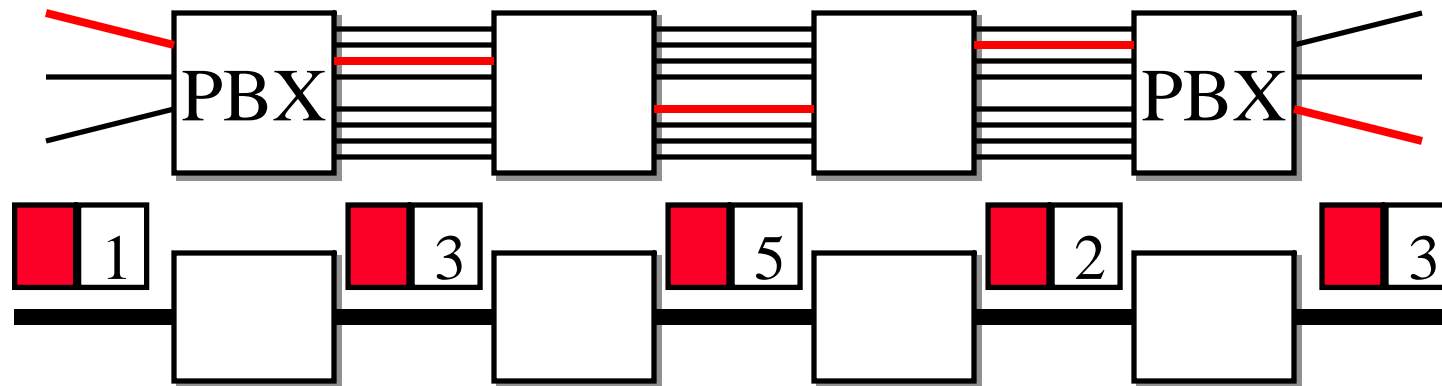


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# IP over DWDM Issues

1. Circuits
2. Data and Control plane separation
3. Signaling
4. Addressing
5. Protection and Restoration

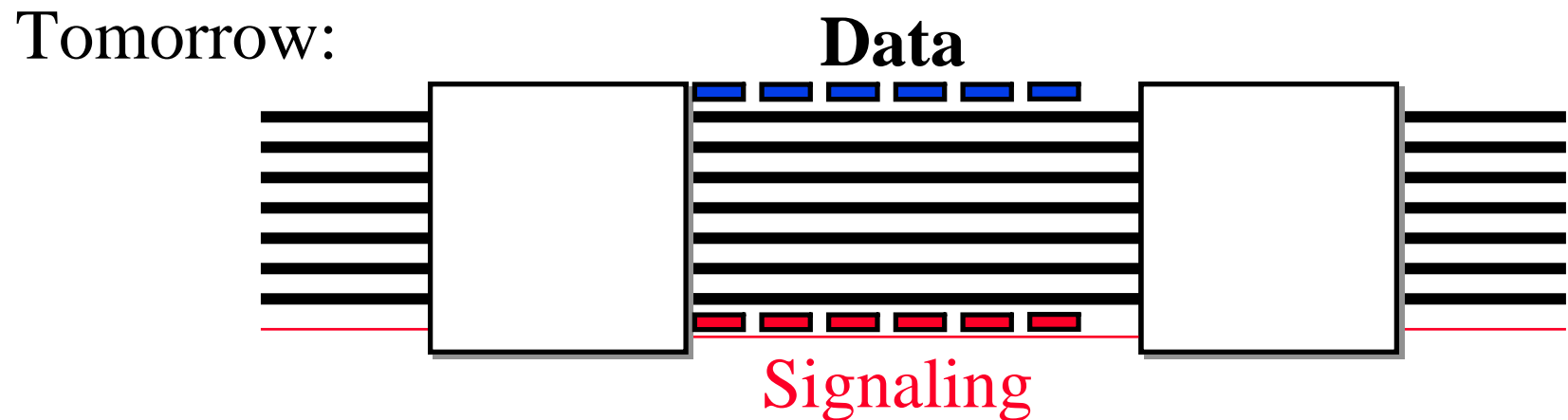
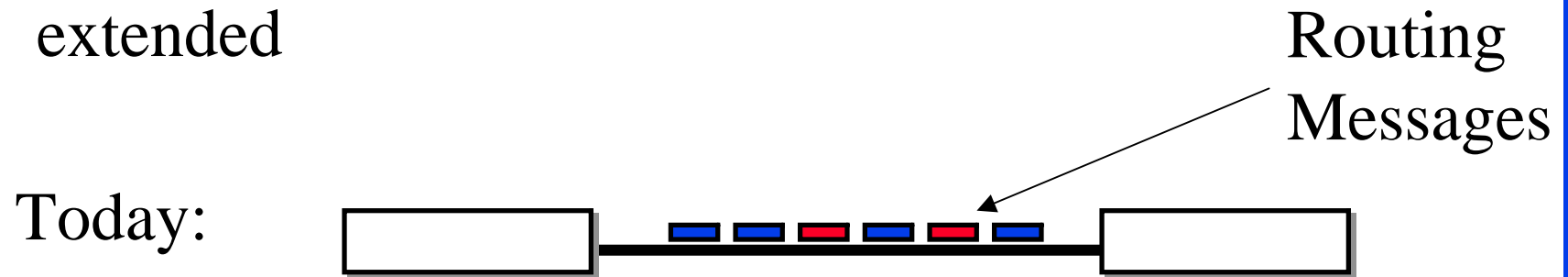
# Multiprotocol Label Switching (MPLS)



- ❑ Allows circuits in IP Networks (May 1996)
- ❑ Each packet has a circuit number
- ❑ Circuit number determines the packet's queuing and forwarding
- ❑ Circuits have to be set up before use
- ❑ Circuits are called Label Switched Paths (LSPs)

# Issue: Control and Data Plane Separation

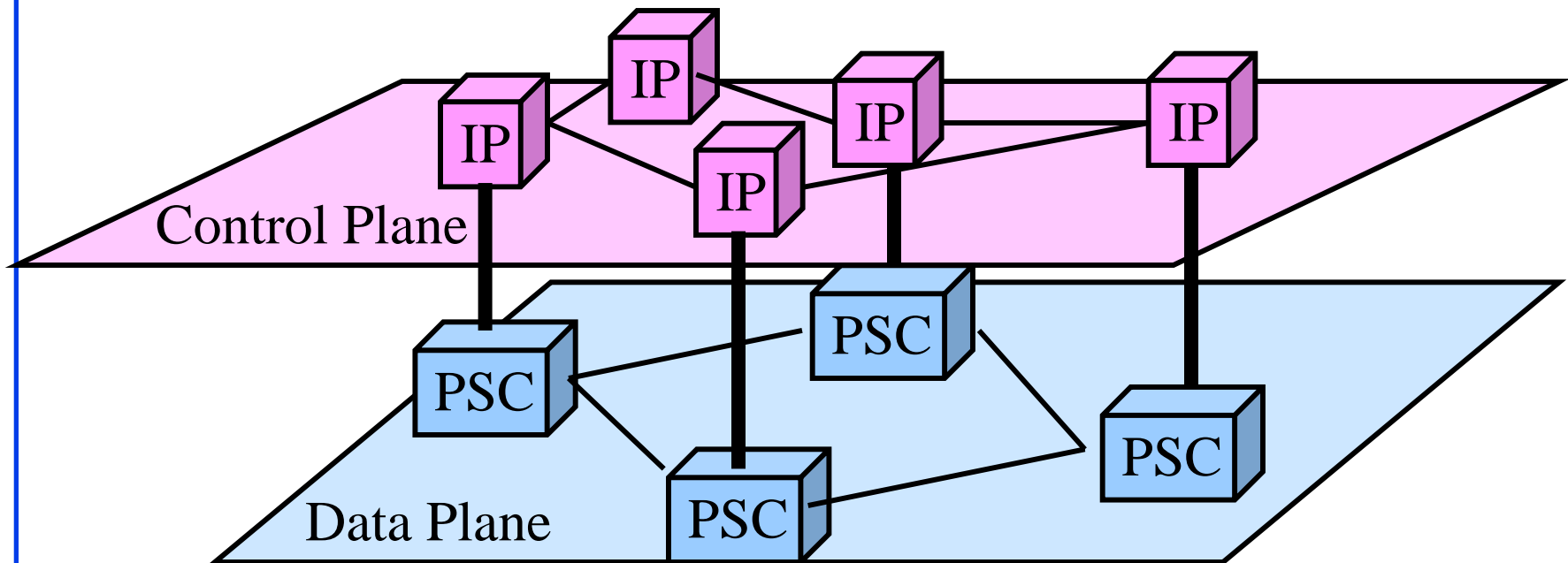
- ❑ Separate control and data channels
- ❑ IP routing protocols (OSPF and IS-IS) are being extended



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# IP-Based Control Plane

- Control is by IP packets (electronic).  
Data can be any kind of packets (IPX, ATM cells).  
⇒ MPLS

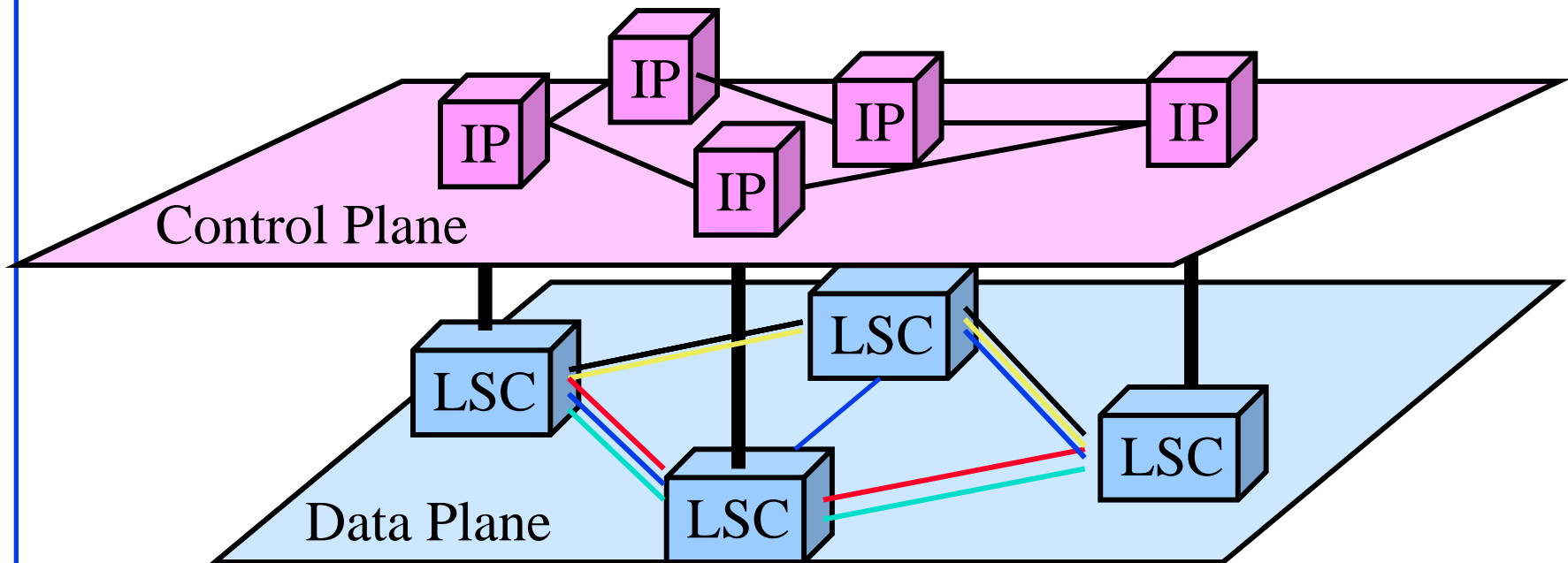


PSC = Packet Switch Capable Nodes

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# MP $\lambda$ S

- Control is by IP packets (electronic).  
Data plane consists of wavelength circuits  
 $\Rightarrow$  Multiprotocol Lambda Switching (October 1999)

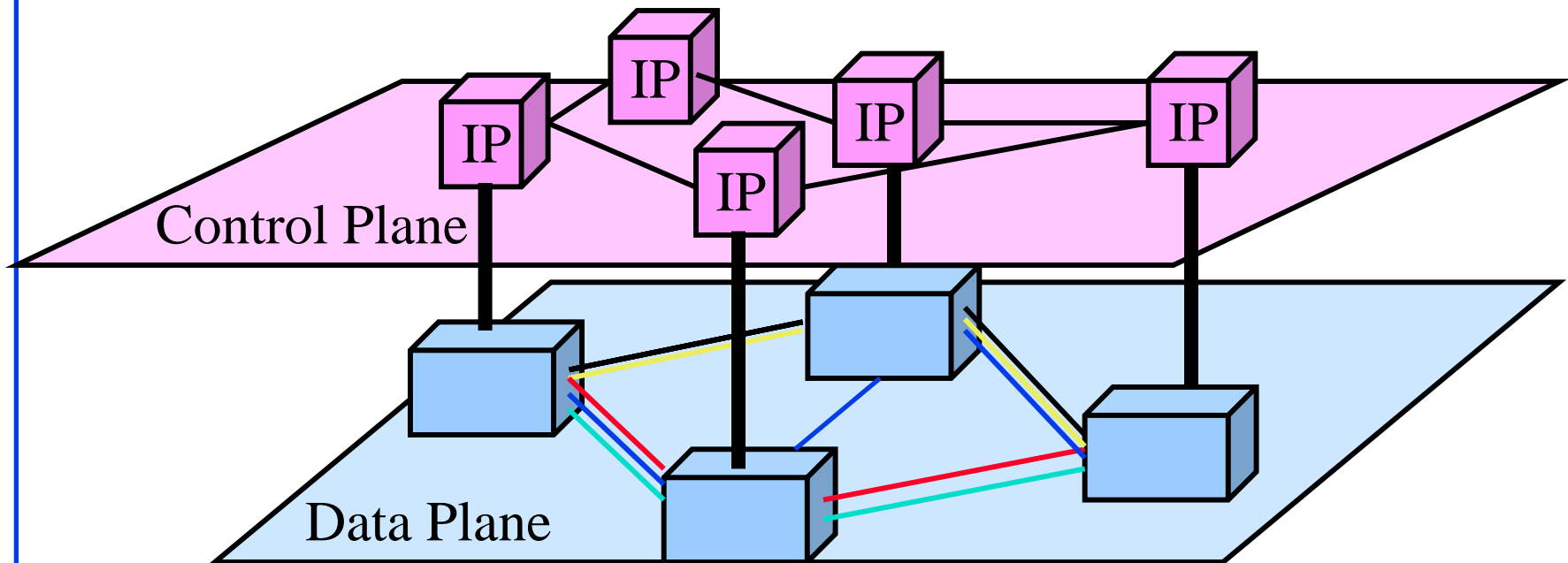


LSC = Lambda Switch Capable Nodes  
= Optical Cross Connects = OXC

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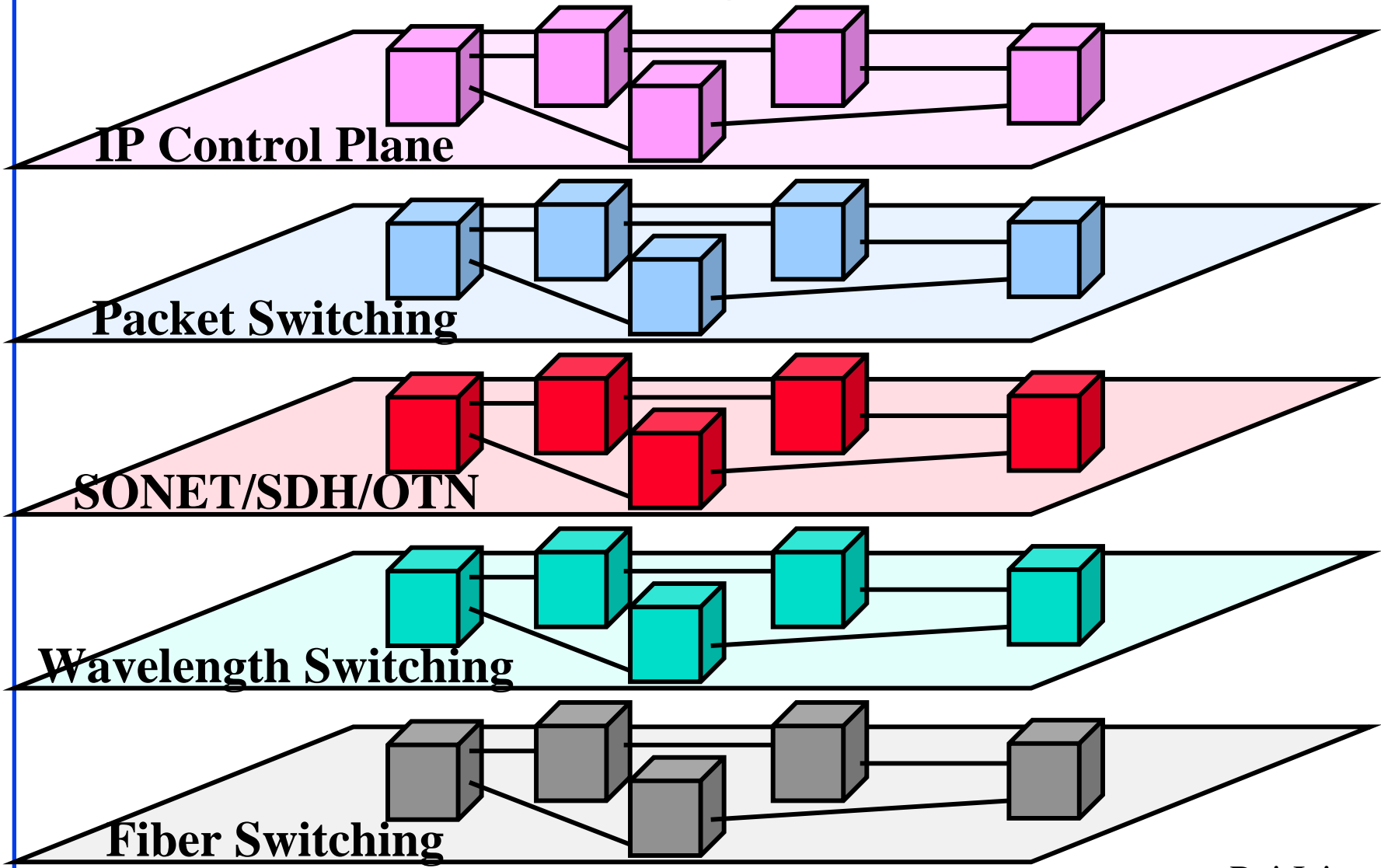
# GMPLS

- Data Plane = Wavelengths, Fibers, SONET Frames, Packets (October 2000)



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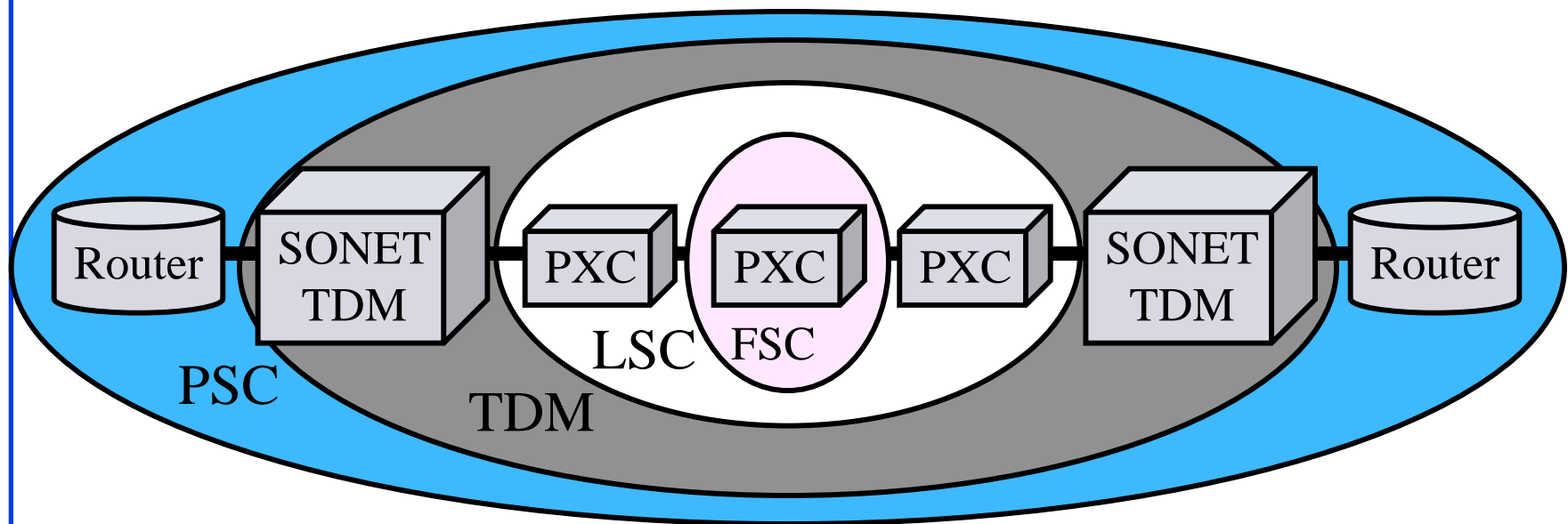
# GMPLS: Layered View



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# GMPLS: Hierarchical View

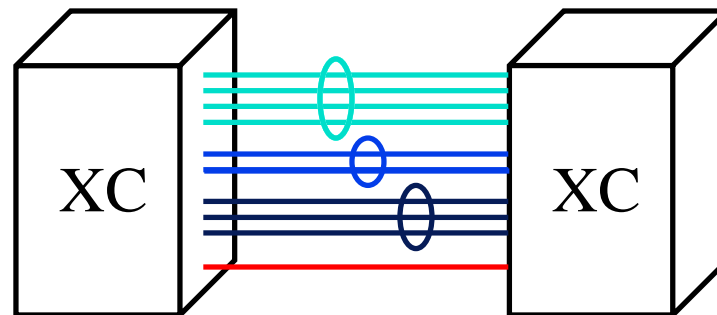
- ❑ Packets over SONET over Wavelengths over Fibers
- ❑ Packet switching regions, TDM regions, Wavelength switching regions, fiber switching regions



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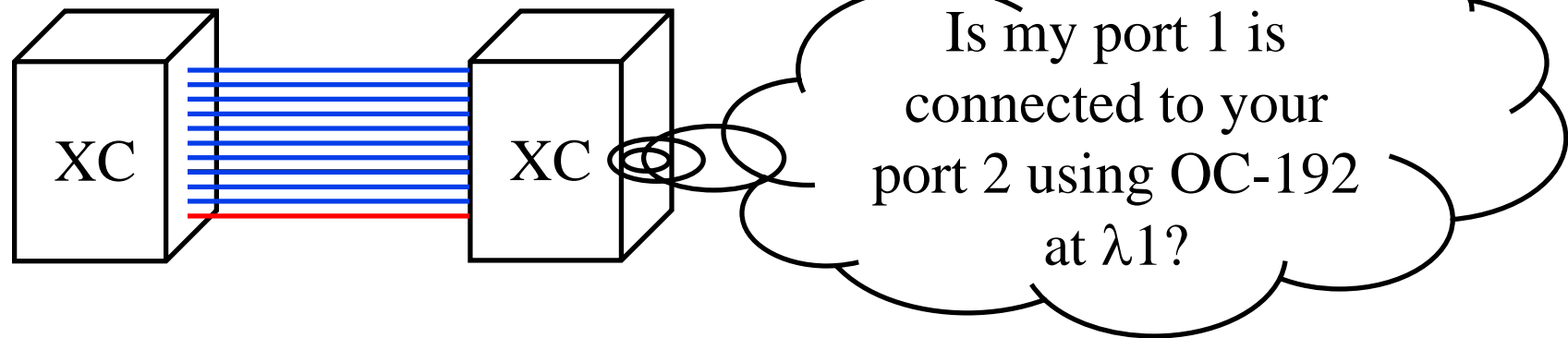
# MPLS vs GMPLS

Issue	MPLS	GMPLS
Data & Control Plane	Same channel	Separate
Types of Nodes and labels	Packet Switching	PSC, TDM, LSC, FSC, ...
Bandwidth	Continuous	Discrete: OC-n, $\lambda$ 's, ..
# of Parallel Links	Small	100-1000's
Port IP Address	One per port	Unnumbered
Fault Detection	In-band	Out-of-band or In-Band



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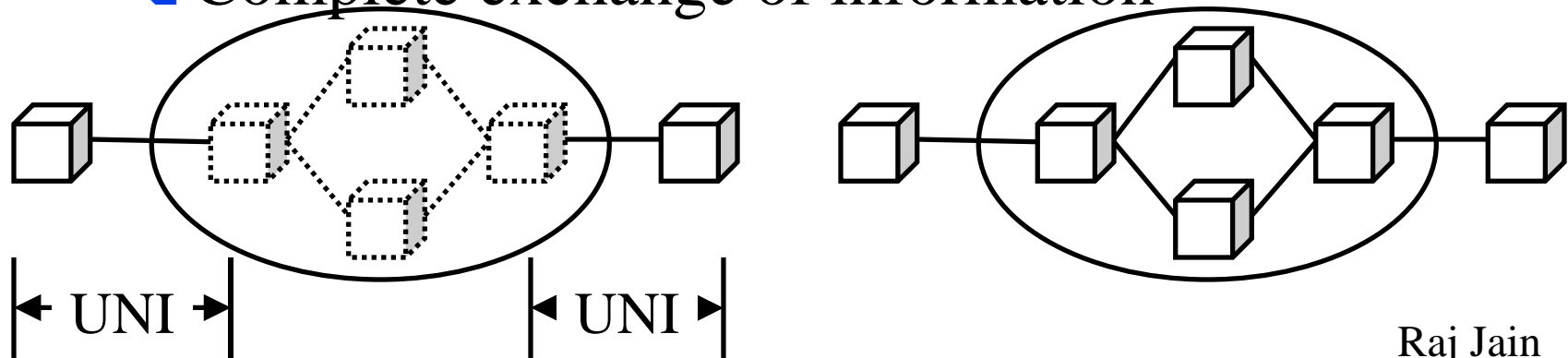
# Link Management Protocol (LMP)



- ❑ Too many channels between crossconnects
- ❑ LMP allows connectivity verification, link parameter correlation, fault notification
- ❑ All communication takes place on control channel
- ❑ Only test messages on data channels to verify connectivity (optional)

# Issue: UNI vs Peer-to-Peer Signaling

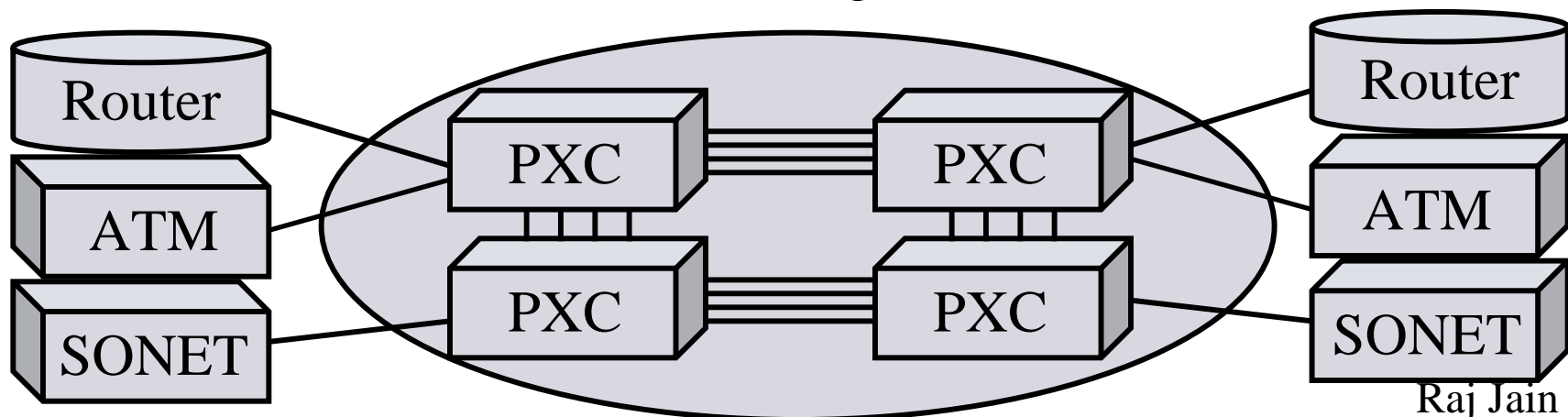
- Two Business Models:
  - Carrier: Overlay or cloud
    - Network is a black-box
    - User-to-network interface (UNI) to create/destroy light paths (in OIF)
  - Enterprise: Peer-to-Peer
    - Complete exchange of information



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# Addressing

- ❑ Many different client types IP, ATM, SONET, ...  
Each type has its own address: IPv4, IPv6, ATM, ...
- ❑ Should a client be addressed by Switch and Port #?
- ❑ **Answer:** Optical Network Assigned Address (ONA)  
Globally Unique. Like Phone Number.
- ❑ Address Resolution Protocol to register and resolve  
name to ONA. Connect using ONA.



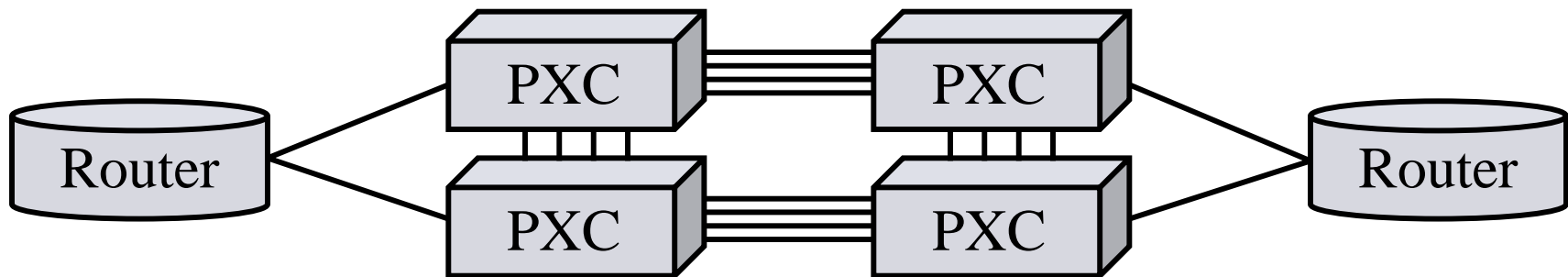
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# Current Issues

- ❑ Protection and Restoration
- ❑ Fault detection and isolation
- ❑ All-Optical networks
- ❑ Network-network Interface

# Protection and Restoration

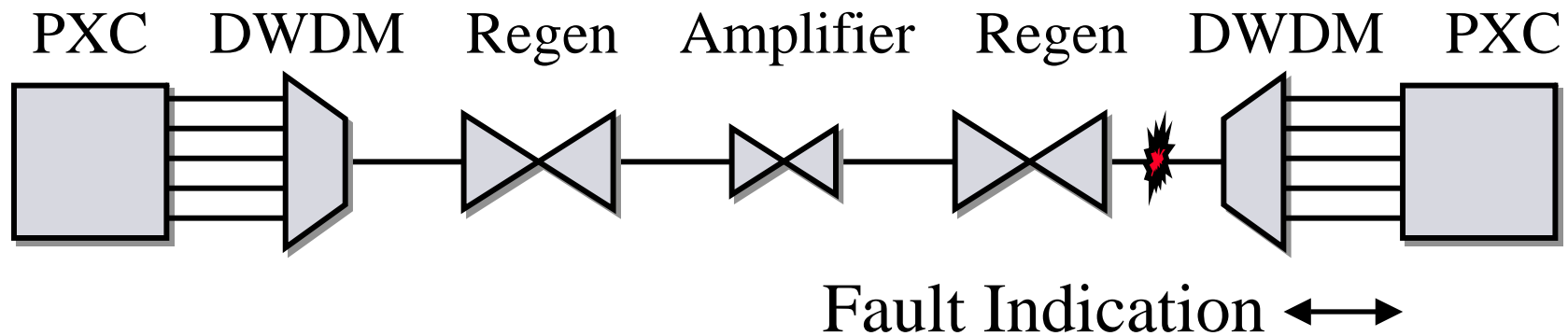
- ❑ Extent: SPAN vs PATH
- ❑ Topology: Ring vs Mesh
- ❑ Redundancy: 1+1, 1:1
- ❑ Finding Paths that do not share the same risk  
Each link has to be assigned a risk group  
Shared Risk Group (**SRG**) = All paths sharing a risk



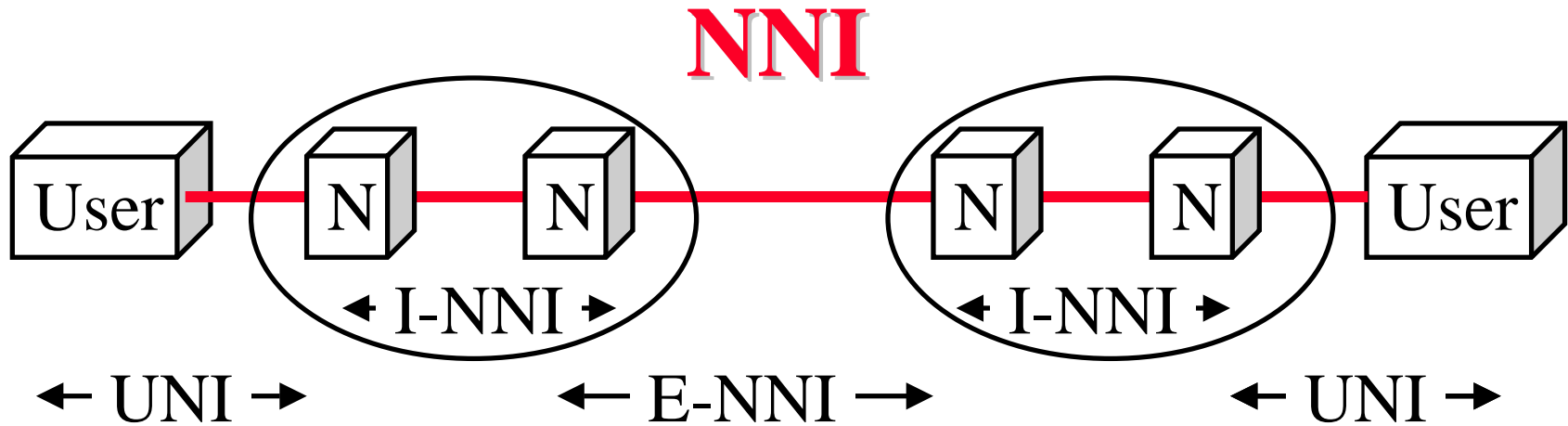
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# Fault Detection and Isolation

- ❑ SONET: Remote Defect Indicator, Alarm Indication Signal, Bit Interleaved Parity
- ❑ Photonic: Loss of signal, Optical degradation of signal
- ❑ Solution: A protocol for active devices to communicate fault information to Photonic switches  
Examples: LMP-DWDM, NTIP



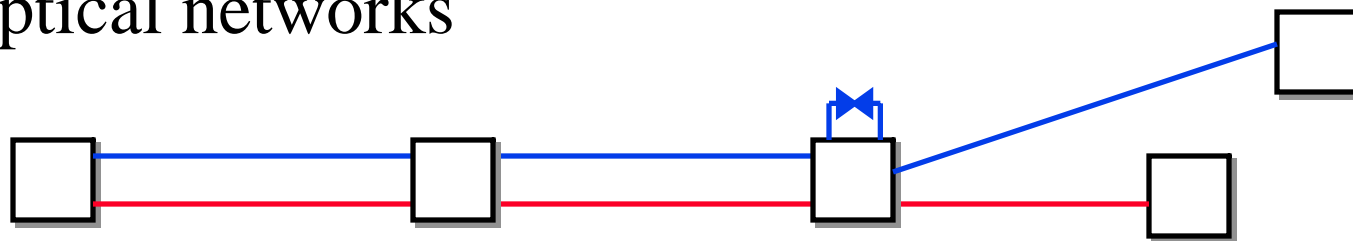
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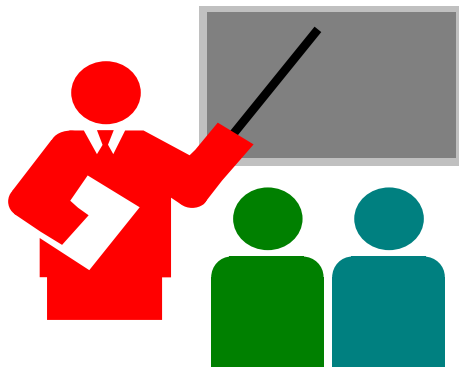
- NNI = Network to Network or  
Node-to-Node or  
Network-to-Node Interface
- Examples: Open Shortest Path First (OSPF)  
Private Network to Node Interface (PNNI)
- OIF is starting a new project on NNI

# All-Optical Networks

- All-Optical  $\Rightarrow$  No electronic conversion
  - $\Rightarrow$  No wavelength conversion
  - $\Rightarrow$  No 3R regeneration
- Optical degradations (attenuation, chromatic dispersion, Polarization Mode Dispersion, ...) limit the paths
- Non-linear function of distance and non-additive
- OIF is about to start a new project to address all-optical networks



# Summary



1. Separation of control and data plane  
IP-Based control plane
2. Transport Plane = Packets  $\Rightarrow$  MPLS  
Transport Plane = Wavelengths  $\Rightarrow$  MP $\lambda$ S  
Transport Plane =  $\lambda$ , SONET, Packets  $\Rightarrow$  GMPLS
3. UNI allows users to setup paths on demand
4. Starting on all-optical networks, protection, fault management, and NNI

# IP over DWDM: Key References

- ❑ Detailed references in [http://www.cis.ohio-state.edu/~jain/refs/opt\\_refs.htm](http://www.cis.ohio-state.edu/~jain/refs/opt_refs.htm)
- ❑ Recommended books on optical networking, [http://www.cis.ohio-state.edu/~jain/refs/opt\\_book.htm](http://www.cis.ohio-state.edu/~jain/refs/opt_book.htm)
- ❑ Optical Networking and DWDM, <http://www.cis.ohio-state.edu/~jain/cis788-99/dwdm/index.html>
- ❑ IP over Optical: A summary of issues, (internet draft) <http://www.cis.ohio-state.edu/~jain/ietf/issues.html>
- ❑ Lightreading, <http://www.lightreading.com>

# Standards Organizations

- ❑ IETF: [www.ietf.org](http://www.ietf.org)
  - Multiprotocol Label Switching (MPLS)
  - IP over Optical (IPO)
  - Traffic Engineering (TE)
  - Common Control and Management Plane (CCAMP)
- ❑ Optical Internetworking Forum (OIF):  
[www.oiforum.com](http://www.oiforum.com)
- ❑ ANSI T1X1.5: [http://www.t1.org/t1x1/\\_x15-hm.htm](http://www.t1.org/t1x1/_x15-hm.htm)
- ❑ ITU, [www.itu.ch](http://www.itu.ch), Study Group 15 Question 14 and Question 12
- ❑ Optical Domain Service Interface (ODSI)
  - Completed December 2000