Current Issues in Telecom Networks: QoS, Traffic Engineering and DWDM

Raj Jain

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

These slides are available at

http://www.cis.ohio-state.edu/~jain/talks/spects.htm

Overview

- Recent trends in network traffic and capacity
- QoS approaches: ATM, Inteserv, Diffserv, MPLS
- Traffic engineering
- IP over DWDM: MPλS

Nickel Sale

Long distance anywhere any time
25¢/minute, … 20¢, 10¢, 5¢, …, free

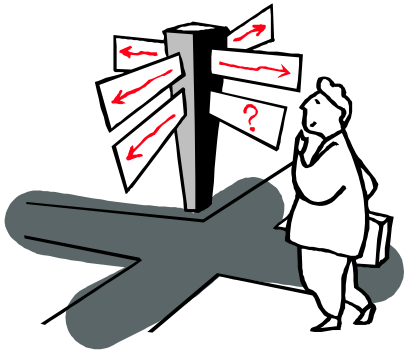
Trend: More Capacity

- Silicon capacity is doubling every 18 months (Moore's Law)
- Storage capacity is doubling every 12 months
- FDDI in 1993: 100 Mbps to 60 km over single mode
- 16 Wavelengths/fiber, 2.5 Gbps/Wavelength
  $\Rightarrow$ 40 Gbps/fiber (1998)
- 1022 Wavelengths/fiber, 40 Gbps/Wavelength
  $\Rightarrow$ 40,000 Gbps/Fiber
  = Growth rate of 1000 in five years
- Networking capacity is doubling every 6-9 months

Trend: More Traffic

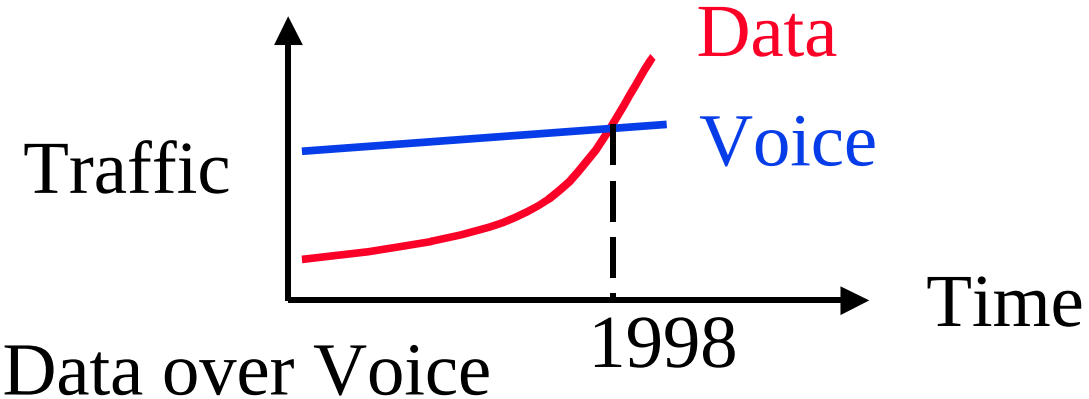
- Number of Internet hosts is growing super-exponentially.
- Traffic per host is increasing: Cable Modems+ADSL
- All projections of network traffic turn out to be lower than actual
- UUNet traffic was doubling every 4 months… 100 days...

Trend: Traffic > Capacity

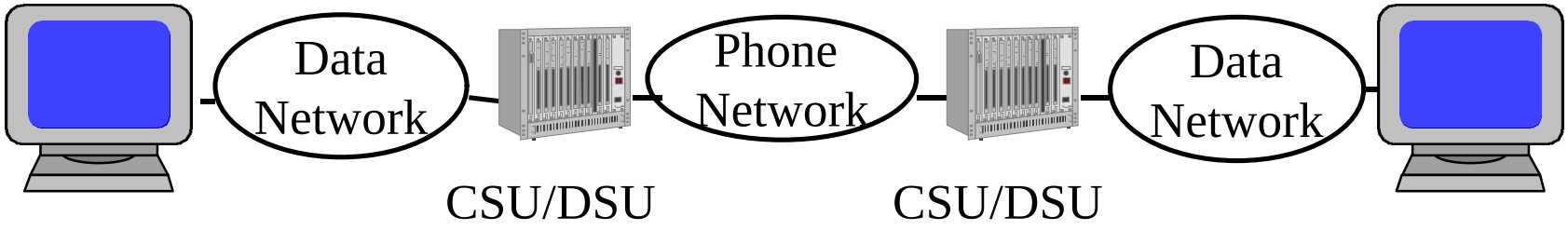


Expensive Bandwidth	Cheap Bandwidth
❑ Sharing	❑ No sharing
❑ Multicast	❑ Unicast
❑ Virtual Private Networks	❑ Private Networks
❑ More efficient use (L3)	❑ Less efficient use
❑ Need QoS	❑ QoS less of an issue
❑ Likely in WANs	❑ Possible in LANs

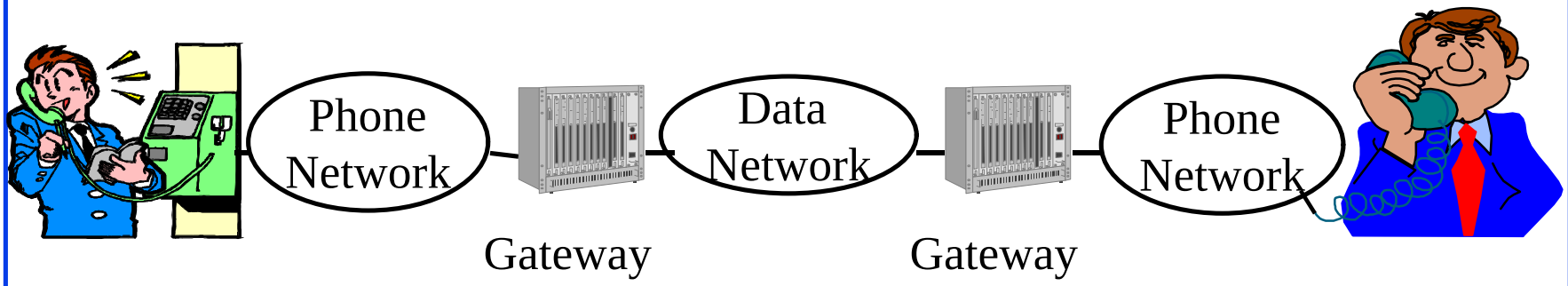
Trend: Data > Voice



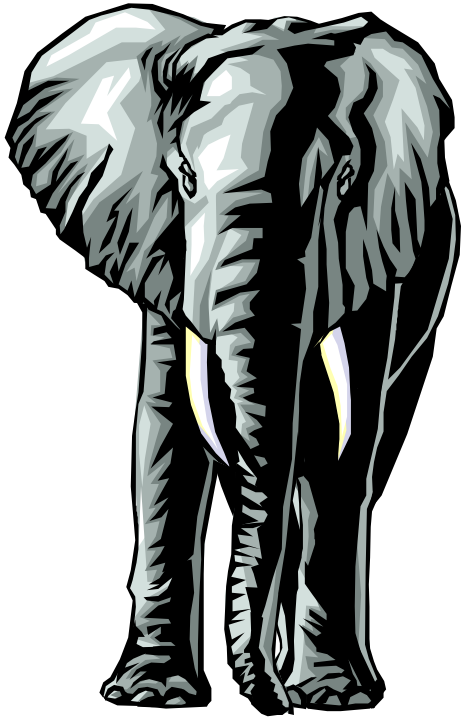
- Past: Data over Voice

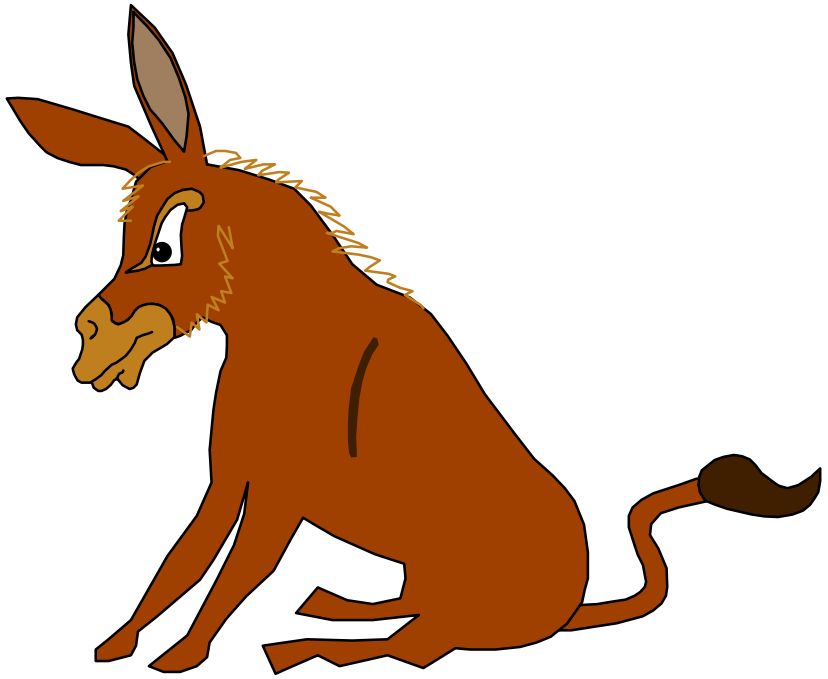


- Future: Voice over Data



Telco vs Data Networks



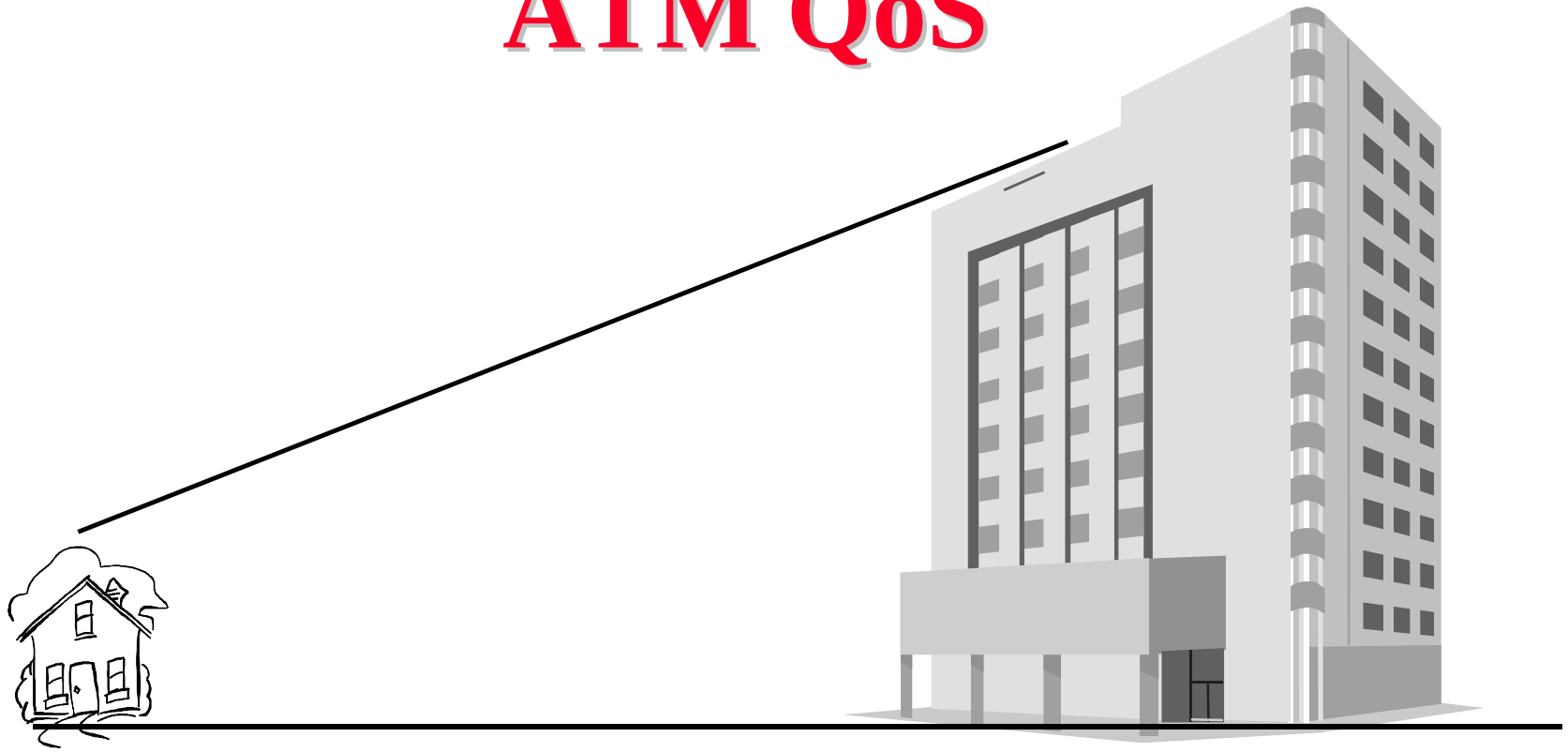


Telco Protocols	Data Protocols
QoS	Simplicity
Reliability	
Protection	Need QoS, ...

Solution 1: ATM

- 1988-1996
- ATM provides:
  - Voice + Data Integration: CBR, VBR, ABR, UBR
  - Signaling
  - Quality of service routing: PNNI
  - Traffic management
- Most carriers including AT&T, MCI, Sprint, UUNET, switched to ATM backbone
- ATM can't reach desktop: Designed by carriers. Complexity in the end systems. Design favors voice.

ATM QoS

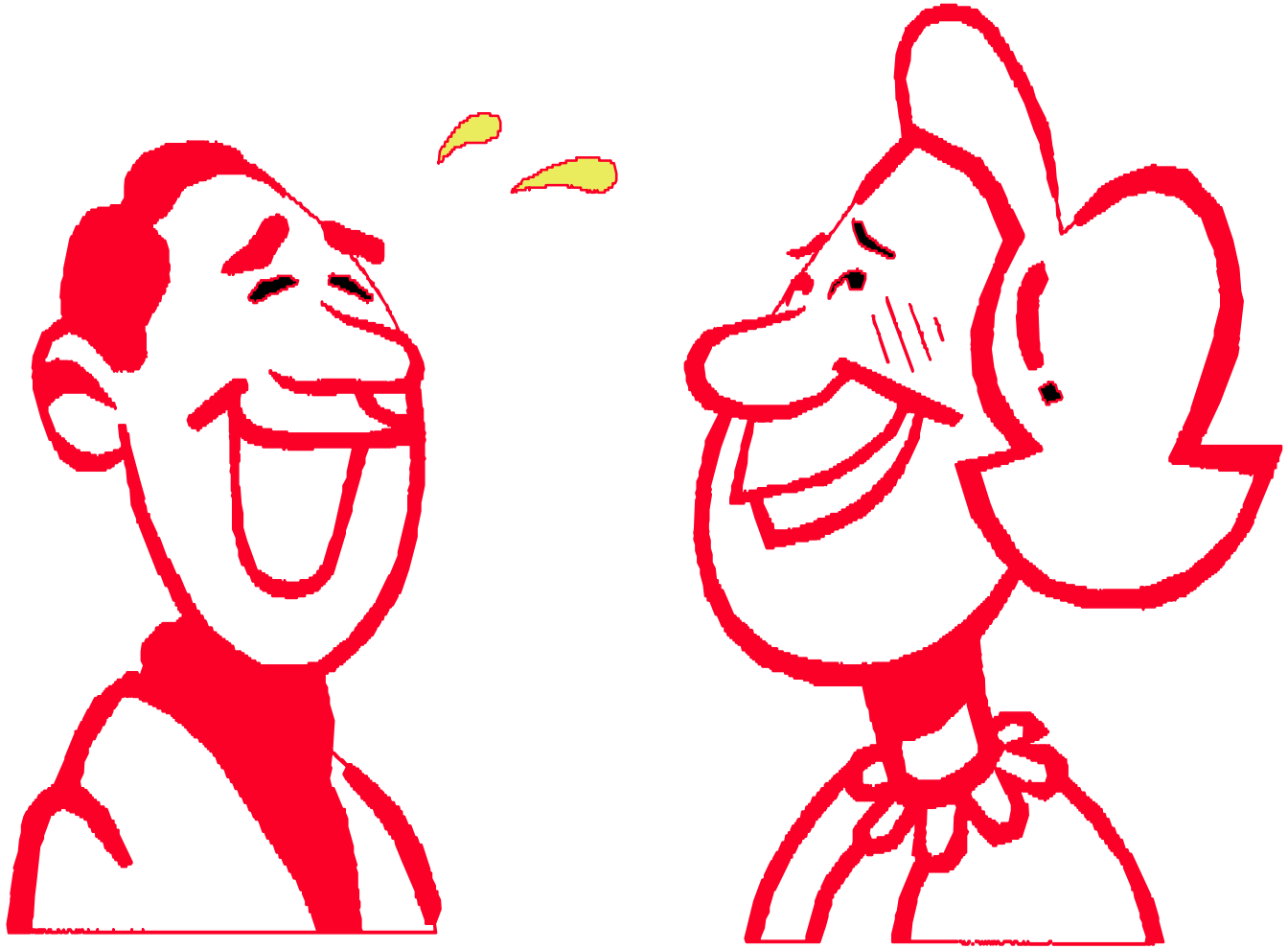


Too much too soon

Solution 2: Integrated Services

- 1996-1998
- Controlled Service and Guaranteed Service (VBR and CBR)
- Per-Flow guarantee
- Receiver Controlled
- Soft State
- End-to-end path based guarantee
- Quantitative and Qualitative
- Absolute
- Requires signaling (RSVP)

Before

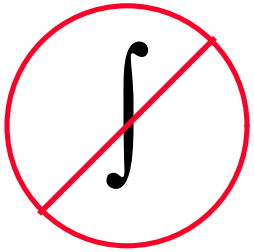


After

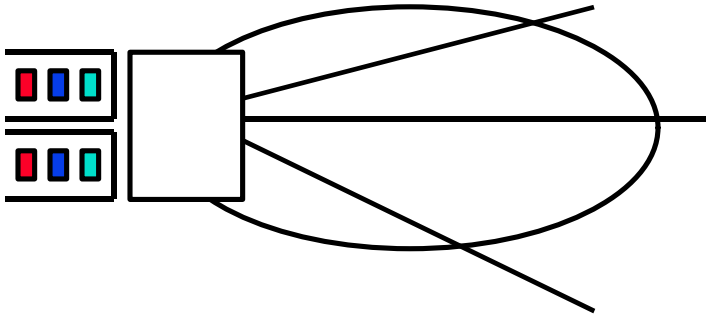
Problems with Integrated Services + RSVP

- Complexity in routers: packet classification, scheduling
- Not scalable with # of flows
- Need a concept of "Virtual Paths" or aggregation
- Need policy controls
- Receiver Based:
  Need sender control/notifications in some cases.
  Which receiver pays for shared part of the tree?
- Soft State: Need route/path pinning (stability).
- No negotiation and backtracking

Solution 3: Differentiated Services



$\Rightarrow$ d/dx



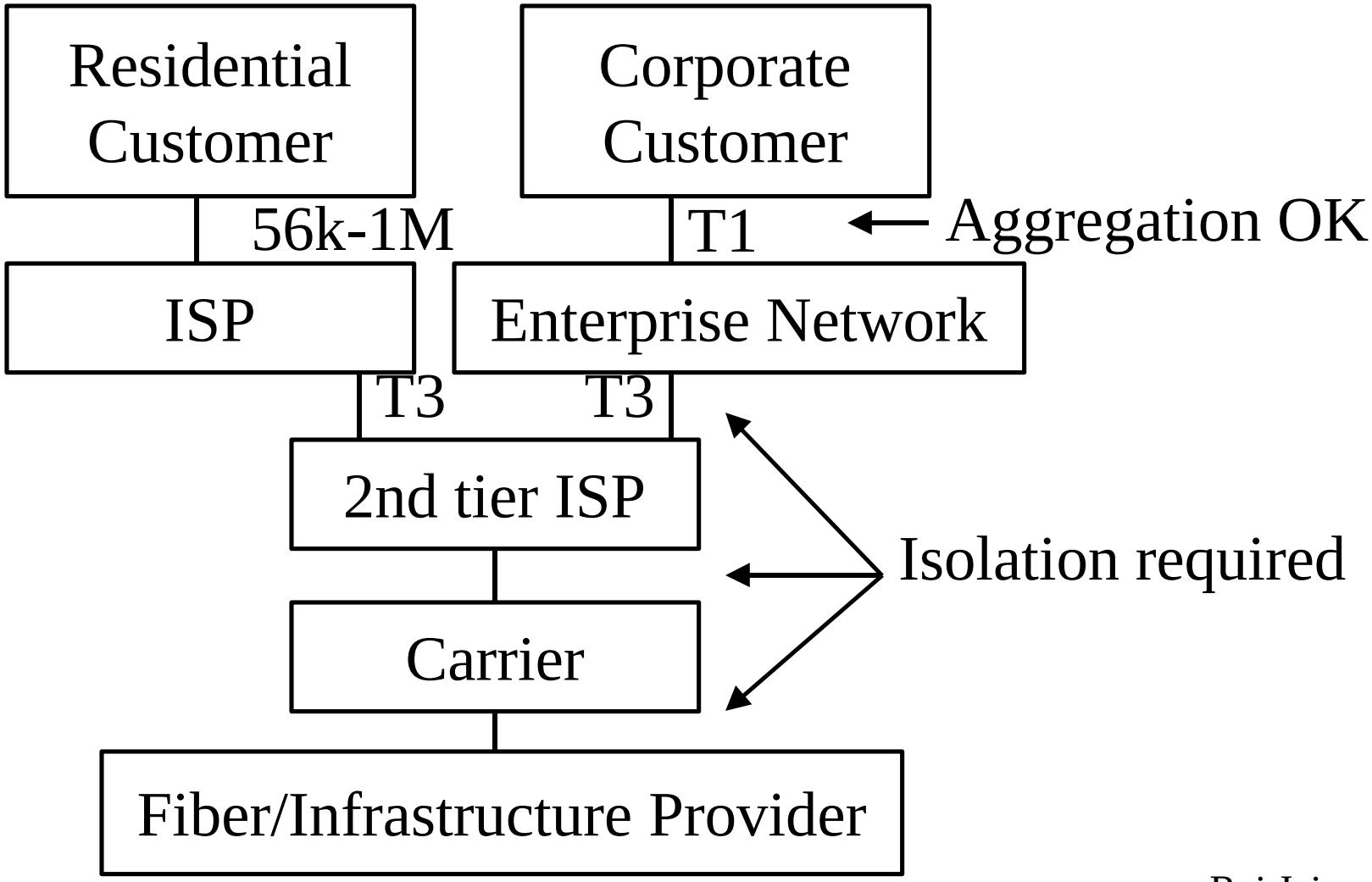
- 1998-1999
- Standardize IPv4 ToS byte's first six bits
- Packets gets marked at network ingress
  Marking $\Rightarrow$ treatment (behavior) in rest of the net
  Six bits $\Rightarrow$ 64 different per-hop behaviors (PHB)
- No per-Flow guarantees. Only aggregate
- Controlled at the ingress. Access based
- No signaling

Diffserv: Key Issues

- How to ensure resource availability inside the network? How to provision?
- QoS is for the aggregate not micro-flows.
  - Large number of low-bandwidth flows are better handled by aggregates.
  - High-bandwidth flows (1 Mbps video) need per-flow guarantees.

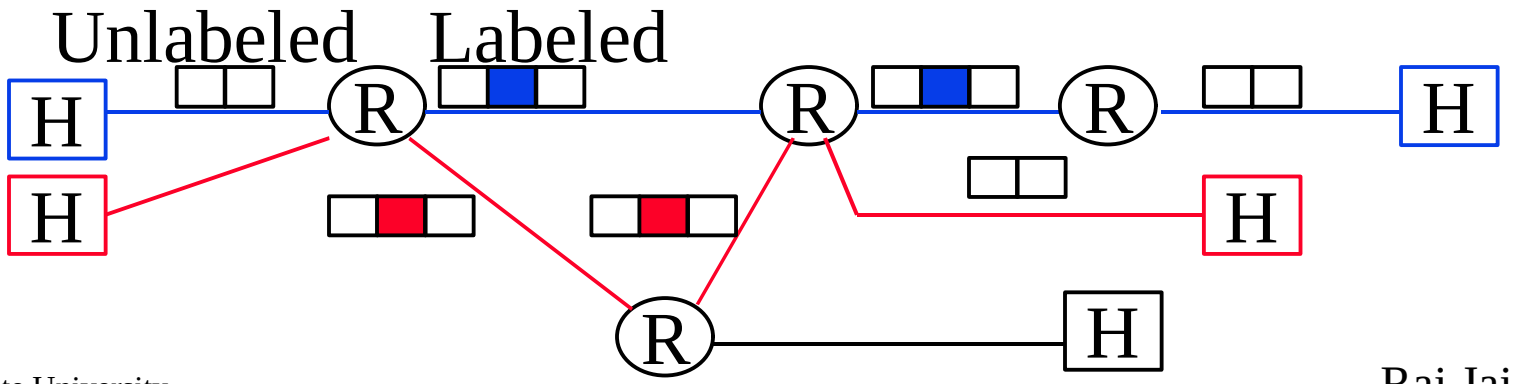
$\Rightarrow$ DiffServ alone is not sufficient for backbone. Signaling via RSVP will be required.

Customer Perspective of QoS



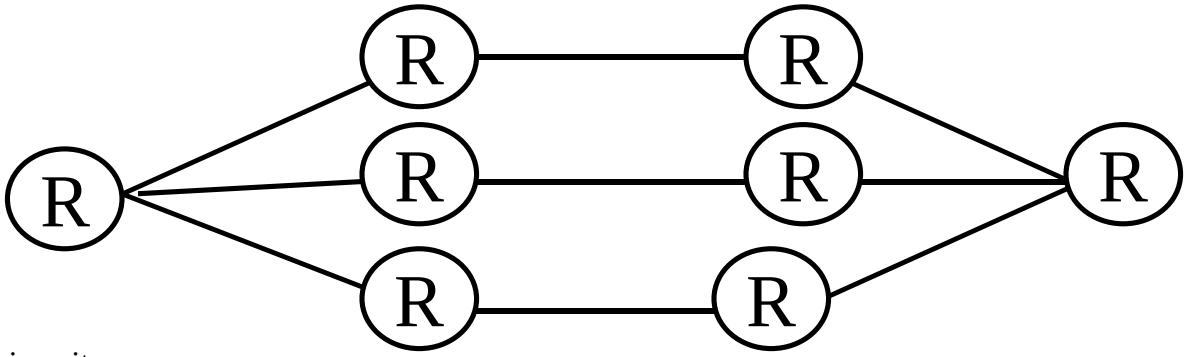
Multiprotocol Label Switching

- MPLS = Allows ATM-like features over switched Ethernet and point-to-point links also.
- Virtual Circuit Id ⇒ Label on each packet
- Ingress router/host puts a label. Exit router strips it off.
- Switches switch packets based on labels.
  Do not need to look inside ⇒ Fast.
  But, we don't need MPLS for speed!



Traffic Engineering Using MPLS

- MPLS allows explicit routes
- Provides isolation, stability, QoS Guarantee
- Current IP routing protocols send all traffic over shortest path ⇒ Congestion
- MPLS allows parallel paths ⇒ Load balancing ⇒ Efficient Utilization of all links
- Protection: working and standby paths



QoS Design Approaches

- Massive Bandwidth vs Managed Bandwidth
- Per-Flow vs Aggregate
- Source-Controlled vs Receiver Controlled
- Soft State vs Hard State
- Path based vs Access based
- Quantitative vs Qualitative
- Absolute vs Relative
- End-to-end vs Per-hop
- Static vs Feedback-based
- Homogeneous multicast vs heterogeneous multicast
- 1-to-n multicast vs n-to-1 multicast

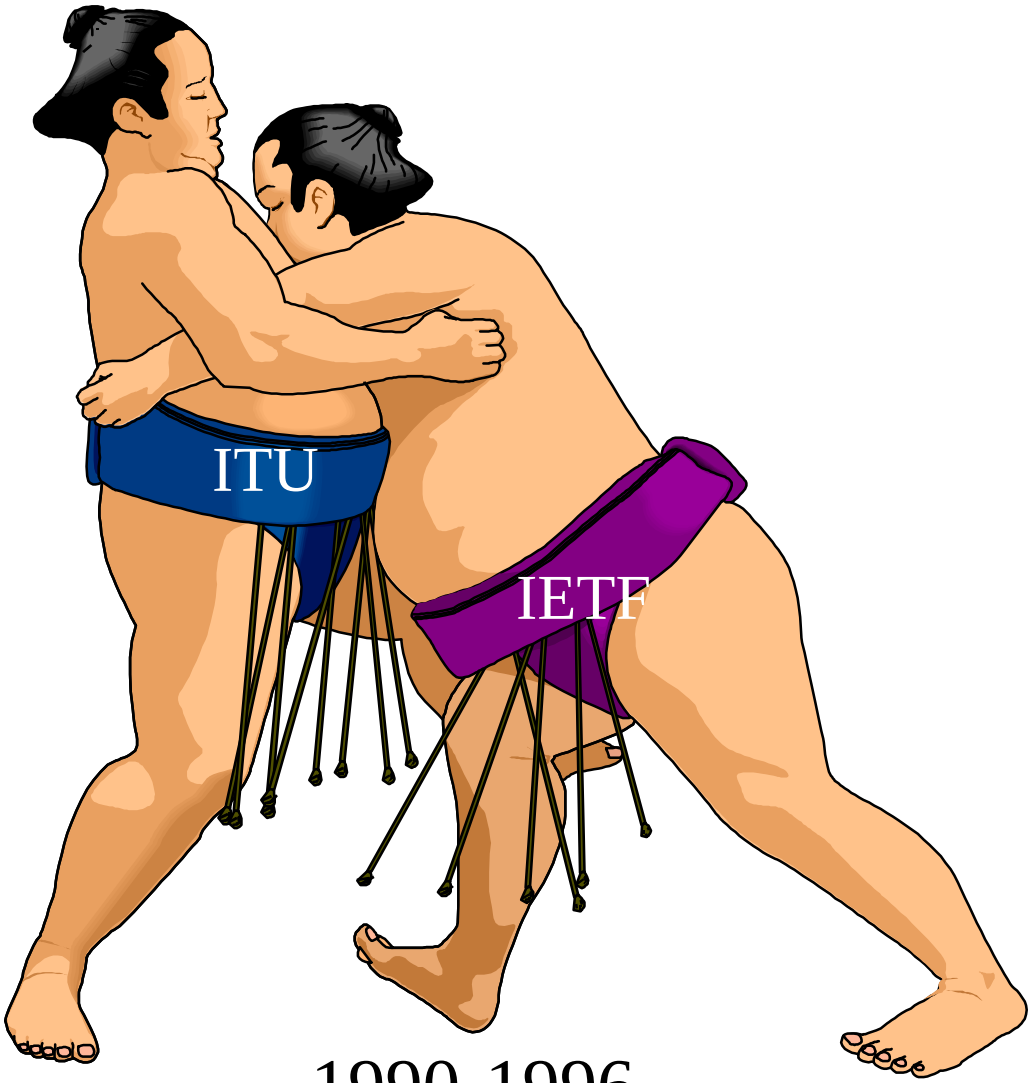
Comparison of QoS Approaches

Issue	ATM	IntServ	DiffServ	MPLS	IEEE 802.3D
Massive Bandwidth vs Managed Bandwidth	Managed	Managed	Massive	Managed	Massive
Per-Flow vs Aggregate	Both	Per-flow	Aggregate	Both	Aggregate
Source-Controlled vs Receiver Controlled	Unicast Source, Multicast both	Receiver	Ingress	Both	Source
Soft State vs Hard State	Hard	Soft	None	Hard	Hard
Path based vs Access based	Path	Path	Access	Path	Access
Quantitative vs Qualitative	Quantitative	Quantitative +Qualitative	Mostly qualitative	Both	Qualitative
Absolute vs Relative	Absolute	Absolute	Mostly Relative	Absolute + relative	Relative

Comparison (Cont)

Issue	ATM	IntServ	DiffServ	MPLS	IEEE 802.3D
End-to-end vs Per-hop	end-end	end-end	Per-hop	end-end	Per-hop
Static vs Feedback-based	Both	Static	Static	Static	Static
Homogeneous multicast vs heterogeneous multicast	Homo-geneous	Hetero-geneous	N/A	Homo-geneous	N/A
1-to-n vs n-to-1 multicast	1-to-n	1-to-n	N/A	Both	Both

ITU vs IETF



1990-1996

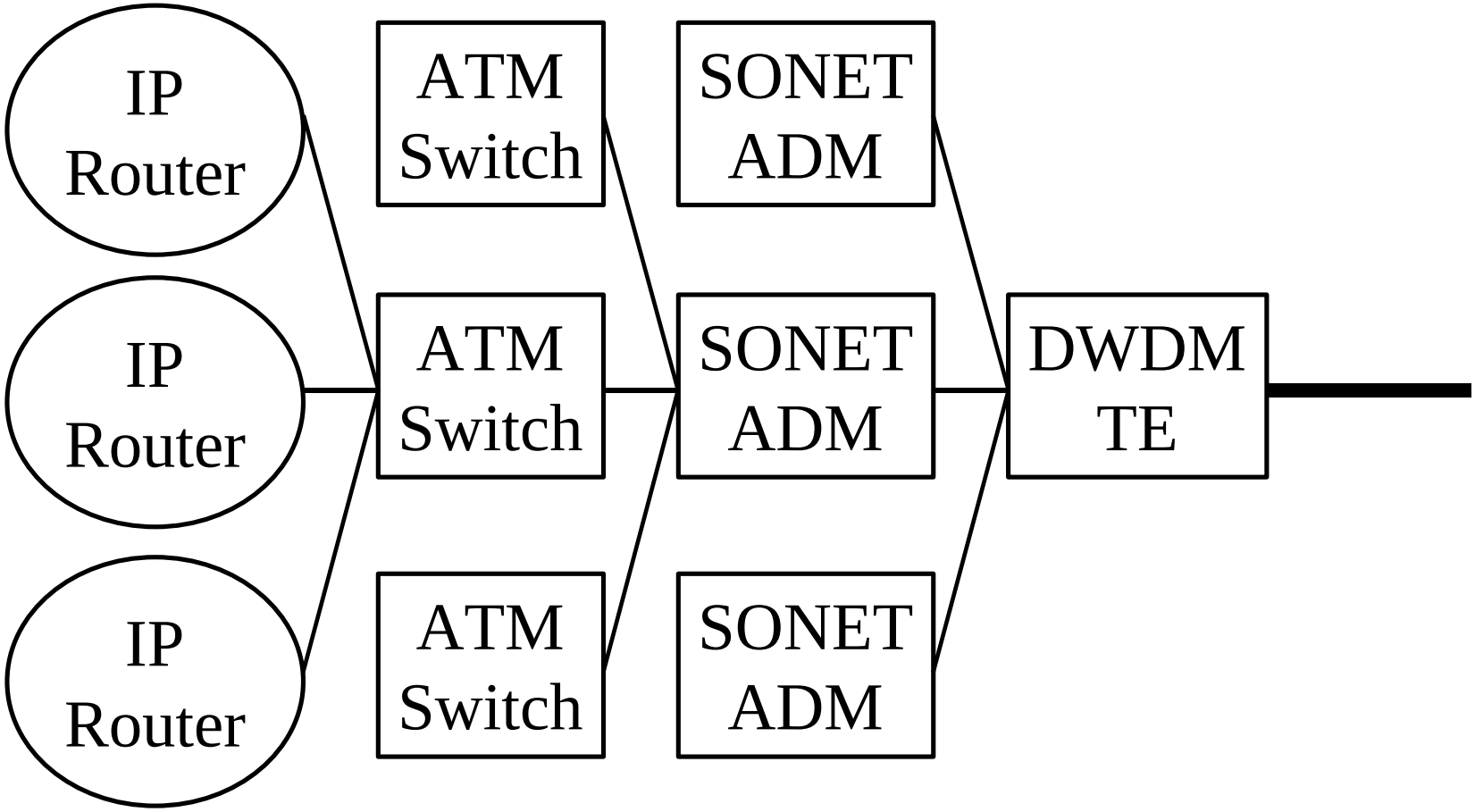
Telecom Discovers IP

Telecom

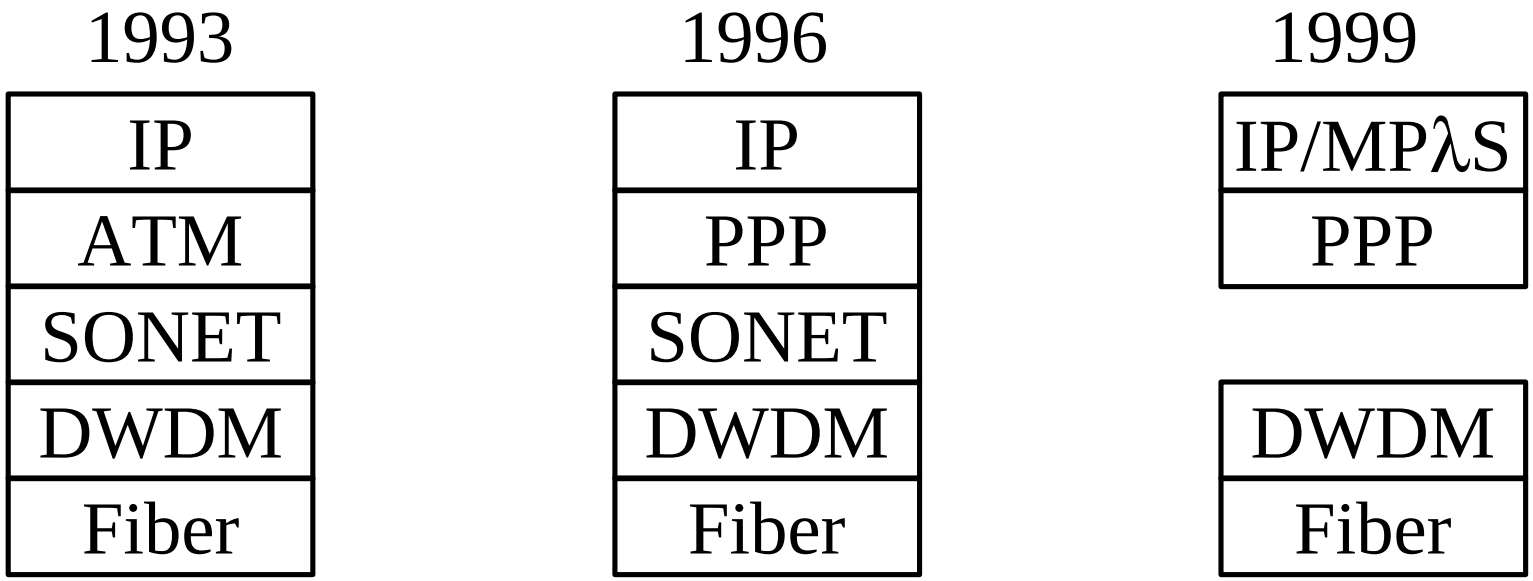
IP

1998-1999

Initial DWDM Deployment



IP over DWDM: Protocol Layers



- IP is good for routing, traffic aggregation, resiliency
- ATM for multi-service integration, QoS/signaling
- SONET for traffic grooming, monitoring, protection
- DWDM for capacity

Multi-layer Stack: Problems

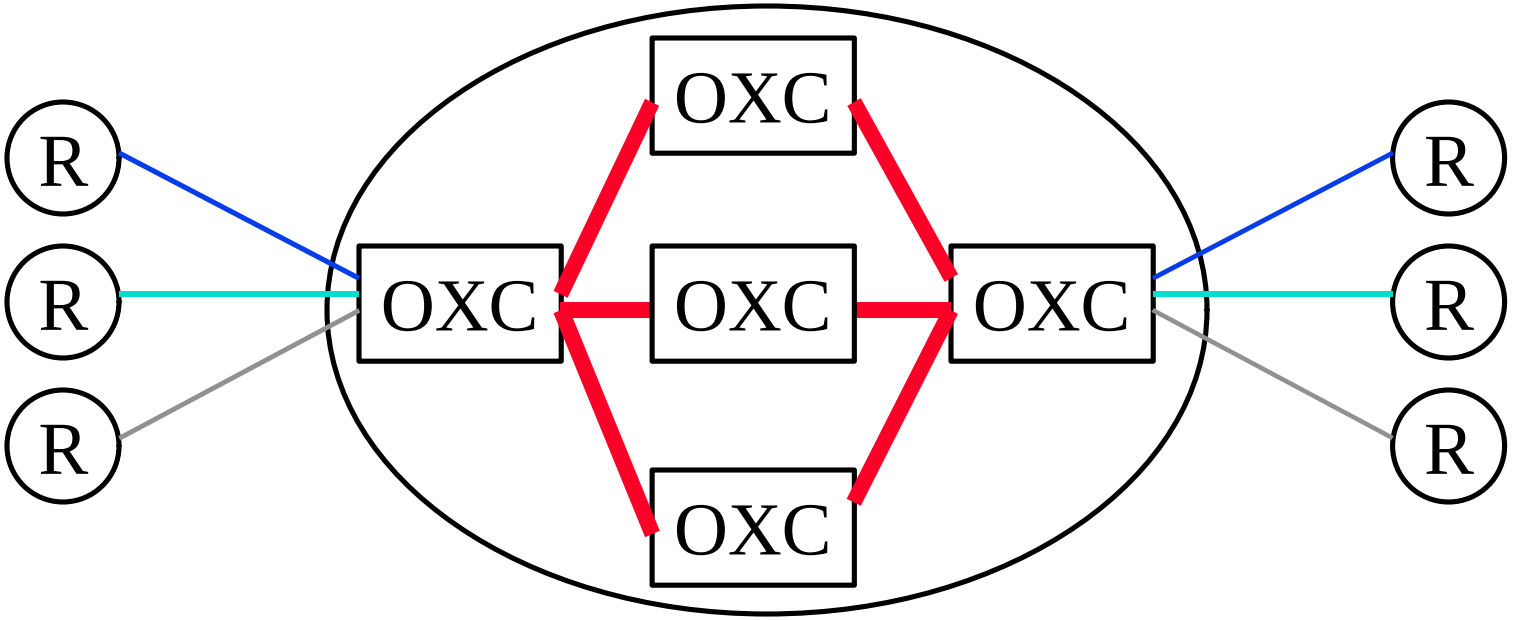
- Functional overlap:
  - Muxing:DWDM λ=ΣSTM=ΣVC=ΣFlows=Σ packets
  - Routing: DWDM, SONET, ATM, IP
  - QoS/Integration: ATM, IP
- Failure affects multiple layers:
  1 Fiber $\Rightarrow$ 64 λ $\Rightarrow$ 1000 OC-3 $\Rightarrow$ 10^5 VCs $\Rightarrow$ 10^8 Flows
- Restoration at multiple layers:
  DWDM $\Rightarrow$ SONET $\Rightarrow$ ATM $\Rightarrow$ IP
- SONET $\Rightarrow$ Manual (jumpers) $\Rightarrow$ months/connection
- Any layer can bottleneck
  $\Rightarrow$ Intersection of Features + Union of Problems

IP over DWDM: Why?

- IP ⇒ Revenue
  DWDM ⇒ Cheap bandwidth
  IP and DWDM ⇒ Winning combination
  Avoid the cost of SONET/ATM equipment
- IP routers at OC-192 (10 Gbps)
  ⇒ Don't need SONET multiplexing
- IP for route calculation, traffic aggregation, protection
- Optical layer for route provisioning, protection, restoration
- Coordinated restoration at optical/IP level
- Coordinated path determination at optical/IP level

MPλS

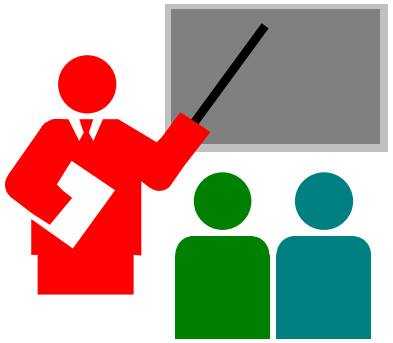
- MPλS = Multi-Protocol Lambda Switching
- All packets with one label are sent on one wavelength
- Optical crossconnects (OXCs) are IP addressable devices and may use OSPF for route calculations



MPλS (Cont)

- Next Hop Forwarding Label Entry (NHFLE)
  $\Rightarrow$ <Input port, λ> to <output port, λ> mapping
- MPλS = Simplified MPLS
  - No label stacks
  - No per-packet forwarding $\Rightarrow$ No queuing, No scheduling, No Priority, No burstiness, No policing
- LDP/CR-LDP and RSVP need extensions for:
  - Resource discovery,
  - Provisioning,
  - Protection/restoration

Summary



- DWDM has resulted in an exponential growth in network capacity
- Traffic growth is still more than capacity ⇒ QoS
- High speed routers ⇒ IP directly over DWDM
- MPλS to provide resource discovery, provisioning, protection and restoration

References:

- Detailed references in http://www.cis.ohio-state.edu/~jain/refs/ipqs_refs.htm and 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
- IP over Optical: A summary of issues, (internet draft) http://www.cis.ohio-state.edu/~jain/ietf/issues.html
- IP over DWDM, (talk) http://www.cis.ohio-state.edu/~jain/talks/ip_dwdm/index.html

Thank You!