

Recent Developments in Optical Networking

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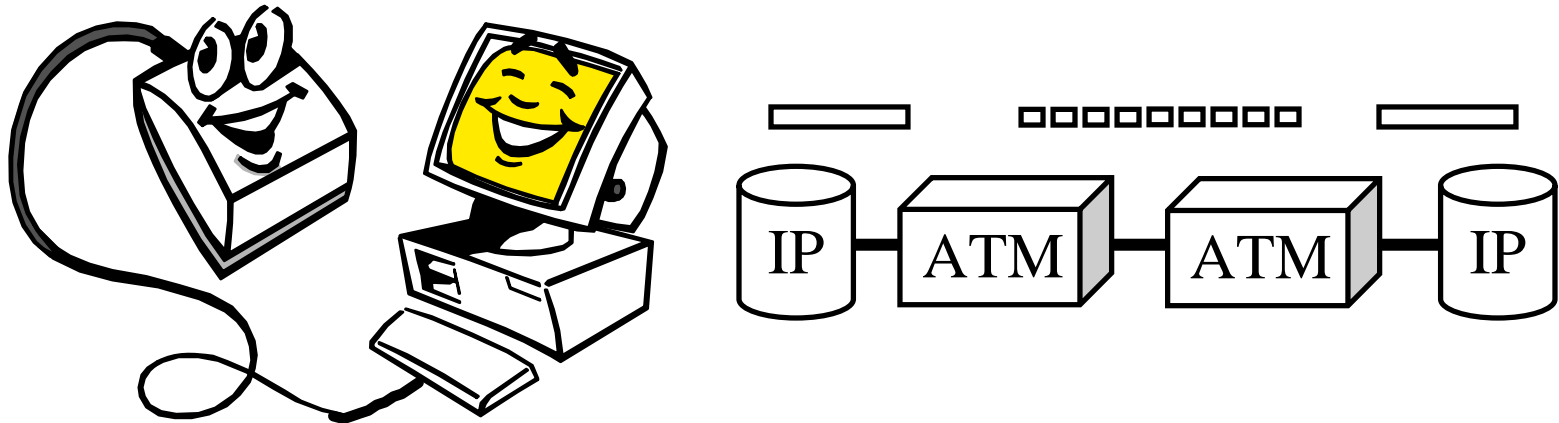
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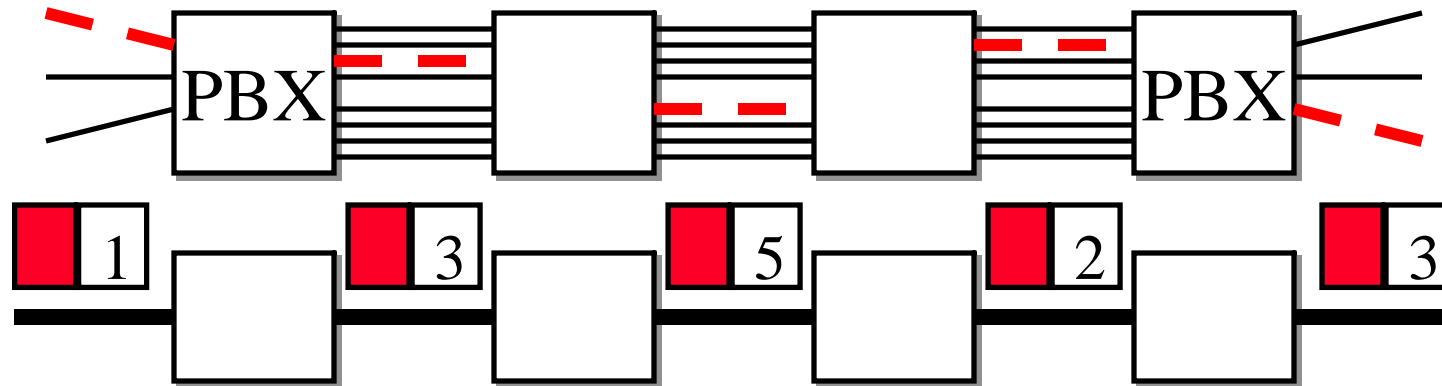
- ❑ All-Optical Networking
- ❑ IP over DWDM
- ❑ UNI
- ❑ ASTN/ASON
- ❑ MPLS, MP λ S, GMPLS
- ❑ Upcoming optical technologies

ATM Networks



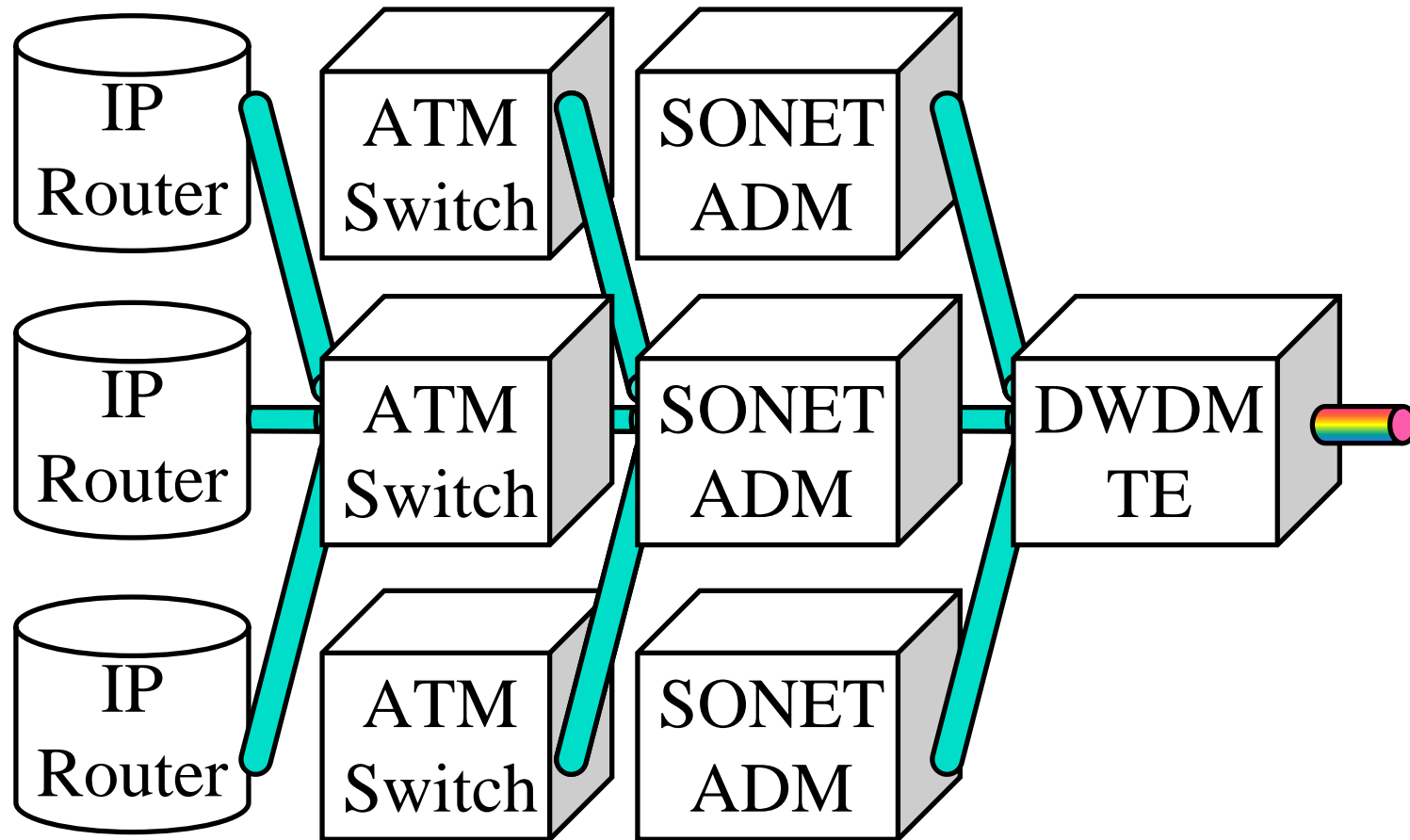
- ❑ Asynchronous Transfer Mode
- ❑ Best of packet switching and circuit switching
- ❑ All cells are 53 bytes long (48 bytes payload + 5 bytes header)
- ❑ Connection oriented technology. ATM Switches.
- ❑ Allows both voice and data on the same network

Virtual Circuit Switching



- ❑ Original phone networks has real circuit switching
- ❑ X.25, Frame Relay, ATM have virtual circuits
- ❑ Each ATM cell has a virtual circuit (VC) number
- ❑ VC # determines the cell's queuing and forwarding
- ❑ VCs have be set up before use

IP over DWDM (Past)

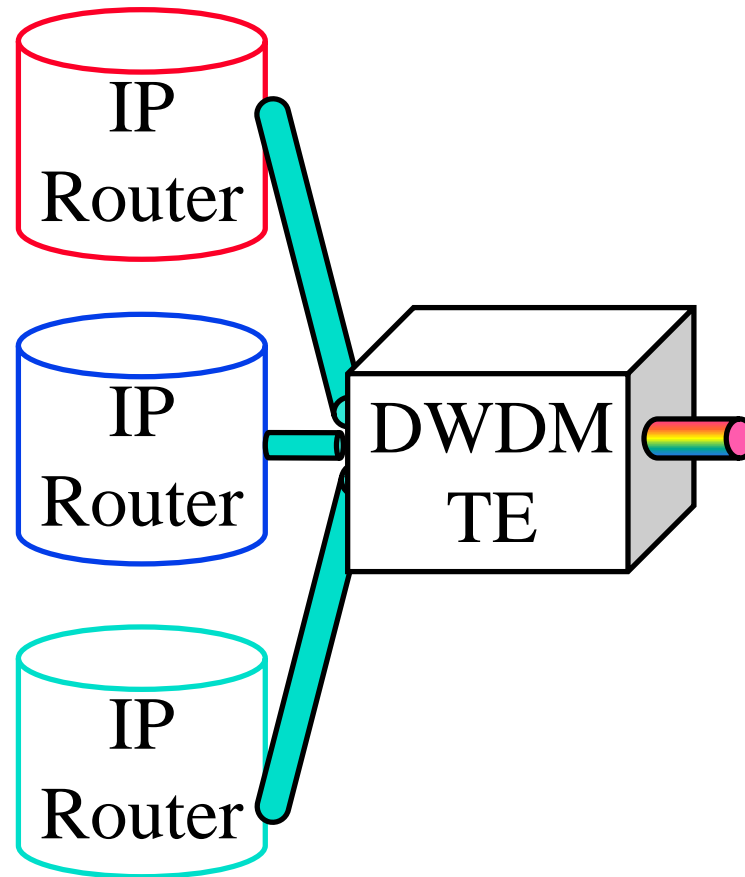


IP over DWDM: Protocol Layers

1993	1996	1999	2001	2005
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

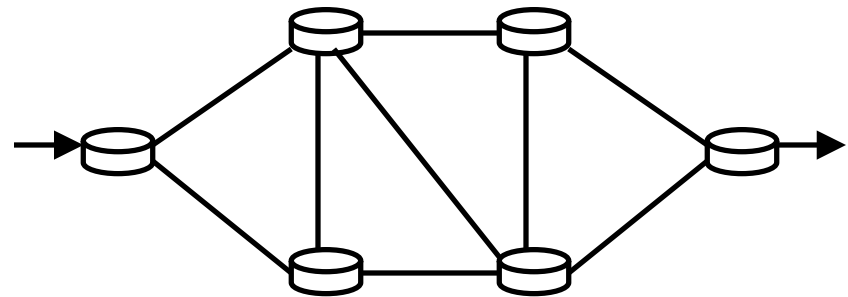
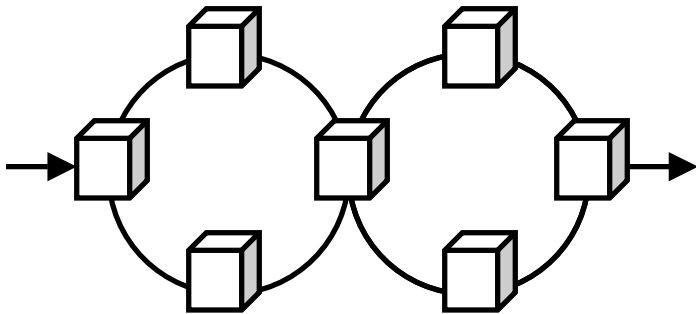
- ❑ IP is good for routing, traffic aggregation, resiliency
- ❑ ATM for multi-service integration, QoS/signaling
- ❑ SONET for traffic grooming, monitoring, protection
- ❑ DWDM for capacity
- ❑ Problem: Restoration in multiple layers, Sonet Manual
⇒ Intersection of features and union of problems

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

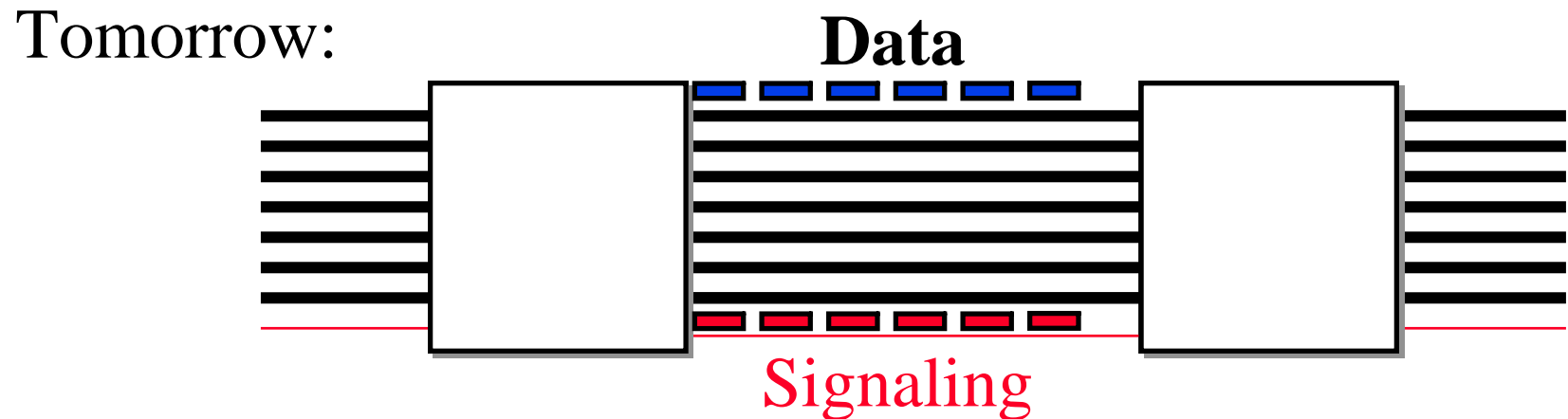
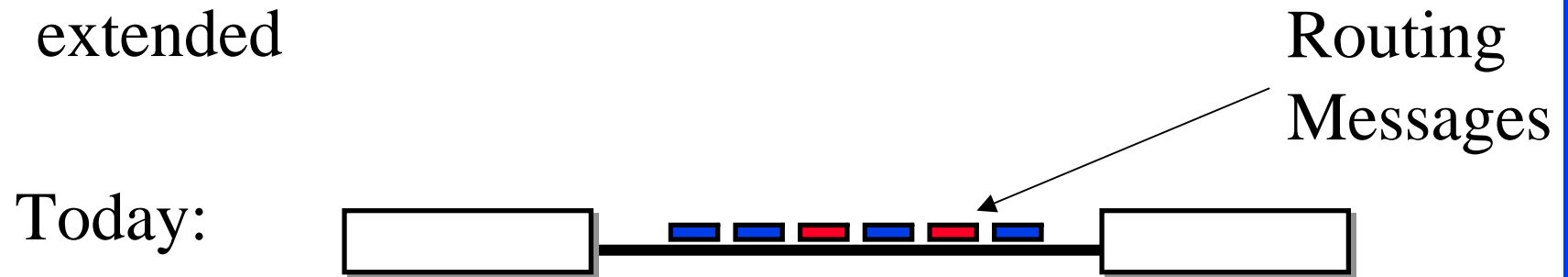


IP over DWDM Issues

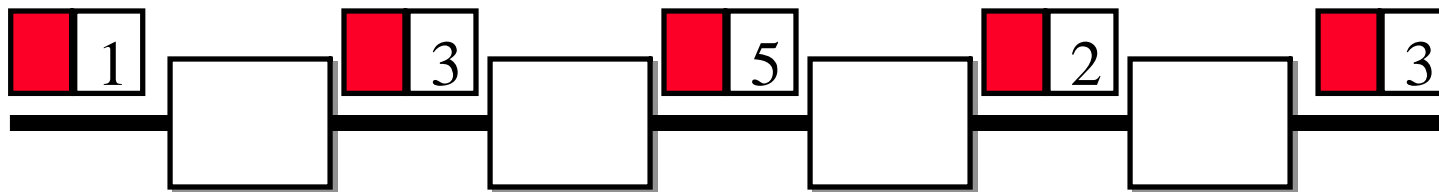
1. Data and Control plane separation
2. Circuits
3. Signaling
4. Addressing
5. Protection and Restoration

Issue: Control and Data Plane Separation

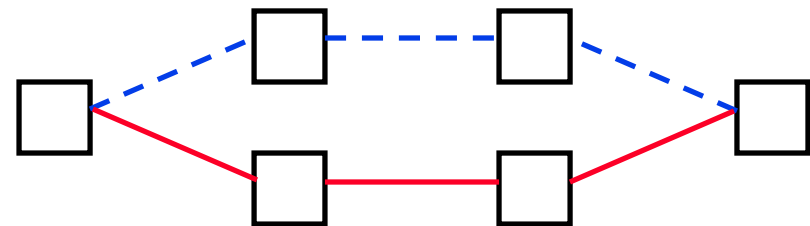
- ❑ Separate control and data channels
- ❑ IP routing protocols (OSPF and IS-IS) are being extended



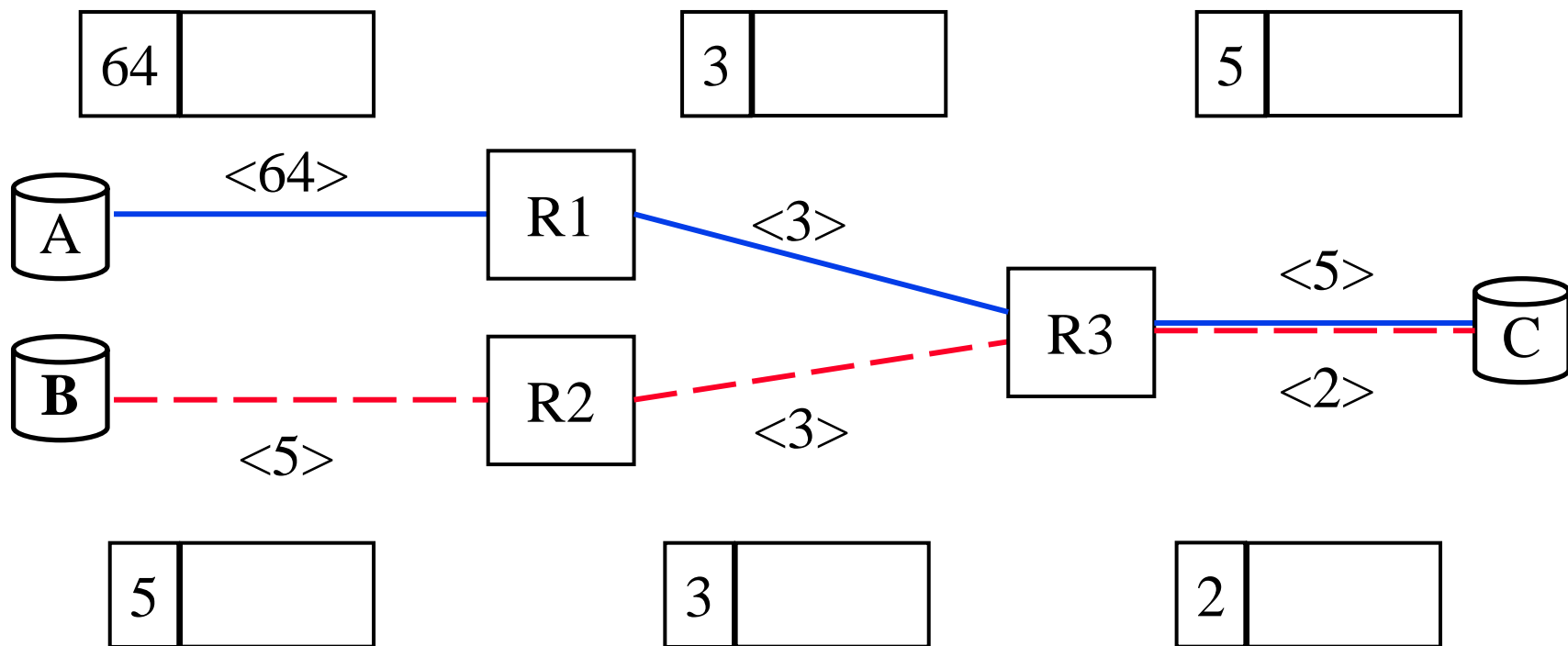
Multiprotocol Label Switching (MPLS)



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



Label Switching Example

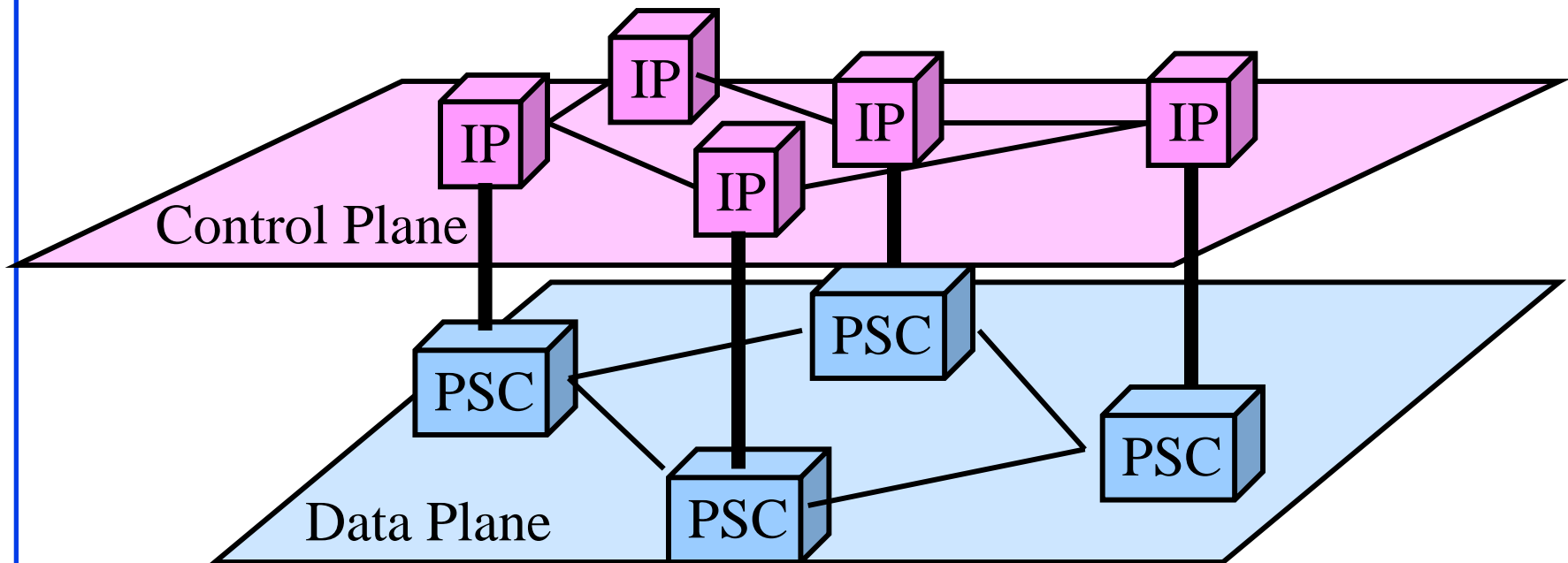


Label Assignment

- ❑ Unsolicited: Topology driven \Rightarrow Routing protocols exchange labels with routing information.
Many existing routing protocols are being extended:
BGP, OSPF
- ❑ On-Demand:
 \Rightarrow Label assigned when requested,
e.g., when a packet arrives \Rightarrow latency
- ❑ Label Distribution Protocol called **LDP**
- ❑ **RSVP** has been extended to allow label request and response

IP-Based Control Plane

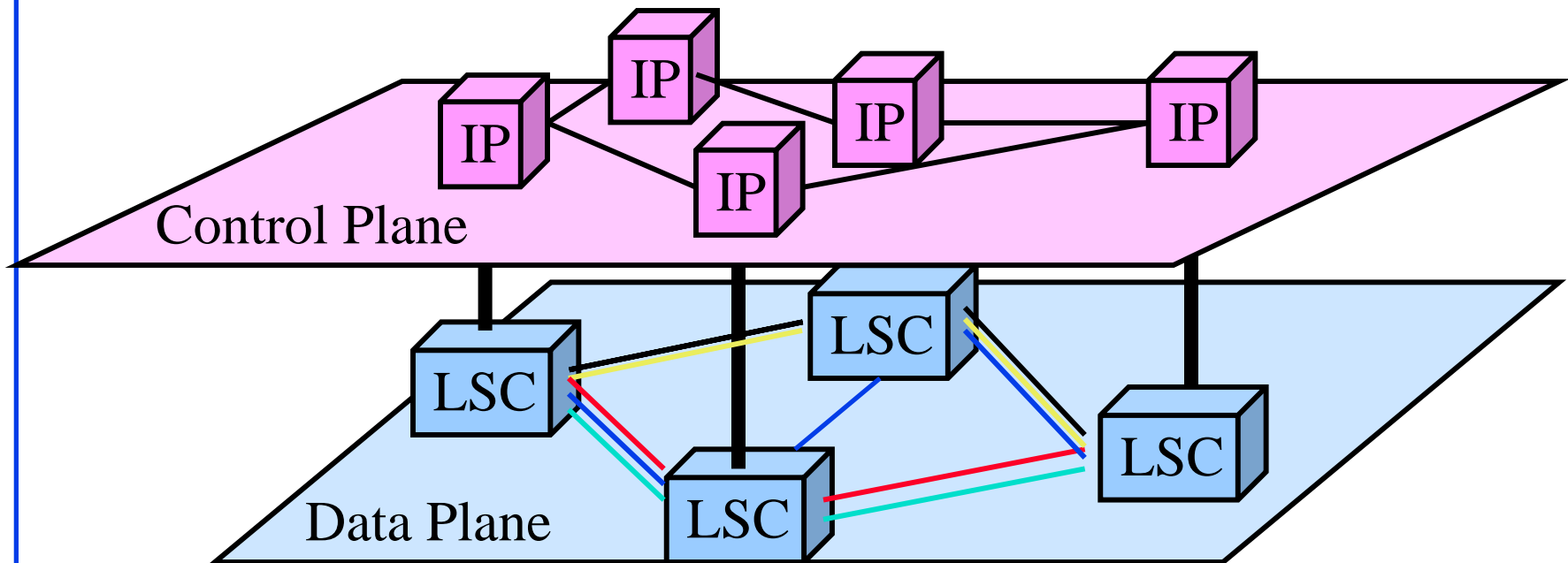
- Control is by IP packets (electronic).
Data can be any kind of packets (IPX, ATM cells).
⇒ MPLS



PSC = Packet Switch Capable Nodes

MP λ S

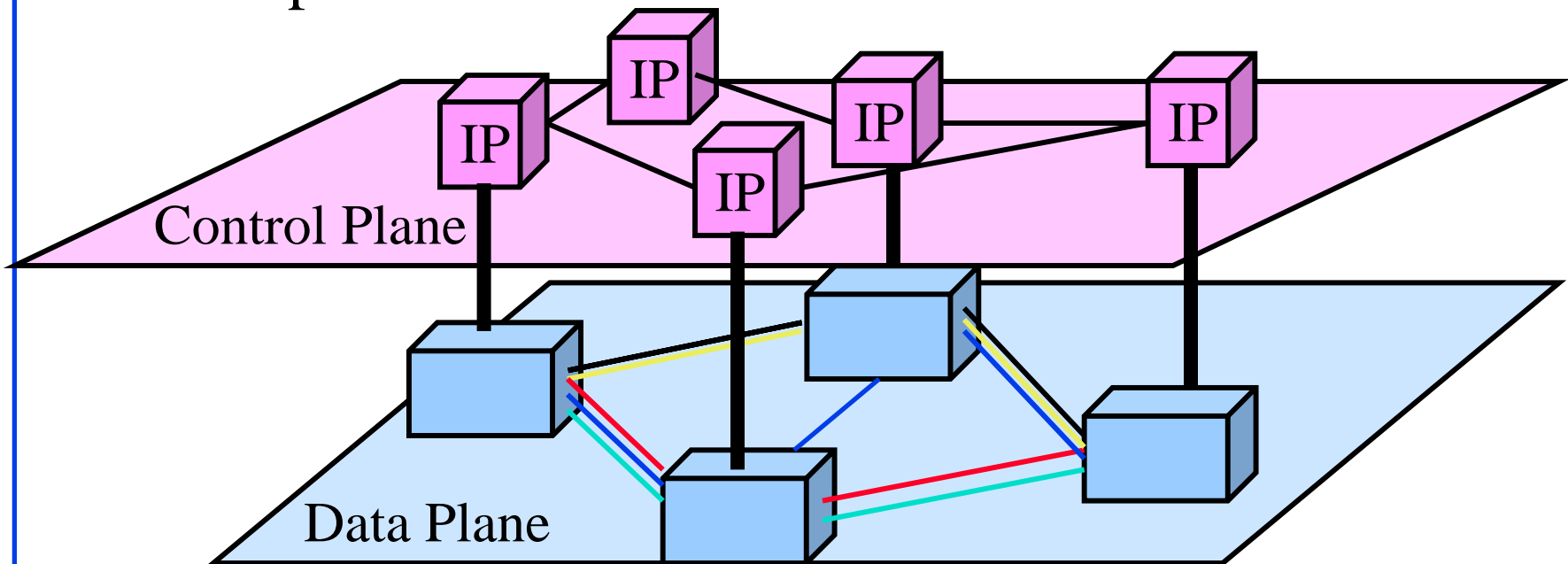
- Control is by IP packets (electronic).
Data plane consists of wavelength circuits
 \Rightarrow Multiprotocol Lambda Switching (October 1999)



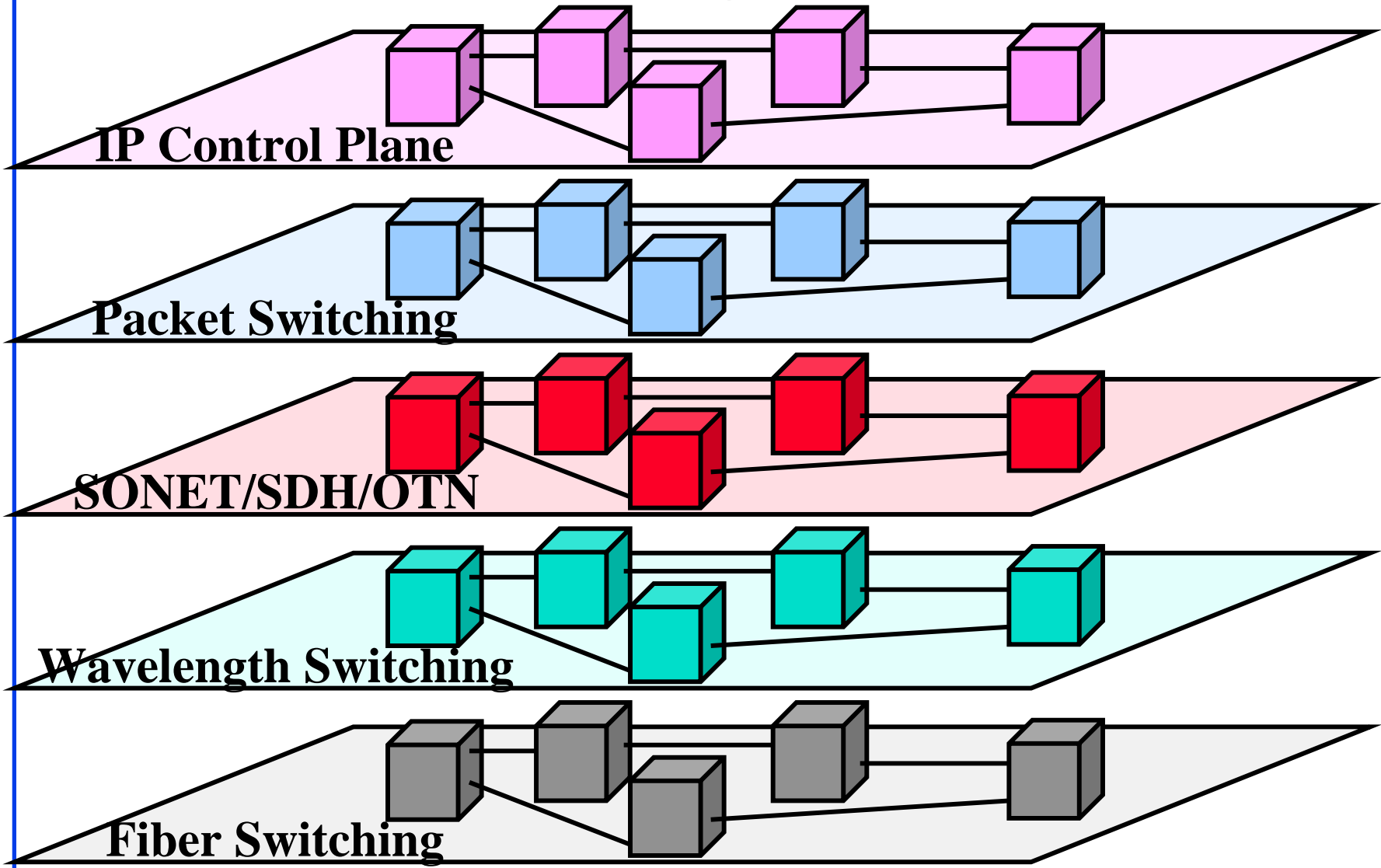
LSC = Lambda Switch Capable Nodes
= Optical Cross Connects = OXC

GMPLS

- ❑ Data Plane = Wavelengths, Fibers, SONET Frames, Packets (October 2000)
- ❑ Two separate routes: Data route and control route

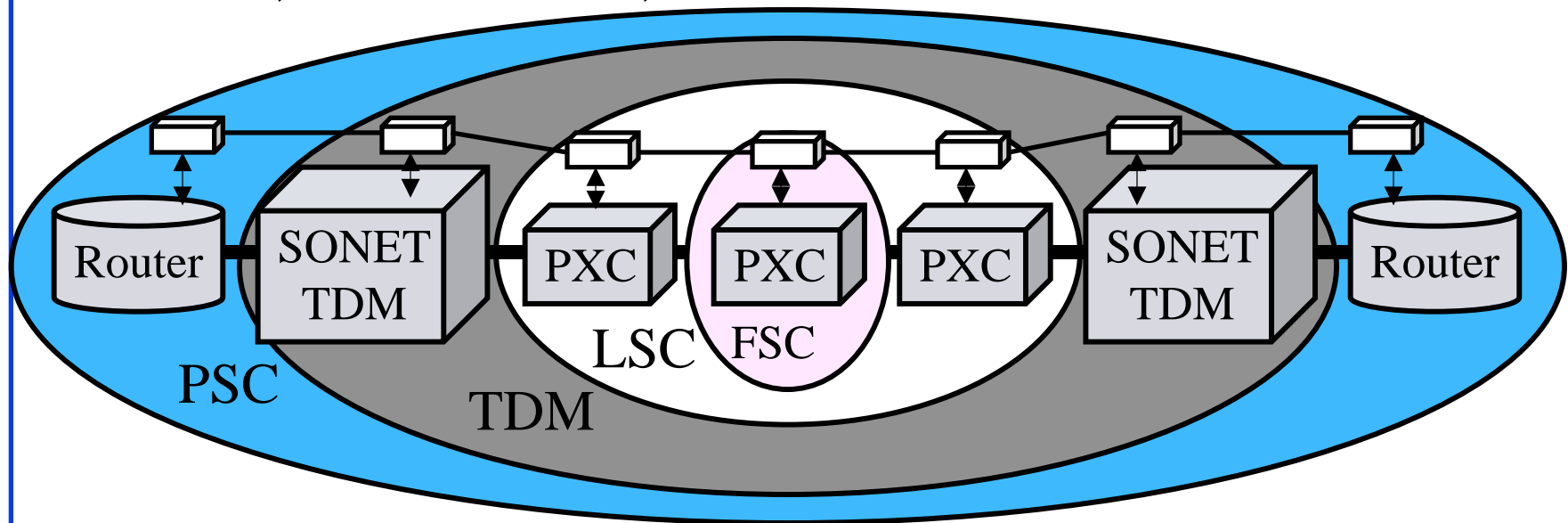


GMPLS: Layered View



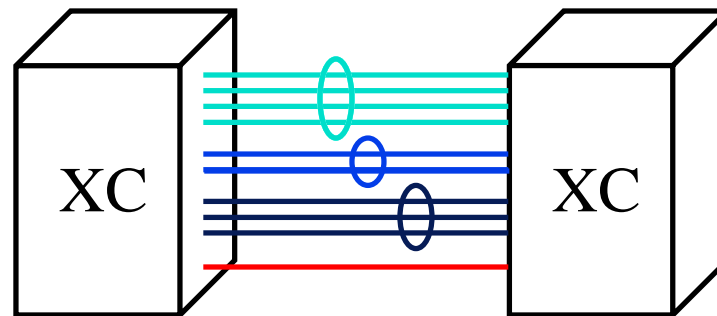
GMPLS: Hierarchical View

- ❑ Packets over SONET over Wavelengths over Fibers
- ❑ Packet switching regions, TDM regions, Wavelength switching regions, fiber switching regions
- ❑ Allows data plane connections between SONET ADMs, PXC's, FSCs, in addition to routers



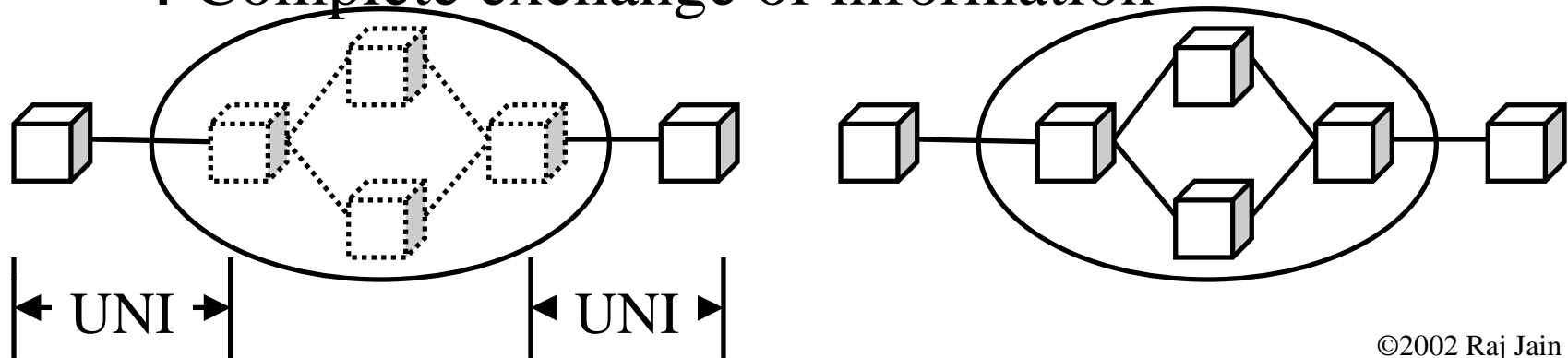
MPLS vs GMPLS

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, λ '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



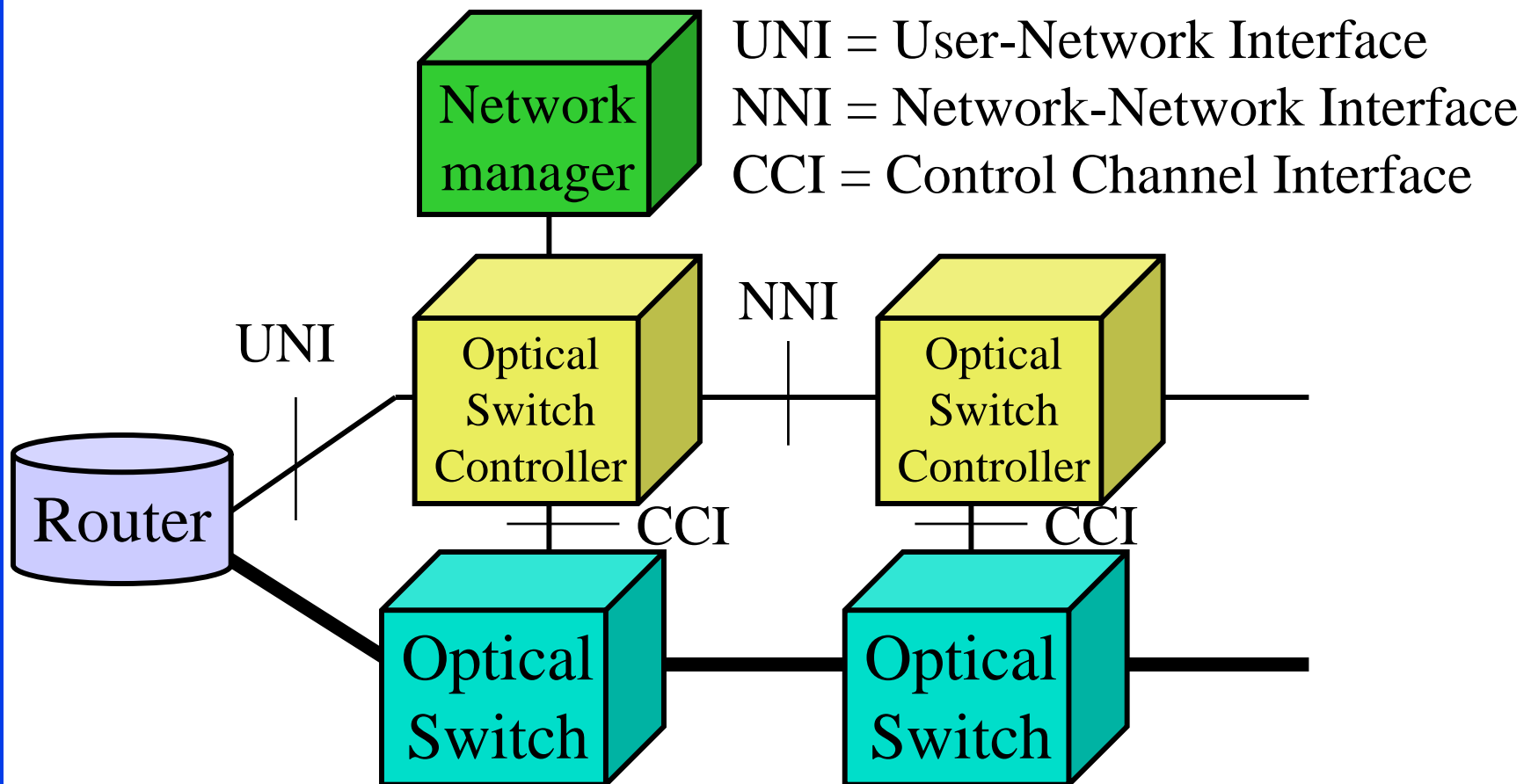
Issue: UNI vs Peer-to-Peer Signaling

- 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



ASTN/ASON

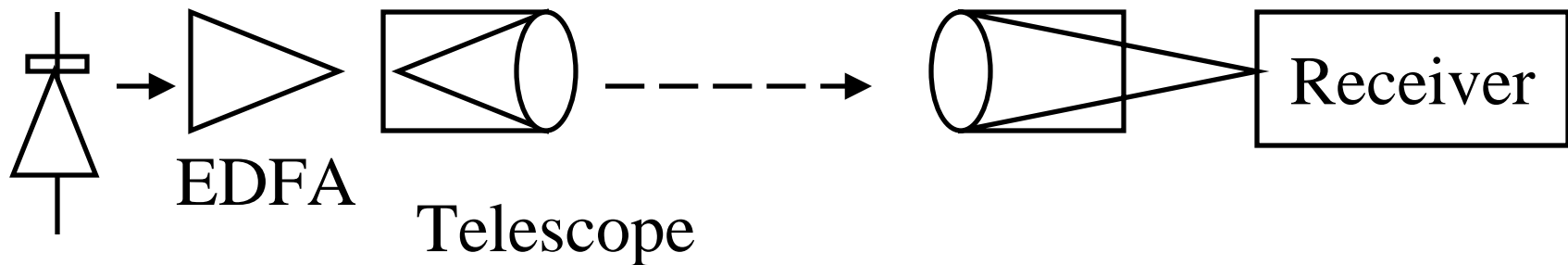
□ Automatically Switched Transport Networks



Upcoming Technologies

- ❑ Higher bit rate, more wavelengths, longer distances
- ❑ Optic Wireless
- ❑ Optical Packet Switching

Free Space Optical Comm



Laser
Source

❑ Uses WDM in open air

❑ Sample Product:

Lucent WaveStar OpticAir: 4×2.5Gbps to 5 km
Available March'00.

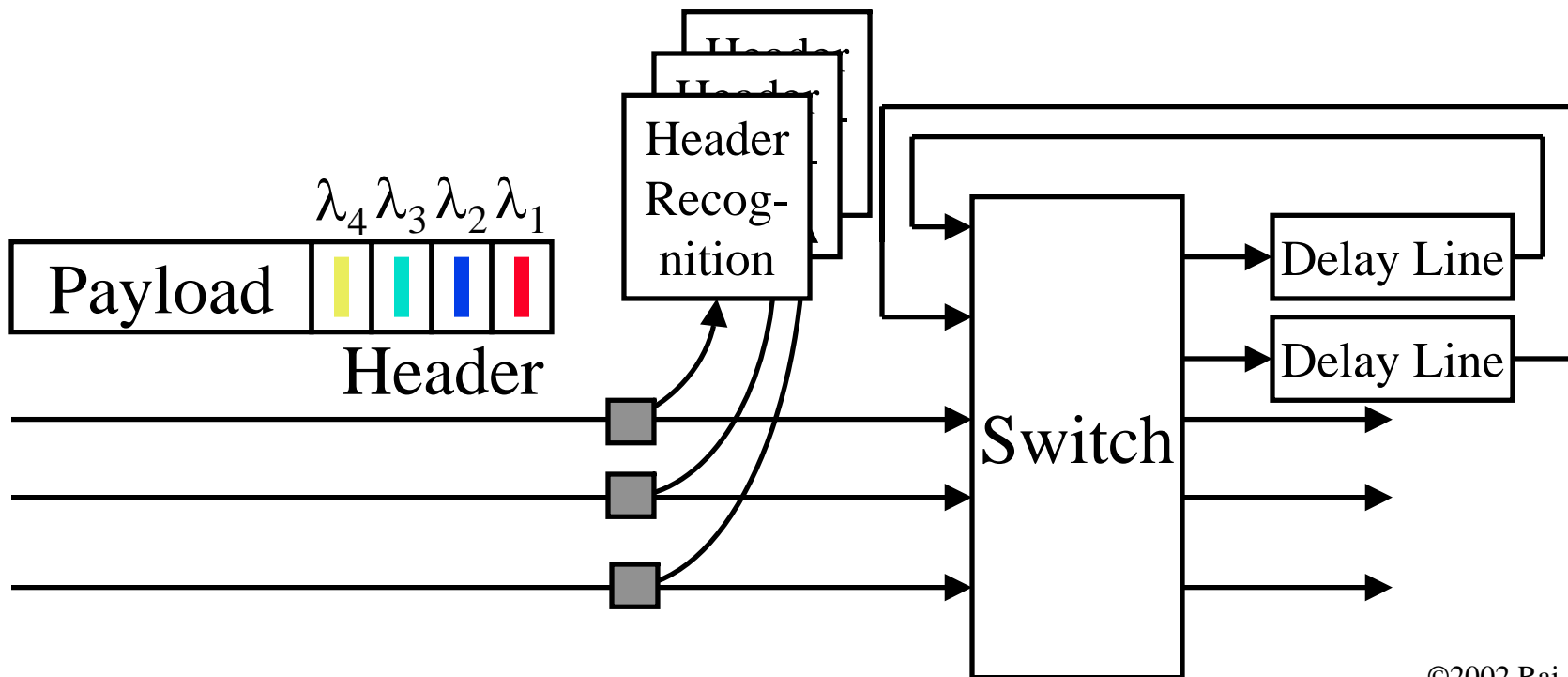
❑ EDFA = Erbium Doped Fiber Amplifier

Free Space Optical Comm

- ❑ No FCC Licensing required
- ❑ Immunity from interference
- ❑ Easy installation
 - ⇒ Unlimited bandwidth, Easy Upgrade
- ❑ Transportable upon service termination or move
- ❑ Affected by weather (fog, rain)
 - ⇒ Need lower speed Microwave backup
- ❑ Example Products: Optical Crossing Optibridge 2500
2.5Gbps to 2km, Texas Instruments TALP1135
Chipset for 10/100 Mbps up to 50m

Optical Packet Switching

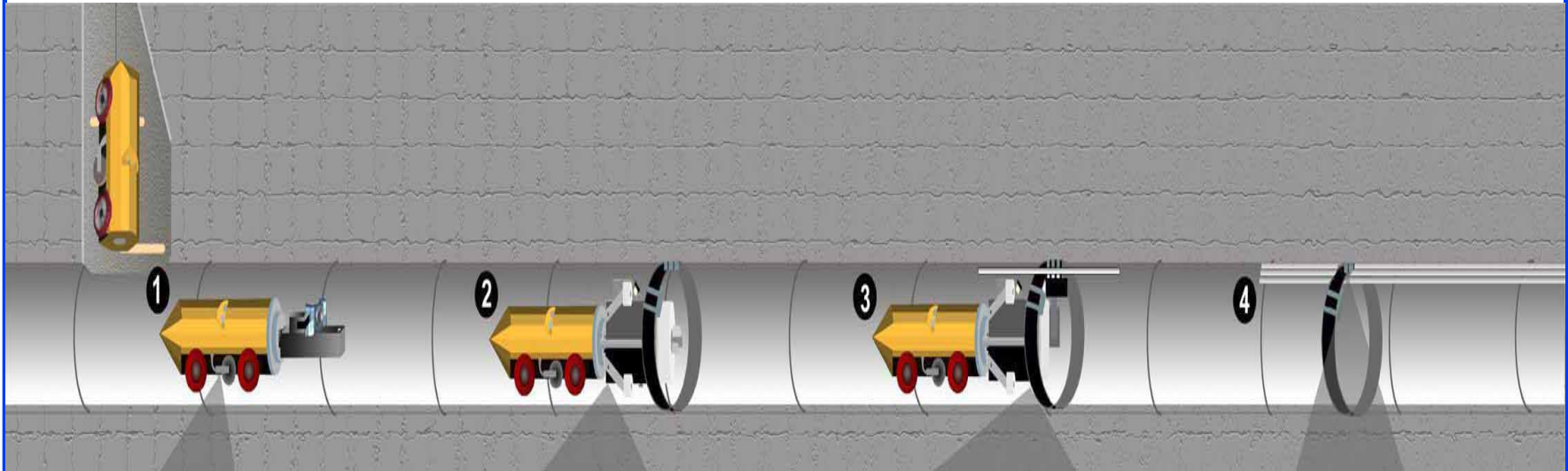
- Header Recognition: Lower bit rate or different λ
- Switching
- Buffering: Delay lines, Dispersive fiber



Fiber Access Thru Sewer Tubes (FAST)

- ❑ Right of ways is difficult in dense urban areas
- ❑ Sewer Network: Completely connected system of pipes connecting every home and office
- ❑ Municipal Governments find it easier and more profitable to let you use sewer than dig street
- ❑ Installed in Zurich, Omaha, Albuquerque, Indianapolis, Vienna, Ft Worth, Scottsdale, ...
- ❑ Corrosion resistant inner ducts containing up to 216 fibers are mounted within sewer pipe using a robot called Sewer Access Module (SAM)
- ❑ Ref: <http://www.citynettelecom.com>, NFOEC 2001, pp. 331

FAST Installation



1. Robots map the pipe
2. Install rings
3. Install ducts
4. Thread fibers

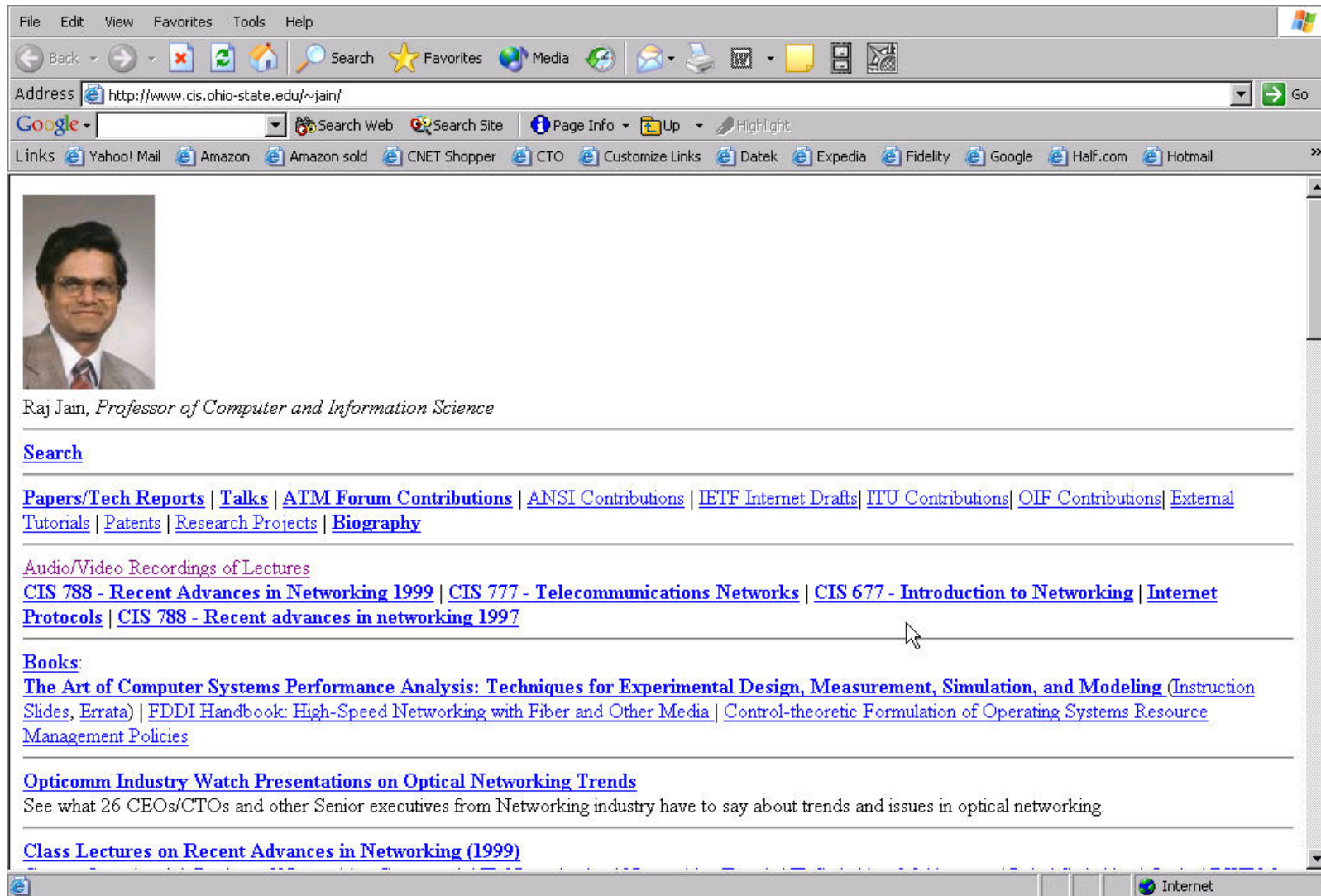
Fast Restoration: Broken sewer pipes replaced with minimal disruption



Summary

1. High speed routers
⇒ IP directly over DWDM
2. Separation of control and data plane
⇒ IP-Based control plane
3. Transport Plane = Packets ⇒ MPLS
Transport Plane = Wavelengths
⇒ MP λ S
Transport Plane = λ , SONET, Packets
⇒ GMPLS
4. UNI allows users to setup paths on demand

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