IP Over DWDM

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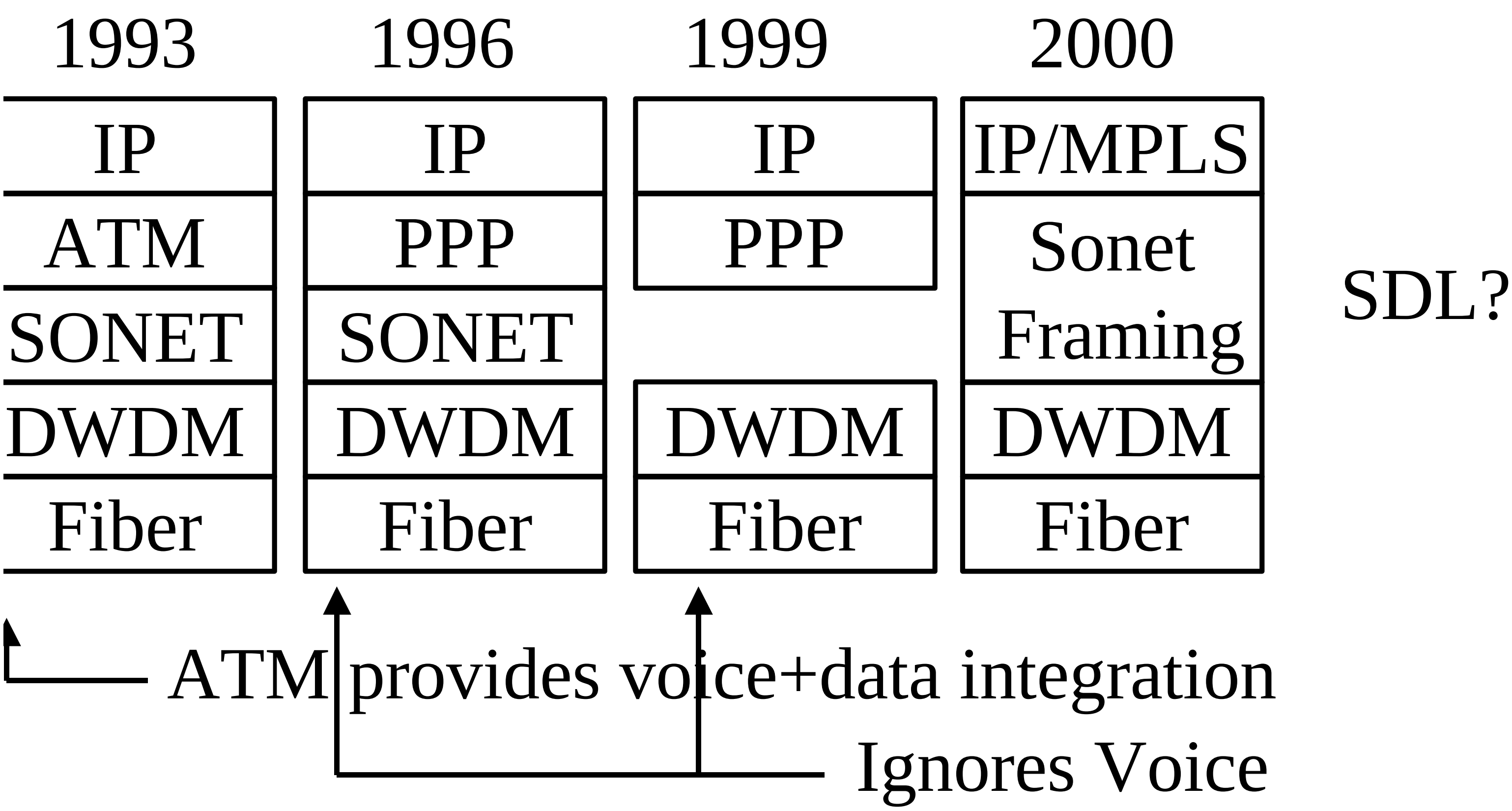
These Slides are available on-line at:

ttp://www.cis.ohio-state.edu/~jain/talks/h_aipwd.htm

- 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



P = Point to point protocol in HDLC-like fra

L = Simple Data Link

Simple Data Link

Framing: How to tell where the frame begins and en

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 ⇒ Dual Ring
- Localized Decision ⇒ Fast Restoration

Multi-Layer Stack: Why?

- Speed: λ > SONET > ATM > IP
- ATM < OC-12, IP < OC-3
- Low speed devices $\Rightarrow$ 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

ncreasing Bandwidth

⇒ Core technologies move towards the edges

Gigabit Routers ⇒ 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 packe
- Routing: DWDM, SONET, ATM, IP
- QoS/Integration: ATM, IP

Static division of bandwidth in SONET good for continuous traffic not for bursty traffic.

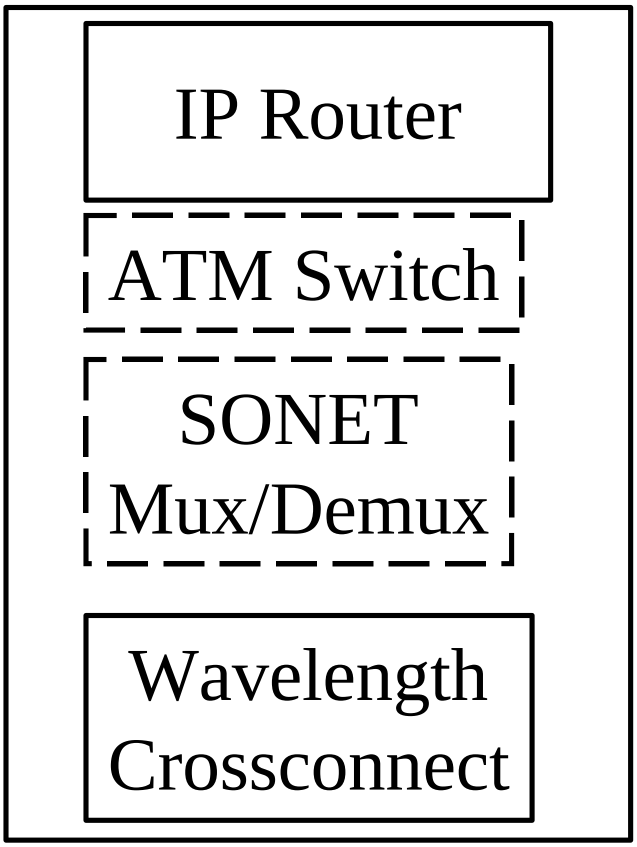
ultilayer Stack Problems (Con

- ailure affects multiple layers:
  - Fiber ⇒ 64 λ ⇒ 160Gbps = 1000 OC-3 ⇒ 10^5 V(
  - ⇒ 10^8 Flows
- estoration at multiple layers:
  - WDM ⇒ SONET ⇒ ATM ⇒ IP
- ONET ⇒ 50% lost = Inefficient Protection
- ONET ⇒ Manual (jumpers) ⇒ Slow provisioning
  - eed Bandwidth on all rings ⇒ months/connection
  - andwidth reserved during setup
- ny layer can bottleneck
  - ⇒ Intersection of Features + Union of Problems

P Directly over DWDM: Why?

- P ⇒ revenue
- WDM ⇒ Cheap bandwidth
- P and DWDM ⇒ Winning combination
- void the cost of SONET/ATM equipment
- P routers at OC-192 (10 Gb/s)
  ⇒ Don't need SONET multiplexing
- oordinated restoration at optical/IP level
- oordinated path determination at optical/IP level
- ONET Framing can remain for error monitoring
- wo parts of a layer: Framing + Protocols

IP over DWDM Node

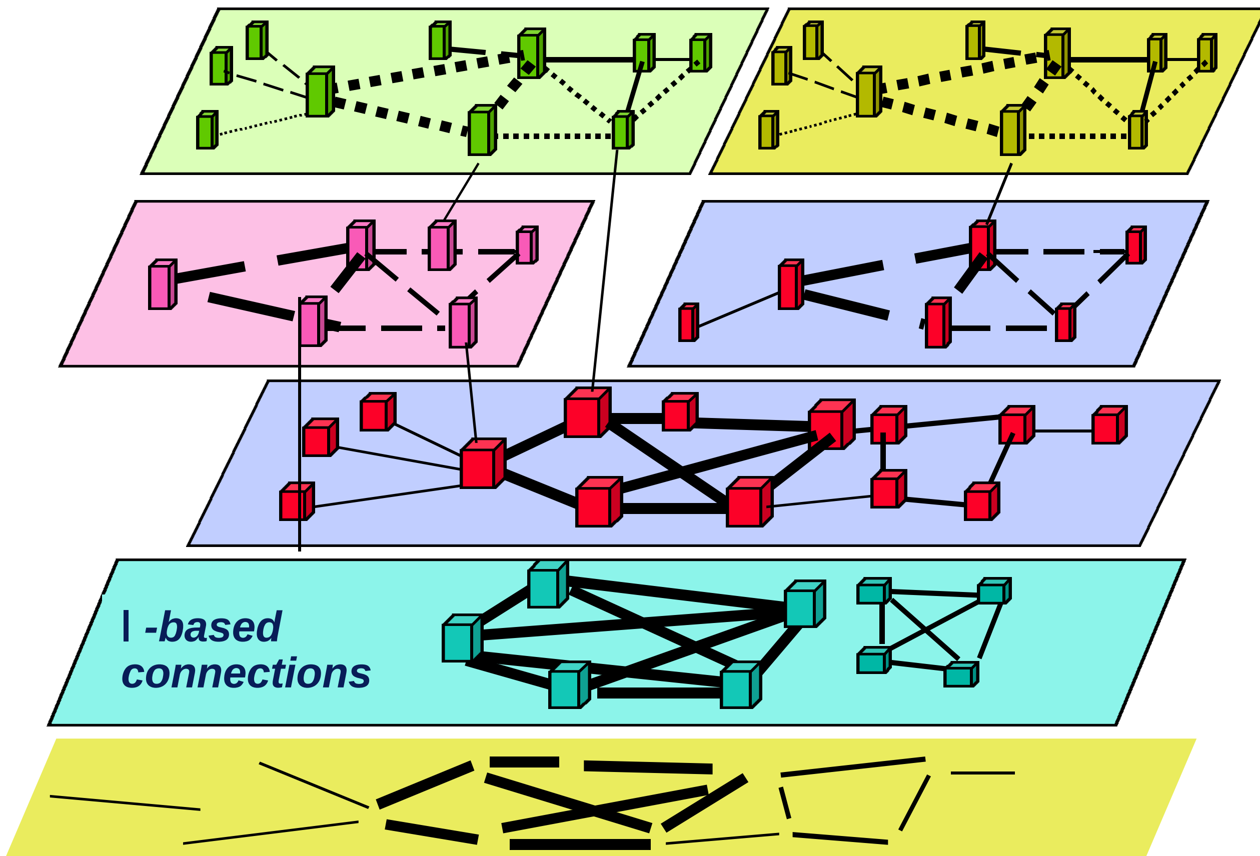


- ach optical node will be an IP addressable device
- Vill implement OSPF/RIP/BGP, Protection, Vavelength Switching, QoS

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



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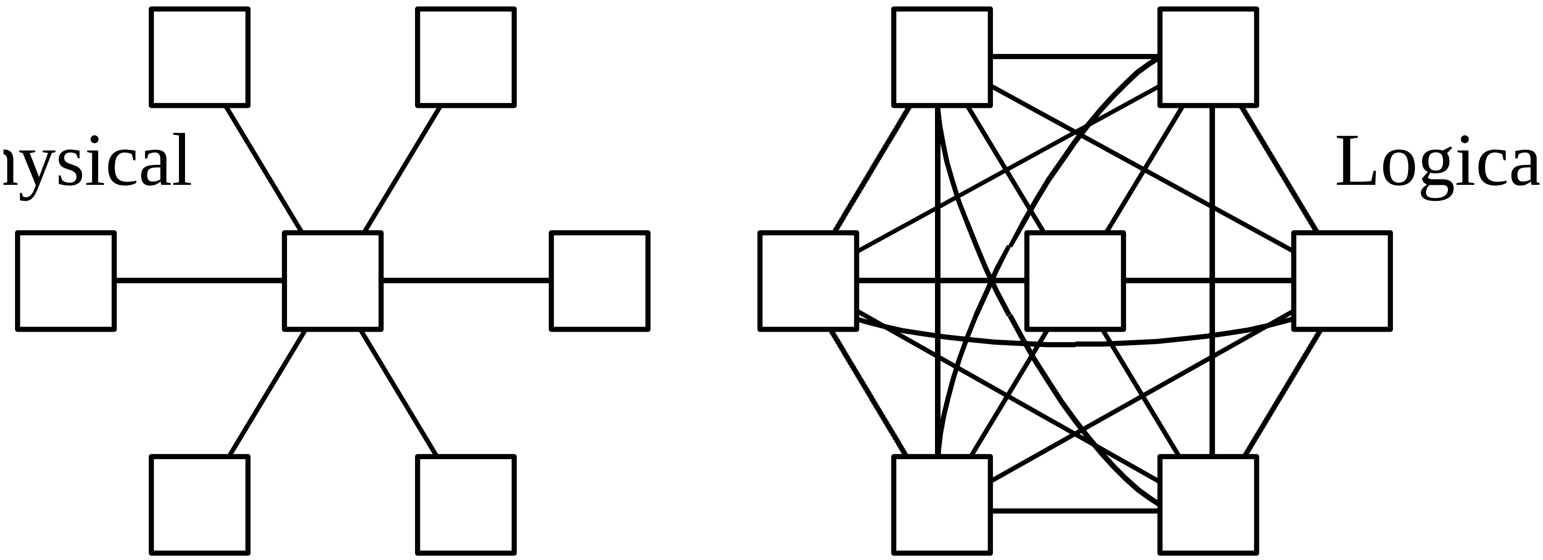
IP over ATM: Lessons



Duplication between PNNI and OSPF

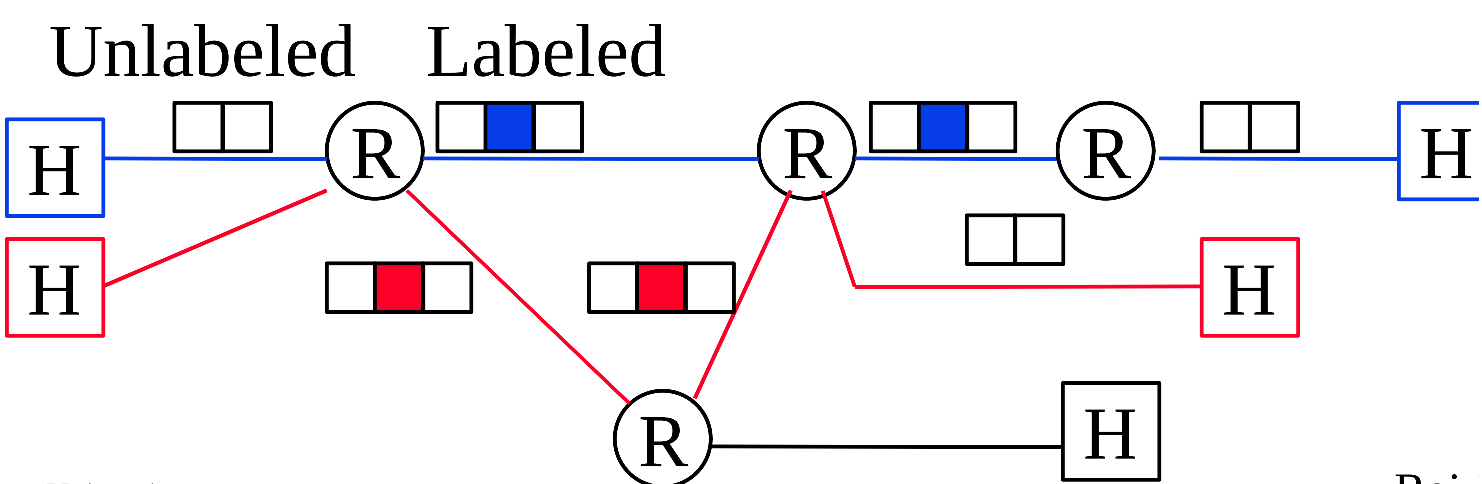
Virtual topology ⇒ n^2 scaling problem

Solutions:

- IP Switching ⇒ Make every switch a router
- MPLS ⇒ Make every switch an LSR

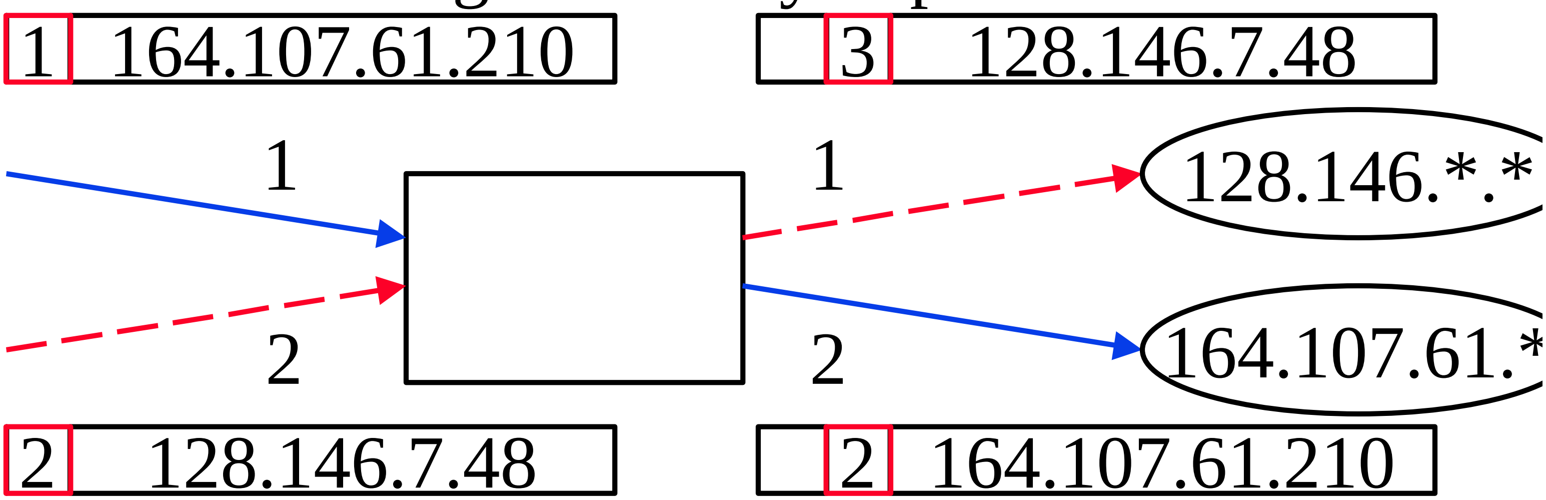
Label Switching

- 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.



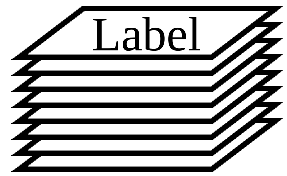
Label Switching (Cont)

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

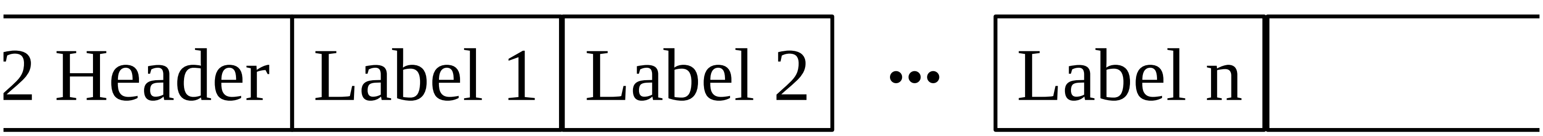


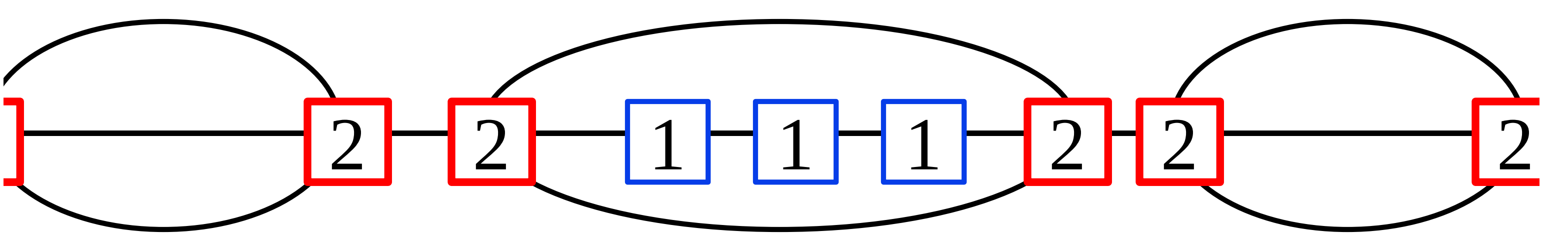
Input Port	Input Label	Adr Prefix	Output Port	Output Label
1	1	164.107.61.*	2	2
2	2	128.146.*.*	1	3

Label Stacks



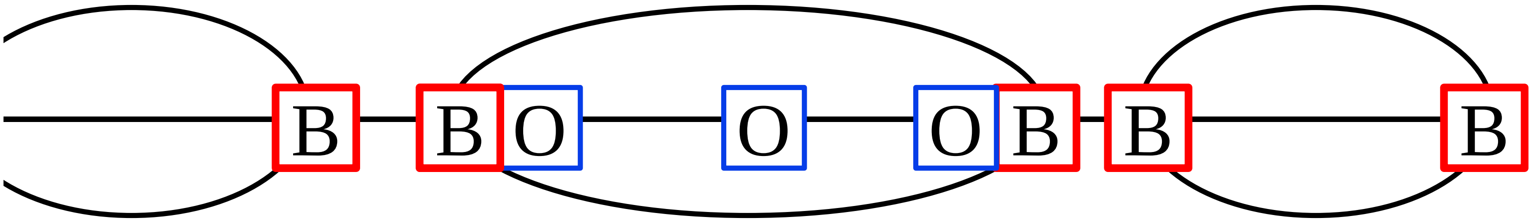
- A MPLS packet may have multiple labels
- Labels are pushed/popped as they enter/leave MPLS domain
- Stack allows hierarchy of MPLS domains
- Bottom label may indicate protocol (0=IPv4, 2=IPv6



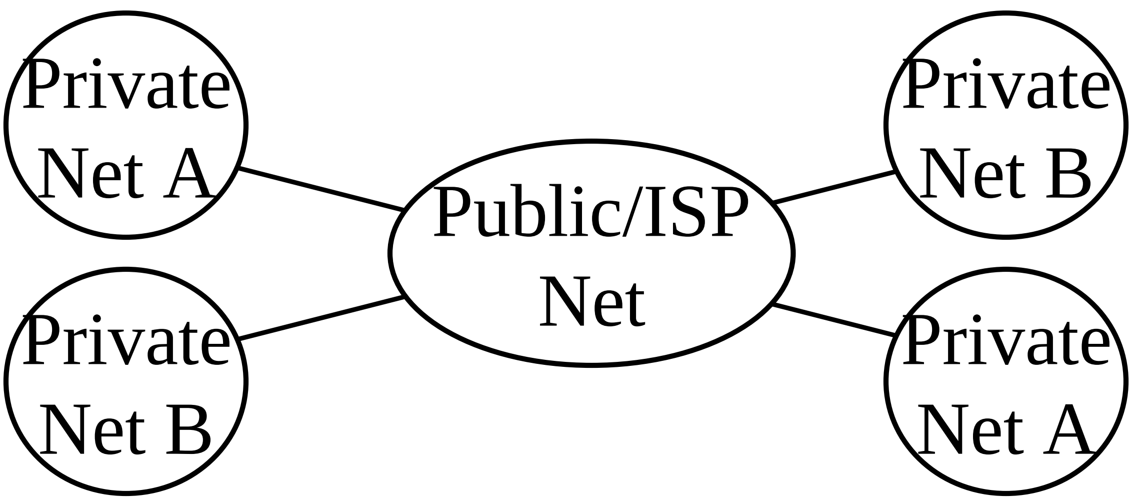


Label Stack Examples

- BGP/OSPF Routing Hierarchy



- 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
  ⇒ Easier management
- No routing over large cloud issue

IP over MPLS over DWDM

- ʼMPLS = Multi-Protocol Lambda Switching
- ꓷWDM network ≈ ATM network with Limitations
- ꓳptical Channel Trail = VC = LSPs = Traffic Trunk
- ꟻiber = Link
- ꓡimited # of channels
- ꓖlobal significance, if no λ conversion
- ꓡocal significance with λ conversion (still complex)
- ꓖranularity = λ ⇒ Fixed datarate
- ꓠo 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, ...

IPLS Control Plane: Tomorrov

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

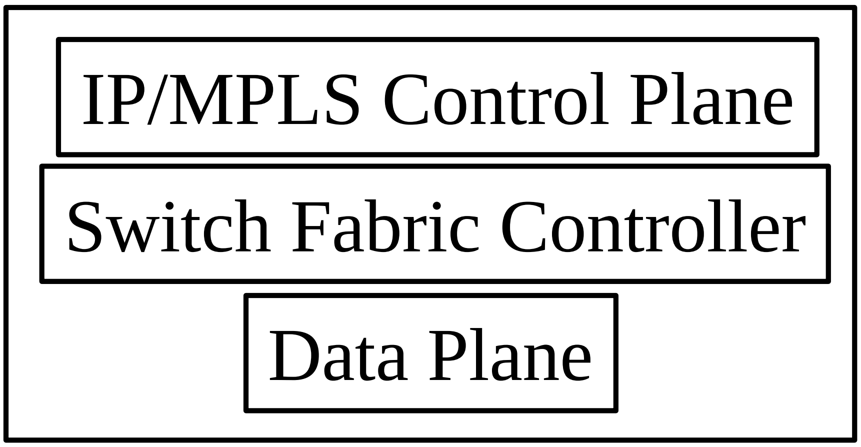
Topologies: Linear and rings to partial Mesh

control plane via network management
⇒ Permanent ⇒ Static routing
⇒ Too slow for restoration

IPLS 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 ⇒ Failures are handled locally
- λ availability will be advertised by optical node/WRouter

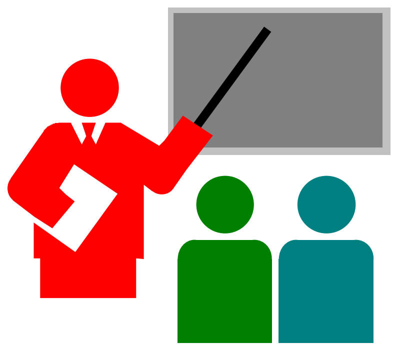
Optical Node Architecture



- Pre-configured control wavelength upon initializatio
- Need to develop hierarchical/aggregation concepts (label stacks or VPs)
  - ⇒ λ-Group (Optical channel, optical path, Light pat
- Add light path constraints to MPLS label distributio or explicit path requests

Ref: draft-awduche-mpls-te-optical-00.txt

Summary



- Iigh IP Routing speeds and volumes
  - ⇒ Need a full wavelength
  - ⇒ Many ATM/SONET functions not needed
- Need MPLS to provide QoS, Isolation
- ?rotection/Restoration/Routing should be coordinate between IP/MPLS and DWDM
- Need to develop hierarchy/aggregation concepts for DWDM

References:

- ;ee references in http://www.cis.ohio-
  ;tate.edu/~jain/refs/opt_refs.htm
- Recommended books on optical networking,
  ıttp://www.cis.ohio-state.edu/~jain/refs/opt_book.ht
-)ptical networking and DWDM, http://www.cis.ohi
  ;tate.edu/~jain/cis788-99/dwdm/index.html
- P over DWDM, http://www.cis.ohio-
  ;tate.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