IP Over DWDM

Raj Jain

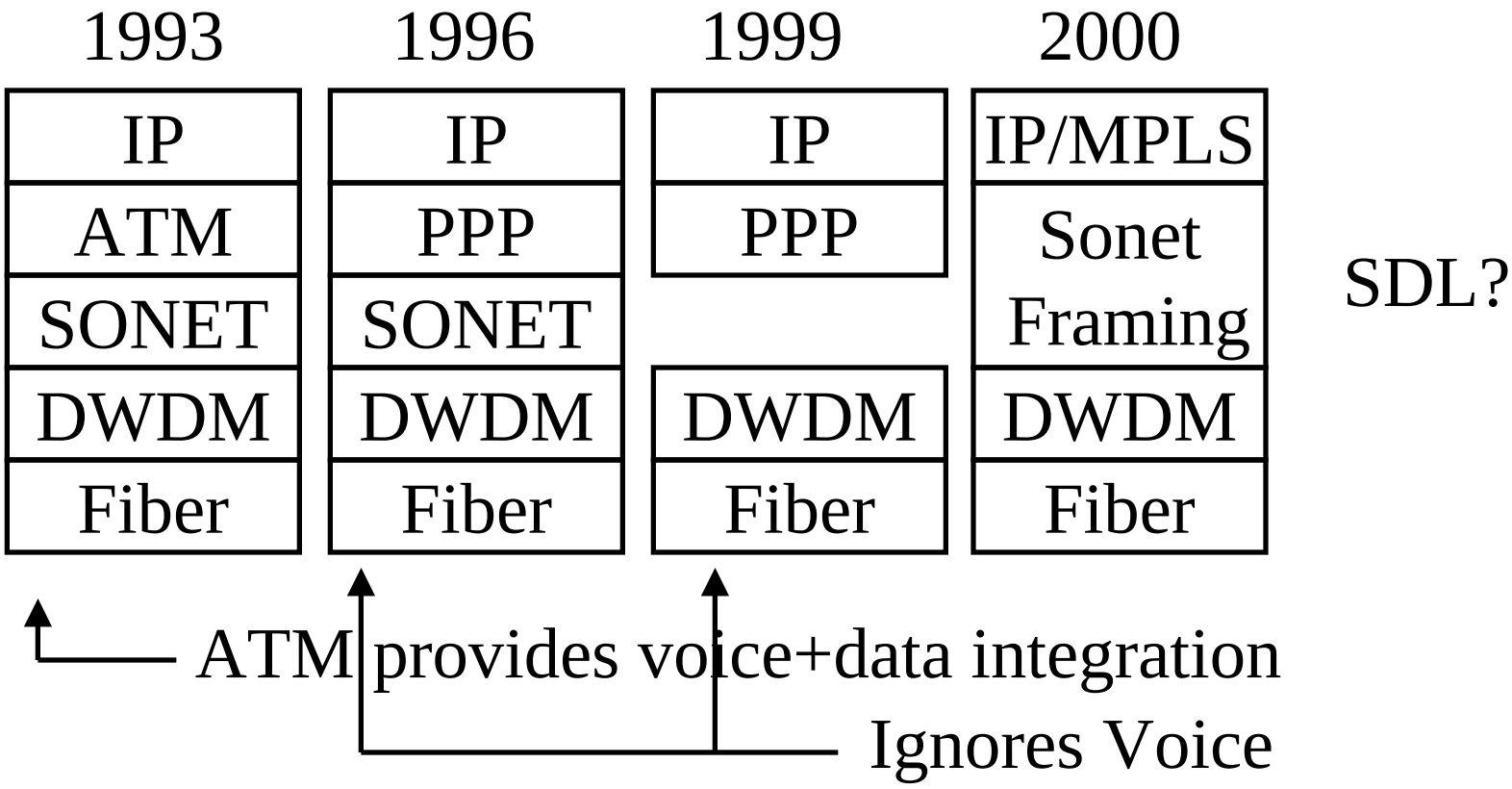
Raj Jain is now at
Washington University in Saint Louis
Jain@cse.wustl.edu
http://www.cse.wustl.edu/~jain/

http://www.cse.ohio-state.edu/~jain/talks/h_aipwd.htm

Overview

- Stack Debate: To SONET or Not to SONET?
- Why we have Multi-Layer Stack?
- What are the Problems with Multi-layer Stack?
- IP over DWDM Node Architecture and Issues
- Virtual Topology Issues
- Multiprotocol Lambda Switching
- IP/MPLS over DWDM

Stack Debate



PPP = Point to point protocol in HDLC-like framing

SDL = Simple Data Link

Simple Data Link

- Framing: How to tell where the frame begins and ends
- Two methods:
  - HDLC: 01111110 Flag
    - Need byte stuffing
      - Arbitrary increase in data rate
      - Need byte-level processing ⇒ slow
  - ATM: Header error check. Hunt and resync.
- SDL: Use HEC plus length (since variable size payload)

SONET Functions

- Clock Synchronization
- Rate Multiplexing/Traffic Grooming
- Rate Division/Inverse multiplexing
- Fault Tolerance
- Signal trace
- Error Monitoring
- Fault Isolation $\Rightarrow$ Dual Ring
- Localized Decision $\Rightarrow$ Fast Restoration

Multi-Layer Stack: Why?

- Speed: λ > SONET > ATM > IP
  ATM < OC-12, IP < OC-3
  Low speed devices ⇒ Not enough to fill a λ
  SONET (1λ) limited to 10 Gbps
- Distance: End-system, Enterprise backbone, Carrier Access, Carrier Backbone, Core
- Some unique function in each layer
  - ATM = Access/Integration/Signaling/QoS/TM
  - SONET = Mux/Transport

Multi-layer Stack: Problems

- Increasing Bandwidth
  $\Rightarrow$ Core technologies move towards the edges
- Gigabit Routers $\Rightarrow$ No need for grooming
  One router port should be able to use all resources.
- Functional overlap:
  - Multiplexing:
    DWDM λ = Σ STM = Σ VC = Σ Flows = Σ packets
  - Routing: DWDM, SONET, ATM, IP
  - QoS/Integration: ATM, IP
- Static division of bandwidth in SONET good for continuous traffic not for bursty traffic.

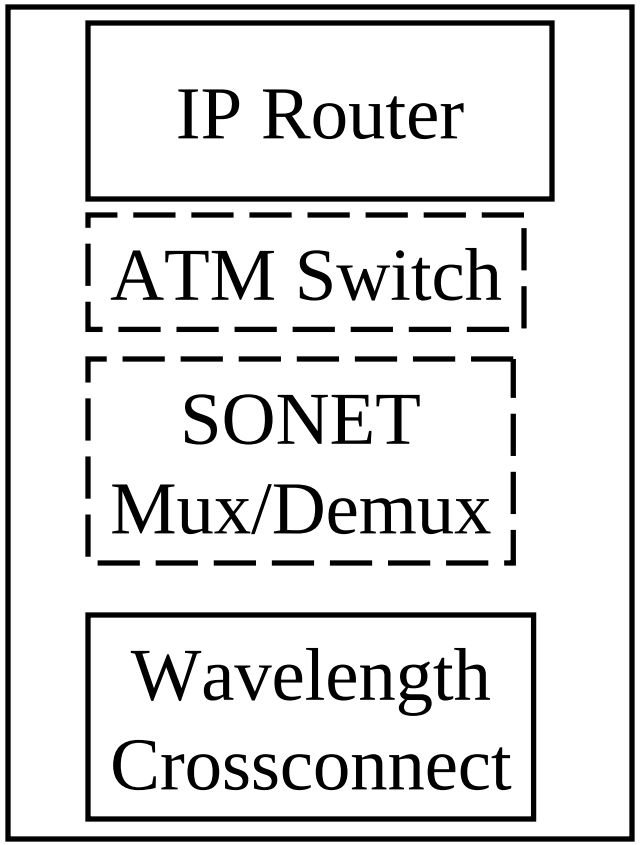
Multilayer Stack Problems (Cont)

- Failure affects multiple layers:
  1 Fiber $\Rightarrow$ 64 λ $\Rightarrow$ 160Gbps = 1000 OC-3 $\Rightarrow$ 10^5 VCs
  $\Rightarrow$ 10^8 Flows
- Restoration at multiple layers:
  DWDM $\Rightarrow$ SONET $\Rightarrow$ ATM $\Rightarrow$ IP
- SONET $\Rightarrow$ 50% lost = Inefficient Protection
- SONET $\Rightarrow$ Manual (jumpers) $\Rightarrow$ Slow provisioning
  Need Bandwidth on all rings $\Rightarrow$ months/connection
  Bandwidth reserved during setup
- Any layer can bottleneck
  $\Rightarrow$ Intersection of Features + Union of Problems

IP Directly over DWDM: Why?

- IP $\Rightarrow$ revenue
  DWDM $\Rightarrow$ Cheap bandwidth
  IP and DWDM $\Rightarrow$ Winning combination
  Avoid the cost of SONET/ATM equipment
- IP routers at OC-192 (10 Gb/s)
  $\Rightarrow$ Don't need SONET multiplexing
- Coordinated restoration at optical/IP level
- Coordinated path determination at optical/IP level
- SONET Framing can remain for error monitoring
  Two parts of a layer: Framing + Protocols

IP over DWDM Node

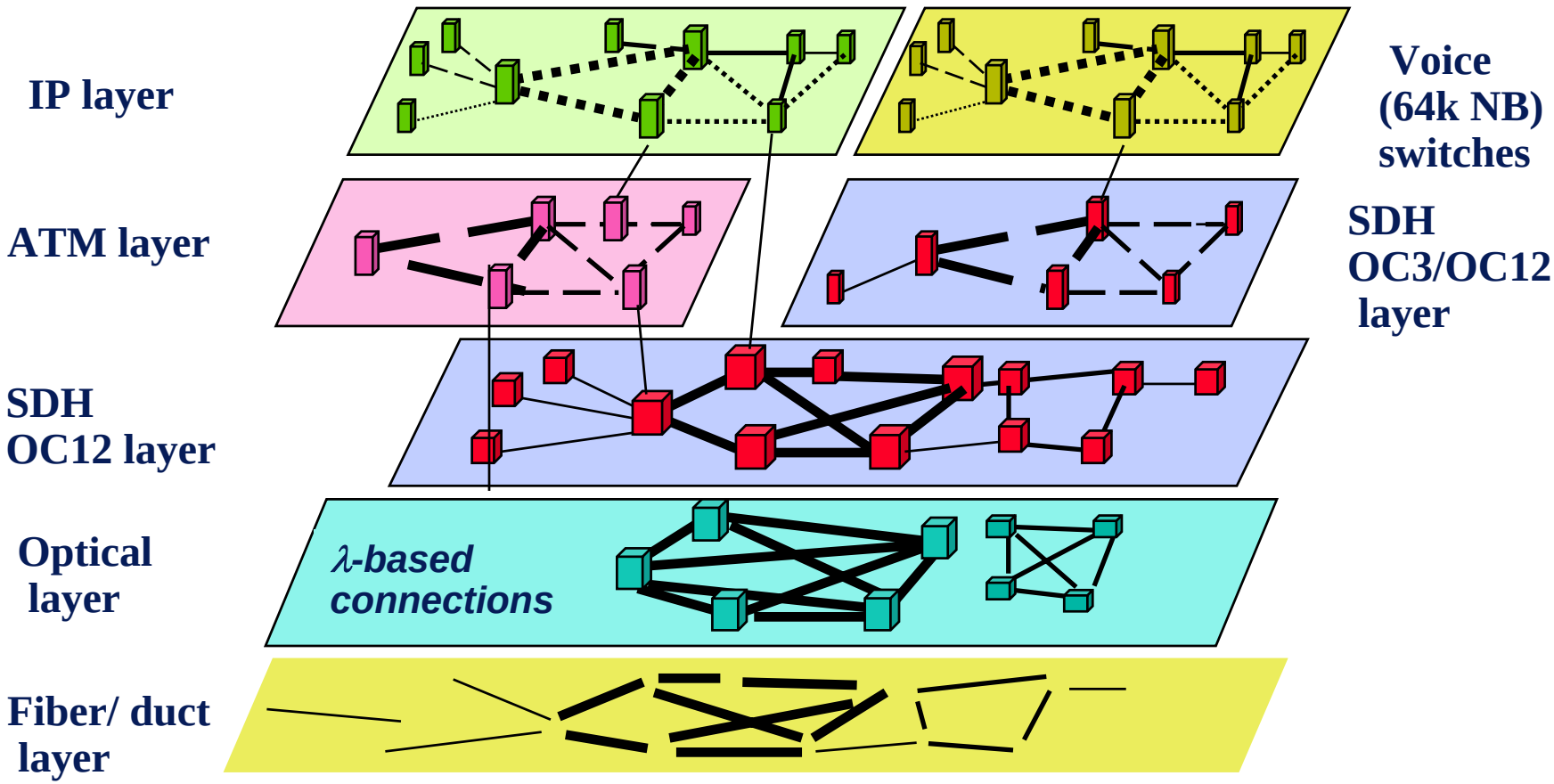


- Each optical node will be an IP addressable device
- Will implement OSPF/RIP/BGP, Protection, Wavelength Switching, QoS

IP over DWDM: Issues

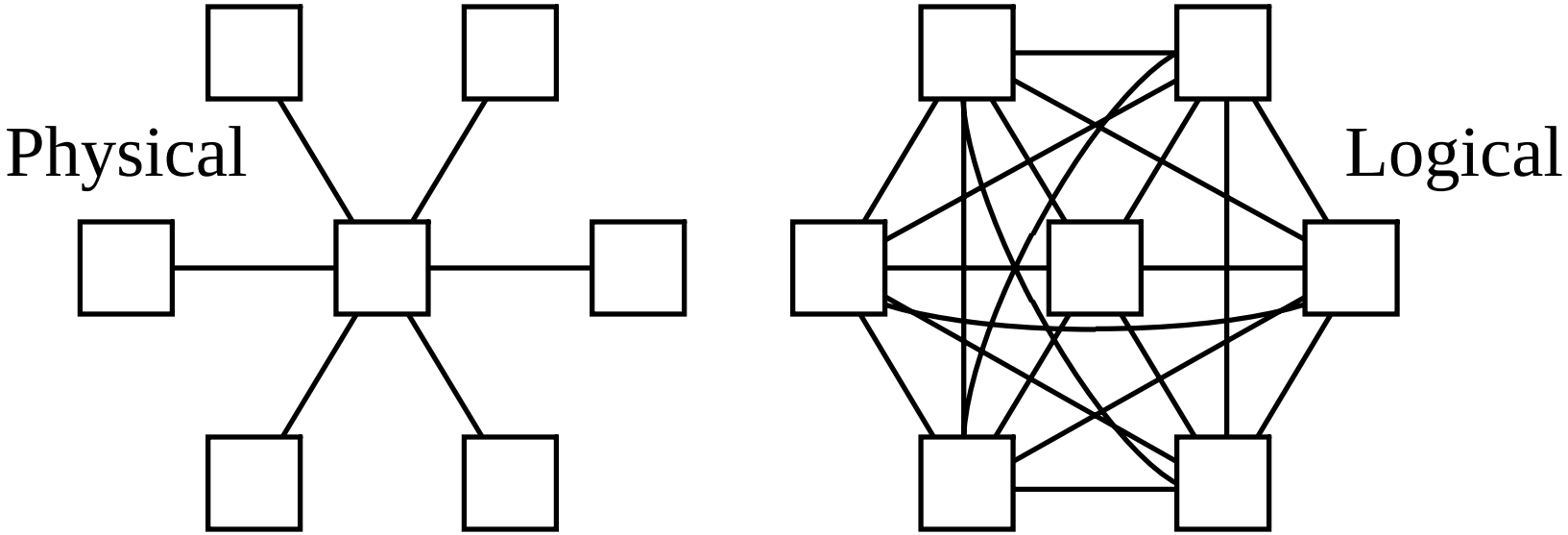
- Routing Wavelength Assignment Algorithms
- Cheaper High-Speed Routers
- Topology design Algorithms
- Wavelength conversion devices
- Packet Switching Architecture
- Protection schemes
- Inverse multiplexing for higher speed pipes
- QoS
- Multicast

Virtual Topology Issue



Ref: Dixit

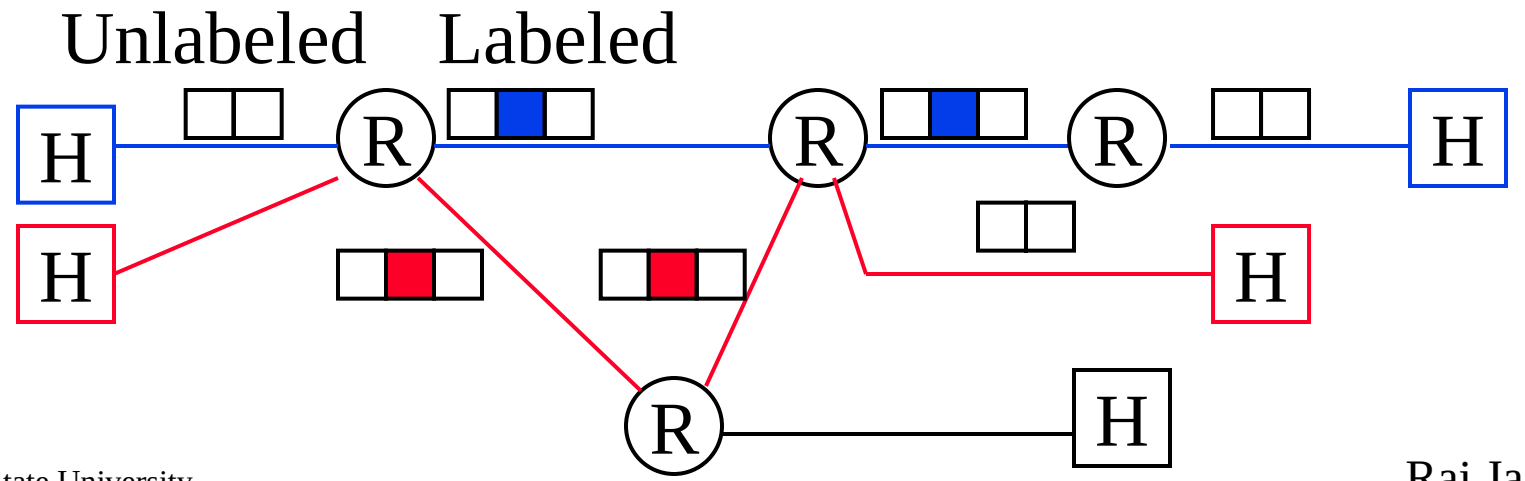
IP over ATM: Lessons



- Duplication between PNNI and OSPF
- Virtual topology $\Rightarrow n^2$ scaling problem
- Solutions:
  - IP Switching $\Rightarrow$ Make every switch a router
  - MPLS $\Rightarrow$ Make every switch an LSR

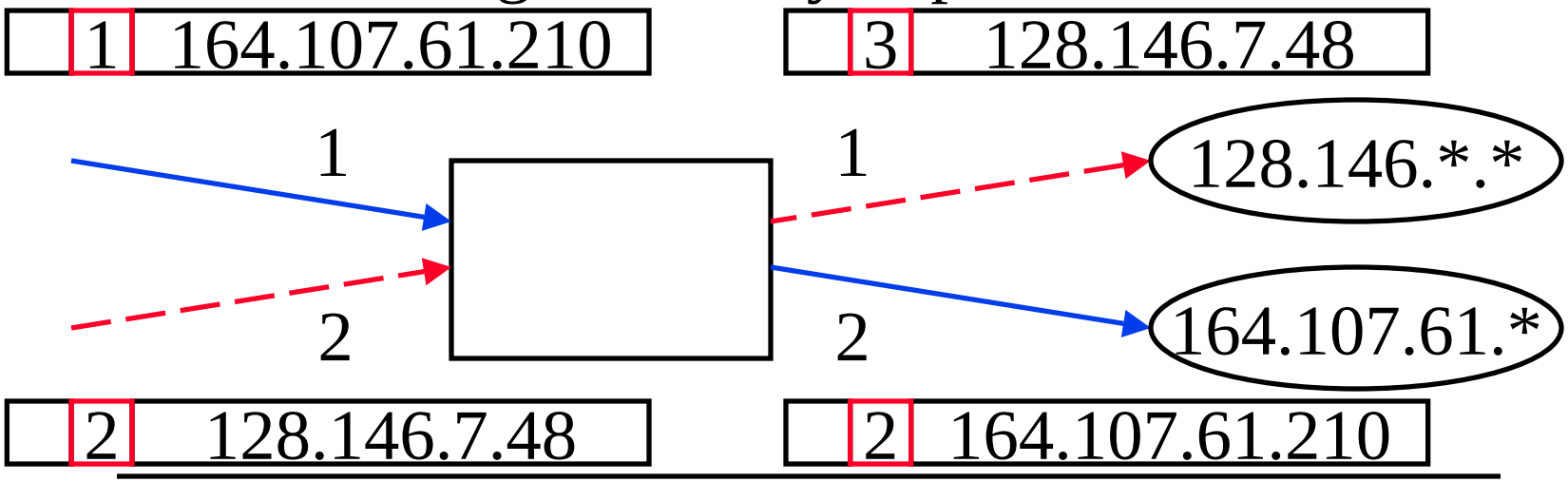
Label Switching

- Label = Circuit number = VC Id
- Ingress router/host puts a label. Exit router strips it off.
- Switches switch packets based on labels.
  Do not need to look inside ⇒ Fast.



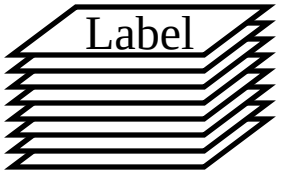
Label Switching (Cont)

- Labels have local significance
- Labels are changed at every hop

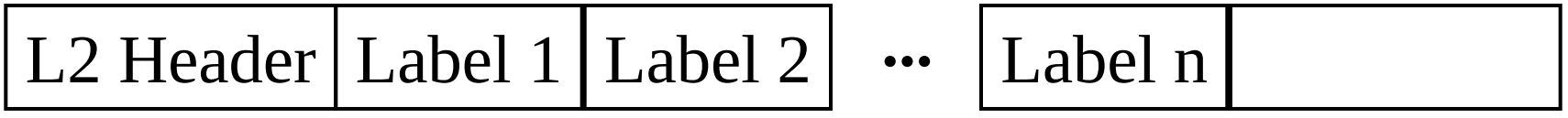


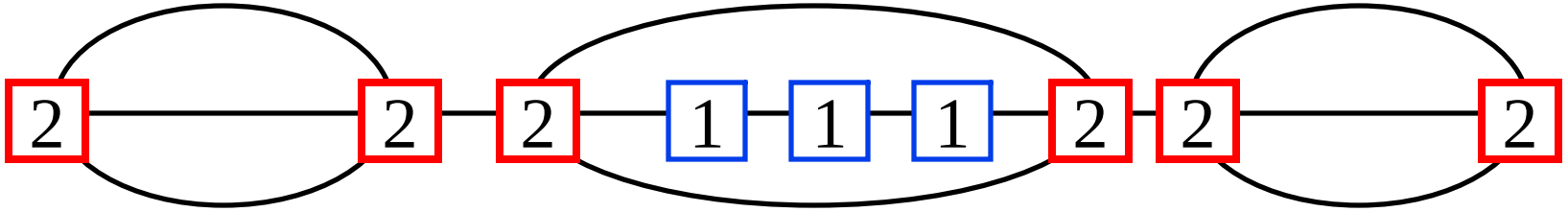
Input Port	Input Label	Adr Prefix	Output Port	Output Label
1	1	164.107.61.*	2	2
2	2	128.146.*.*	1	3

Label Stacks



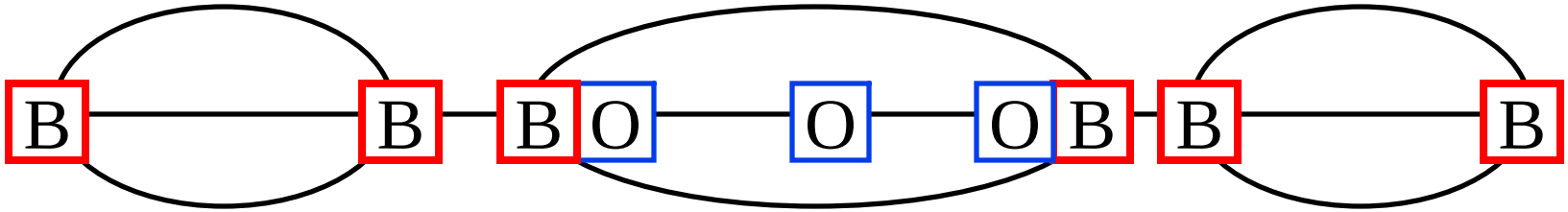
- A MPLS packet may have multiple labels
- Labels are pushed/popped as they enter/leave MPLS domain
- Stack allows hierarchy of MPLS domains
- Bottom label may indicate protocol (0=IPv4, 2=IPv6)



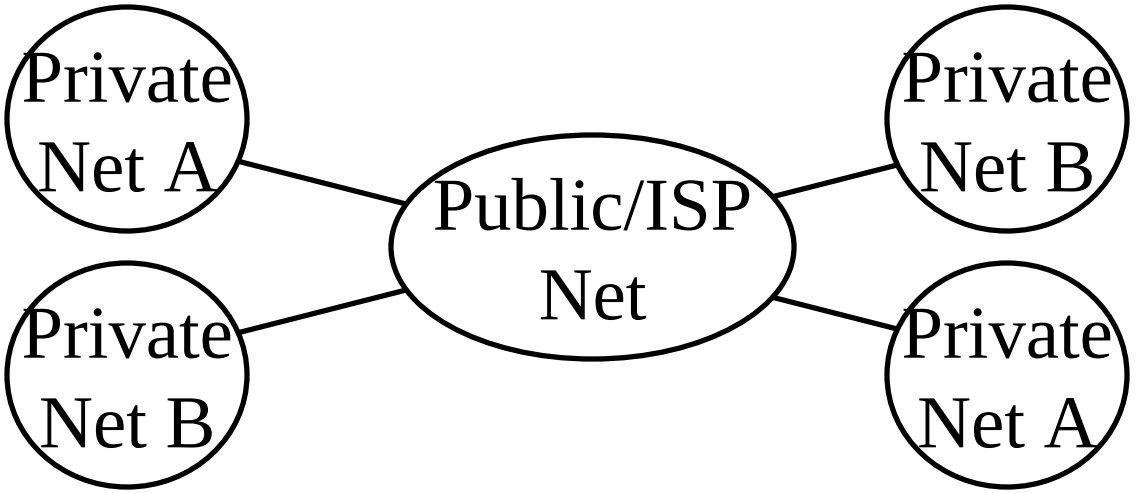


Label Stack Examples

1. BGP/OSPF Routing Hierarchy



2. VPN: Top label used in public network.
   Net A and B can use the same private addresses.



Advantages of MPLS

- MPLS takes the best of both IP and ATM networks
- Works on both ATM and non-ATM networks
- Common routing and label distribution on all media
  $\Rightarrow$ Easier management
- No routing over large cloud issue

IP over MPLS over DWDM

- MPLS = Multi-Protocol Lambda Switching
- DWDM network ≈ ATM network with Limitations
- Optical Channel Trail = VC = LSPs = Traffic Trunk
- Fiber = Link
- Limited # of channels
- Global significance, if no λ conversion
- Local significance with λ conversion (still complex)
- Granularity = λ ⇒ Fixed datarate
- No aggregation yet ⇒ No label merging

MPLS over DWDM (Cont)

- No hierarchy yet ⇒ No label stacks
- No TDM yet ⇒ No cells or packets
- No queueing ⇒ No scheduling, No Priority, No burstiness, No policing
- Need Shaping/grooming at entry
- Faster restoration via redundancy (rings/mesh)
- Vendor specific management
  ⇒ Interoperability issues

MPLS Control Plane: Today

- Resource Discovery: IGP (OSPF/PNNI)
- Path Computation: IGP (OSPF/PNNI)
- Connection Management: Label Distribution via IGP(OSPF), LDP, RSVP
- Survivability: Rerouting,...
- Constraint-based routing based on data rate, overbooking, delay, ...

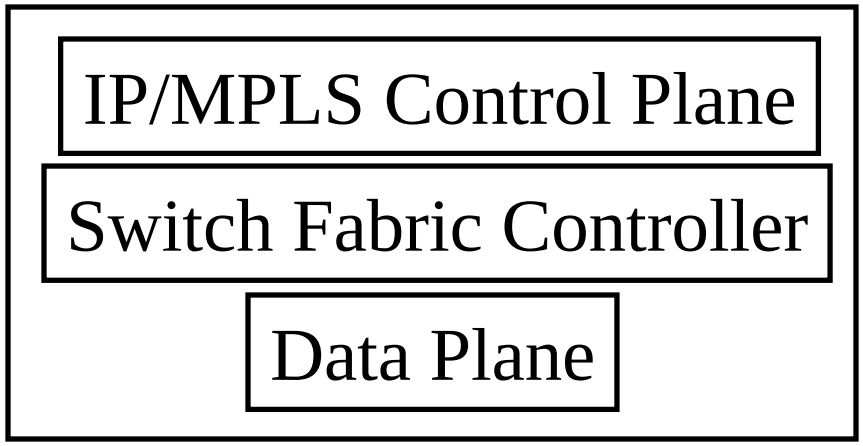
MPLS Control Plane: Tomorrow

- Next Hop Forwarding Label Entry (NHFLE)
  = Preprogrammed λ switching
  = Wavelength Forwarding Information Base matrix
  ⇒ <Input port, λ> to <output port, λ> mapping
- Constraints: Data rate, Attenuation, Dispersion, Length, delay
- Topologies: Linear and rings to partial Mesh
- λ control plane via network management
  ⇒ Permanent ⇒ Static routing
  ⇒ Too slow for restoration

MPLS Control Tomorrow (Cont)

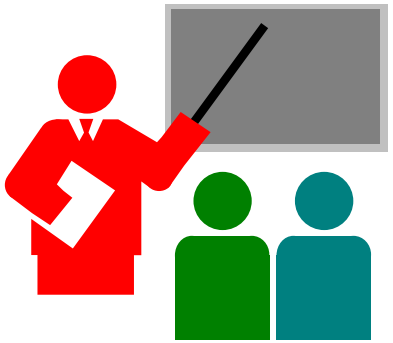
- Can add resilience (survivability) preemption, resource class affinity attributes to trails
- Each OXC will be an IP addressable device
- Control plane can be out-of-band IP channel, dedicated supervisory channel
- Need to build on concept of "Abstract Node" in IP routing $\Rightarrow$ Failures are handled locally
- λ availability will be advertised by optical node/WRouter

Optical Node Architecture



- Pre-configured control wavelength upon initialization
- Need to develop hierarchical/aggregation concepts (label stacks or VPs)
  $\Rightarrow$ λ-Group (Optical channel, optical path, Light path)
- Add light path constraints to MPLS label distribution or explicit path requests
- Ref: draft-awduche-mpls-te-optical-00.txt

Summary



- High IP Routing speeds and volumes
  $\Rightarrow$ Need a full wavelength
  $\Rightarrow$ Many ATM/SONET functions not needed
- Need MPLS to provide QoS, Isolation
- Protection/Restoration/Routing should be coordinated between IP/MPLS and DWDM
- Need to develop hierarchy/aggregation concepts for DWDM

References:

- See references in http://www.cse.ohio-state.edu/~jain/refs/opt_refs.htm
- Recommended books on optical networking, http://www.cse.ohio-state.edu/~jain/refs/opt_book.htm
- Optical networking and DWDM, http://www.cse.ohio-state.edu/~jain/cis788-99/dwdm/index.html
- IP over DWDM, http://www.cse.ohio-state.edu/~jain/cis788-99/ip_dwdm/index.html
- Newsgroup: sci.optics.fiber

Acronyms

- ATM Asynchronous Transfer Mode
- BGP Border Gateway Protocol
- DWDM Digital Wavelength Division Multiplexing
- GHz Giga Hertz
- IGP Interior Gateway Protocol
- IP Internet Protocol
- IPv4 IP Version 4
- IPv6 IP Version 6
- MIP Millions of Instructions per second
- MPLS Multiprotocol Label Switching
- NHFLE Next Hop Forwarding Label Entry

Acronyms (Cont)

- OC Optical Carrier
- OSPF Open Shortest Path First
- OXC Optical cross connect
- PC Personal Computers
- PNNI Private Network to Node Interface
- PPP Point-to-point protocol
- SONET Synchronous Optical Network
- TDM Time Division Multiplexing
- VC Virtual Circuit
- VPs Virtual Paths
- WRouter Wavelength Router