

# Multiprotocol Label Switching

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# MBone Instructions

- ❑ Handouts for the class are available on-line:  
<http://www.cis.ohio-state.edu/~jain/cis788-97/index.html> or  
<http://www.netlab.ohio-state.edu/~jain/cis788-97/index.html> or  
<ftp://netlab.ohio-state.edu/pub/jain/cis788-97/>
- ❑ The schedule keeps changing. Please always check current schedule at:  
<http://www.cis.ohio-state.edu/~jain/cis788-97/schedule.html>

# Instructions (Cont)

- ❑ Please email your positive and negative feedback about the quality of the reception as well as the content with a subject field of “**Feedback**” to [mbone@netlab.ohio-state.edu](mailto:mbone@netlab.ohio-state.edu)
- ❑ If you are not able to receive the program due to some technical difficulties, please email “**Feedback**” to [mbone@netlab.ohio-state.edu](mailto:mbone@netlab.ohio-state.edu)
- ❑ Please email technical questions with the subject field “**Question**” to [mbone@netlab.ohio-state.edu](mailto:mbone@netlab.ohio-state.edu). We will try to answer selected questions live.



- ❑ Review of MPOA and IP Switching
- ❑ Tag Switching (CISCO)
- ❑ ARIS (IBM)
- ❑ Multi-protocol label switching

# Disclaimer

- ❑ This technology is currently evolving.  
⇒ All statements are subject to change.
- ❑ Features not in a scheme may be implemented later in that scheme.
- ❑ Problems claimed to be in a scheme may later not be a problem.

# L3 Switching

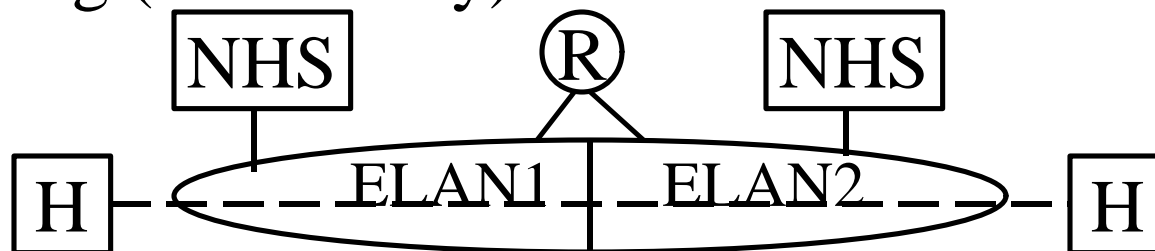
- Layer 3 forwarding at wire speeds
  - Switching based on Layer 3 (L3) header
  - Switched IP forwarding
  - Several million packets per second (Mpps)
    - 8 Mpps announced by ODS
- Layer 2 switching  $\Rightarrow$  Large flat networks
  - Problem: Broadcast, security
  - Solution: Virtual LANs (VLANs)
    - $\Rightarrow$  Need routing between VLANs

# Technology Evolution

- ❑ New technology gets absorbed by the old
- ❑ FDDI  $\Rightarrow$  100 Mbps Ethernet
- ❑ Fiber Channel  $\Rightarrow$  Gigabit Ethernet
- ❑ ATM Switches  $\Rightarrow$  LAN switches
- ❑ ATM ELANs  $\Rightarrow$  VLANs
- ❑ ATM shortcuts  $\Rightarrow$  L3 Switching

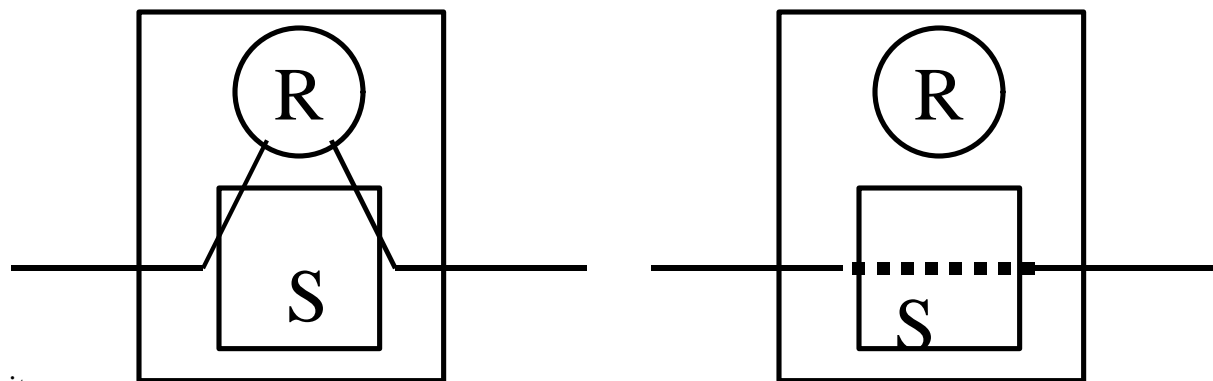
# MPOA

- ❑ Multiprotocol over ATM
- ❑ Extension of LANE
- ❑ Solves the problem of needing routers between emulated LANs
- ❑ Uses NHRP to find the shortcut to the next hop
- ❑ NHRP servers communicate with each other to find the destination
- ❑ No routing (reassembly) in the ATM network



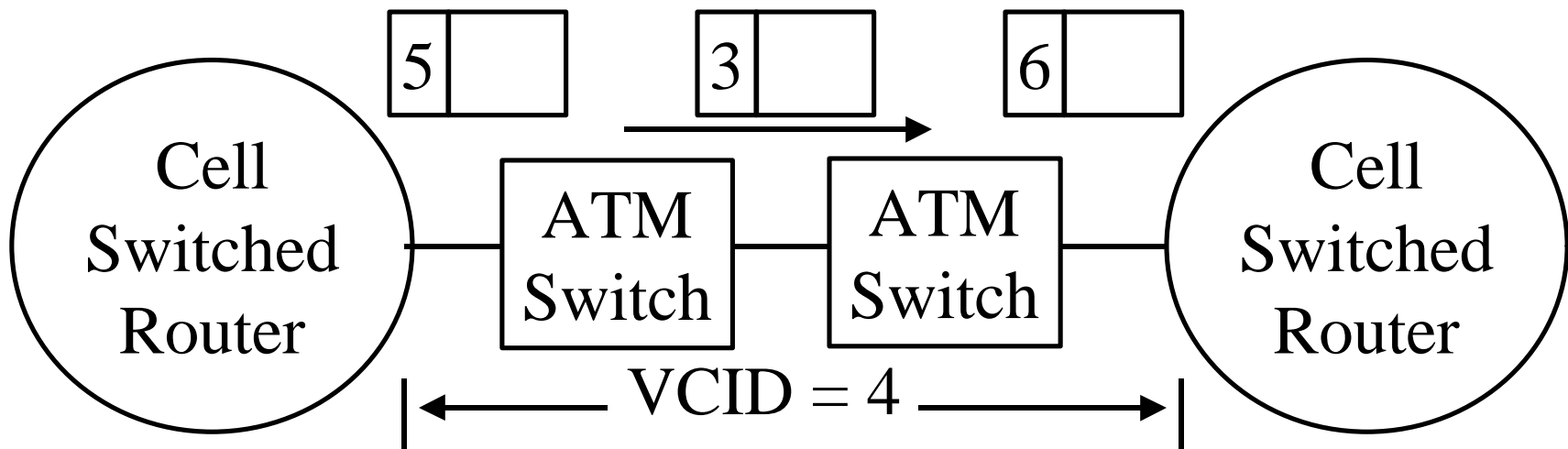
# IP Switching

- ❑ Developed by Ipsilon
- ❑ Routing software in every ATM switch in the network
- ❑ Initially, packets are reassembled by the routing software and forwarded to the next hop
- ❑ Long term flows are transferred to separate VCs. Mapping of VCIs in the switch  $\Rightarrow$  No reassembly



# Cell Switched Router (CSR)

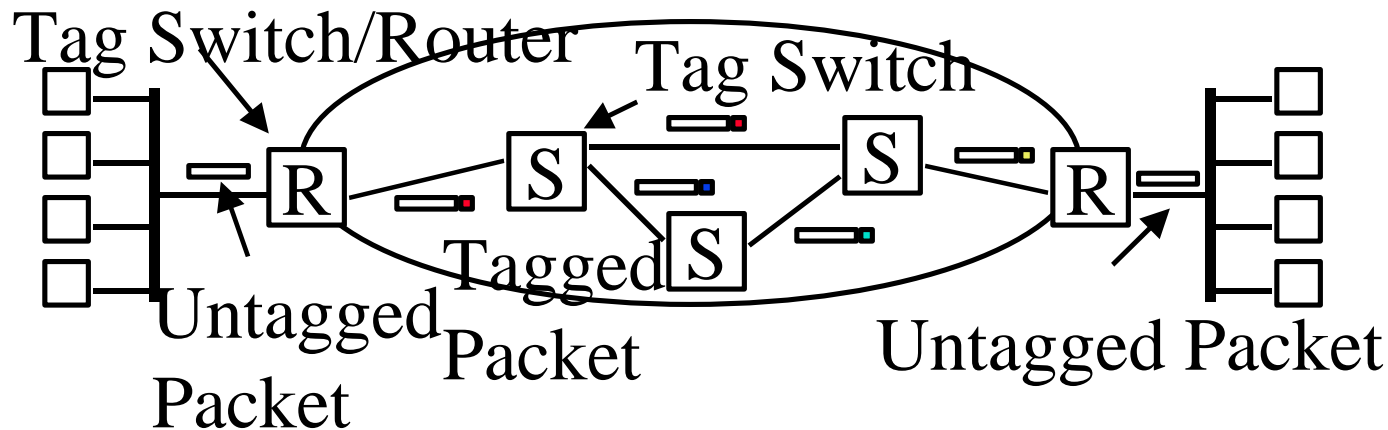
- ❑ Proposed by Toshiba
- ❑ Flow driven (similar to Ipsilon)
- ❑ VCID separate from VCI  $\Rightarrow$  Switches between CSRs
- ❑ Upstream assigns a VCID and sends downstream



# CSR (Cont)

- ❑ VCs are set up in advance and are bounded as needed
- ❑ Classifies flows by IP source/destination address pair
- ❑ Soft connections  $\Rightarrow$  Periodically refreshed

# Tag Switching



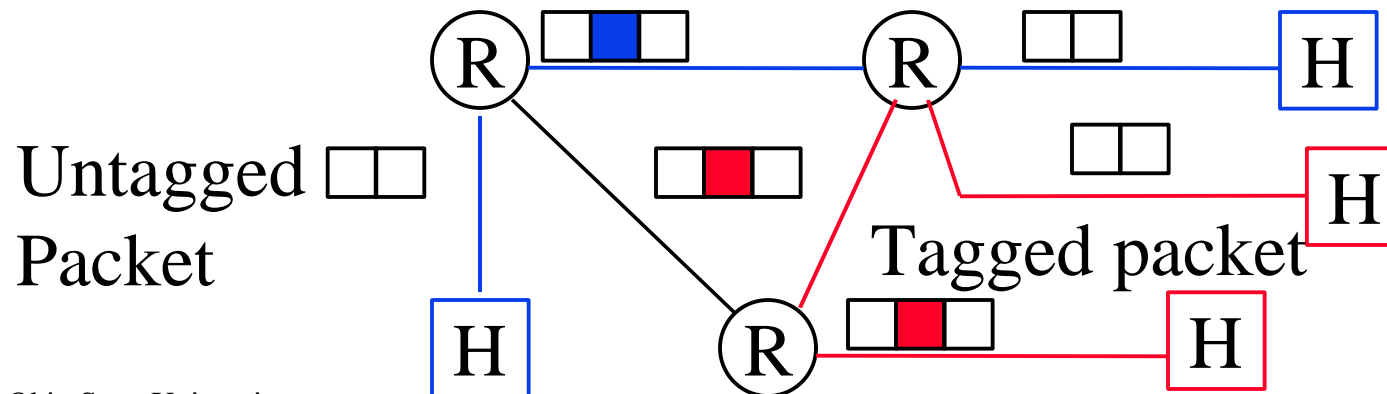
- ❑ Entry router/switch attaches a label (tag) to the packet based on the route
- ❑ Switches switch packets based on labels.  
Do not need to look inside  $\Rightarrow$  Fast.
- ❑ Tags have local significance  
 $\Rightarrow$  Different tag at each hop (similar to VC #)
- ❑ Exit router/switch strips off the tag

# Tag Switching

- ❑ Proposed by CISCO
- ❑ Similar to VLAN tags
- ❑ Tags can be explicit or implicit L2 header

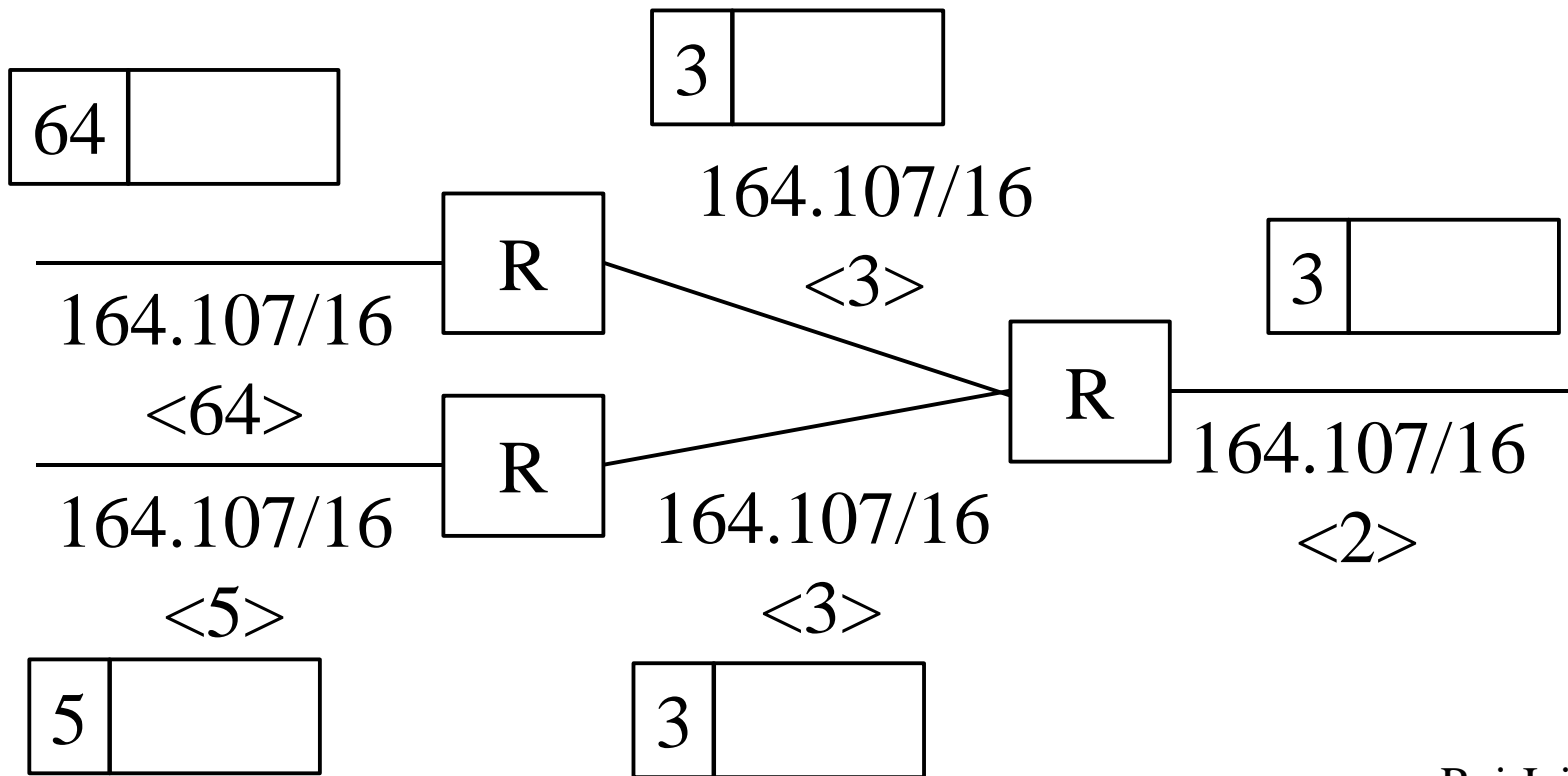


- ❑ Ingress router/host puts a tag



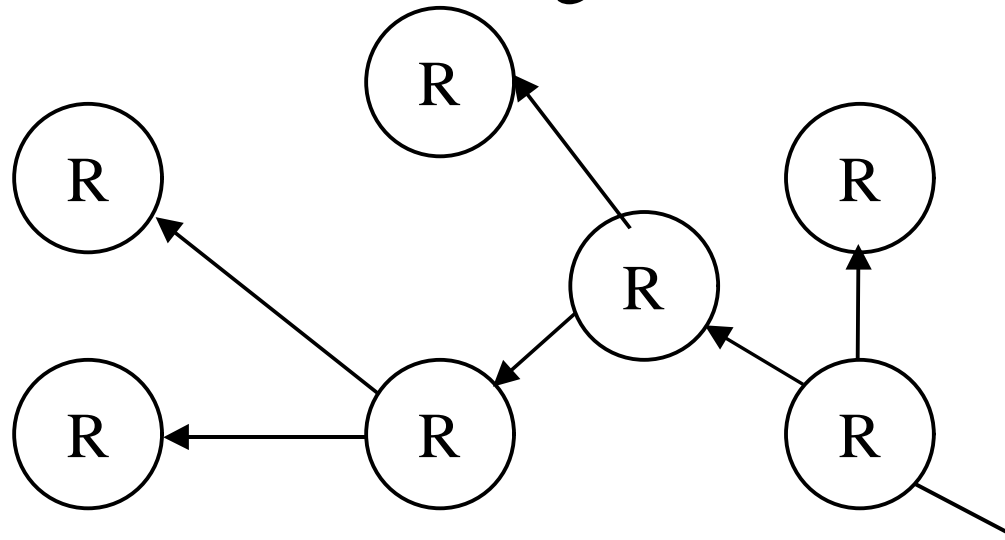
# Tag Switching (Cont)

- One VC per routing table entry
- One memory reference compared to 4-16 in router



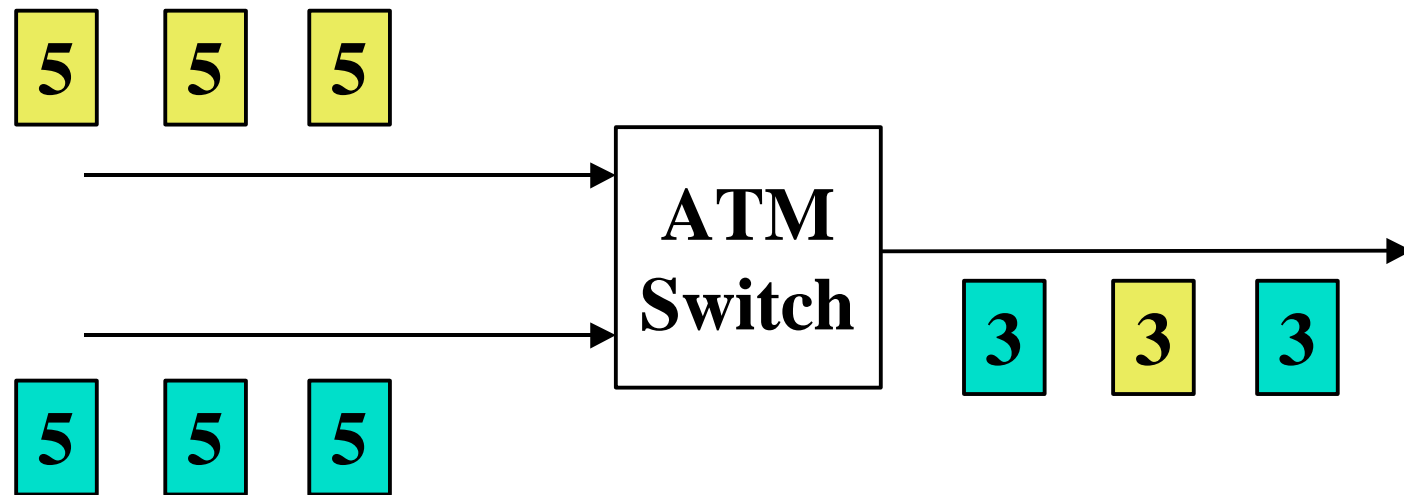
# ARIS

- ❑ Aggregate Route-Based IP Switch
- ❑ Proposed by IBM
- ❑ Topology based. One VC per egress router.
- ❑ Egress router initiates the setup of switched path
- ❑ Supports LAN media switching



# ARIS (Cont)

- mpt-to-pt VC  $\Rightarrow$  VC merge
- Integrated Switch Routers (ISRs)
- Globally unique labels  $\Rightarrow$  Each ISR has a VCI block



# Switched IP Forwarding: Comparison

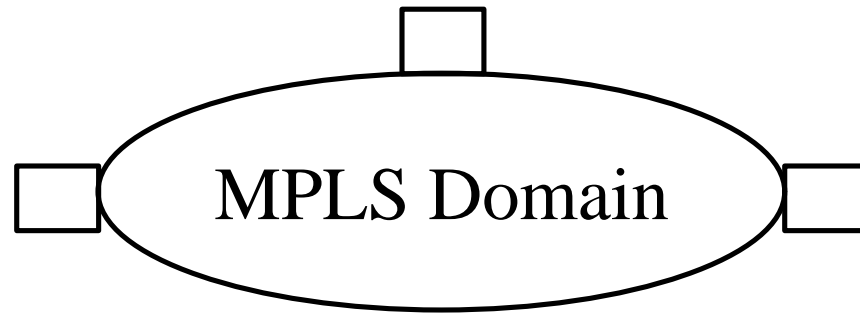
<b>Issue</b>	<b>IP Switch</b>	<b>CSR</b>	<b>Tag</b>	<b>ARIS</b>
Datalink	ATM	ATM, FR	ATM, FR, Ethernet	ATM, FR
Network Layer	IP	IP	IP, XNS, ...	IP
Initiator	Downstream	Both	Both	Egress
VC Setup Protocol	IFMP	FANP	TDP	ARIS
Mapping	Traffic	Traffic	Topology	Topology
# of VCs	# of L4 flows	# of L3 flows	# of routes	# of Egress routers

# MPLS

- ❑ Multiprotocol Label Switching
- ❑ IETF working group to develop switched IP forwarding
- ❑ Initially focused on IPv4 and IPv6.  
Technology extendible to other L3 protocols.
- ❑ Not specific to ATM. ATM or LAN.
- ❑ Not specific to a routing protocol (OSPF, RIP, ...)
- ❑ Optimization only. Labels do not affect the path.  
Only speed. Networks continue to work w/o labels
- ❑ Complete spec by the end of 1997

# Terminology

- ❑ Label = Short fixed length, physically contiguous, locally significant
- ❑ Stream =  $\Sigma$  flows = pt-pt, pt-mpt, mpt-pt, mpt-mpt
- ❑ Stream Merge  $\Rightarrow$  Stream =  $\Sigma$  streams
- ❑ Label information base (LIB)  $\cong$  Routing info base
- ❑ Label distribution protocol (LDP)  $\cong$  Routing protocols
- ❑ MPLS edge node = Egress or ingress node

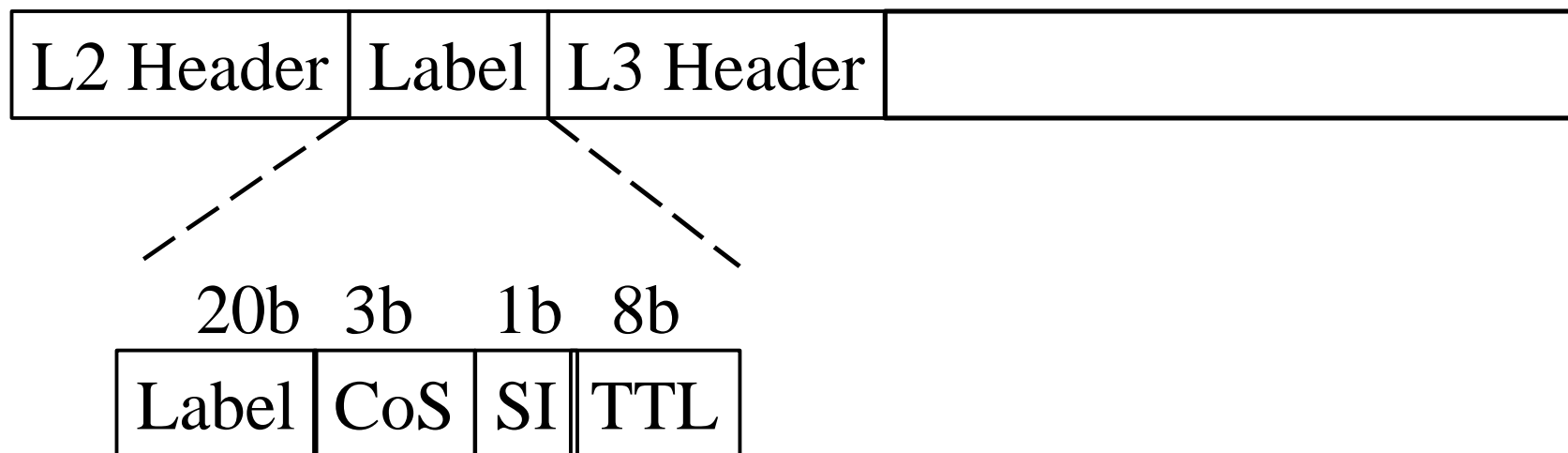


# Label Assignment

- ❑ Binding between a label and a route
- ❑ Traffic, topology, or reservation driven
- ❑ Traffic: Initiated by upstream/downstream/both
- ❑ Topology: One per route, one per MPLS egress node.
- ❑ Labels may be preassigned
  - ⇒ first packet can be switched immediately
- ❑ Reservations: Labels assigned when RSVP “RESV” messages sent/received.
- ❑ Unused labels are "garbage collected"
- ❑ Labels may be shared, e.g., in some multicasts

# Label Format

- ❑ Labels = Explicit or implicit L2 header
- ❑ TTL = Time to live
- ❑ CoS = Class of service
- ❑ SI = Stack indicator



# Label Stacks

- ❑ Labels are pushed/popped as they enter/leave MPLS domain
- ❑ Routers in the interior will use Interior Gateway Protocol (IGP) labels. Border gateway protocol (BGP) labels outside.

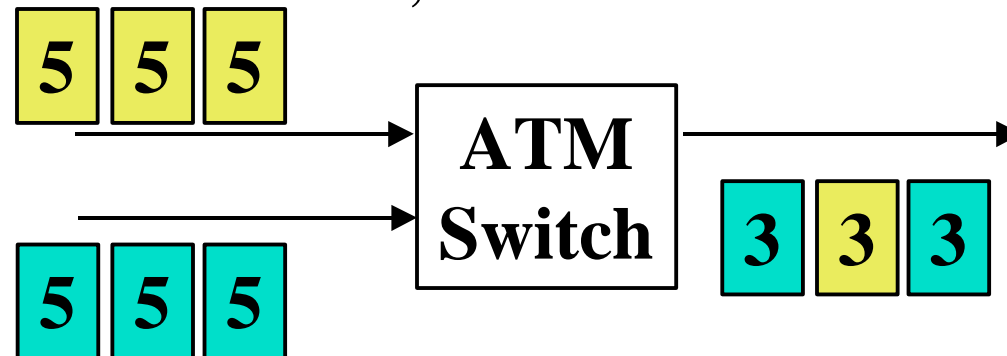


# Label Distribution

- ❑ Who assigns labels for communication between A and B?
  - A, B, or someone else?
  - Downstream, upstream, ...
- ❑ Where is the control for the entire path?  
A, B, ingress or egress LSR?
- ❑ Separate protocol or existing route distribution mechanisms?
  - Tag Distribution Protocol (TDP)
  - Flow Attribute Notification Protocol (FANP)

# Stream Merging

- ❑ Required for egress based labels
- ❑ Helpful for mpt-to-pt streams
- ❑ In ATM/AAL5, cells of frames on the same VC cannot be intermingled  $\Rightarrow$  VCs cannot be merged.
- ❑ VC-merge: Store all cells of a frame and forward together  $\Rightarrow$  Need more buffering. Delay.
- ❑ VP Merge: VPI = Labels, VCI = source

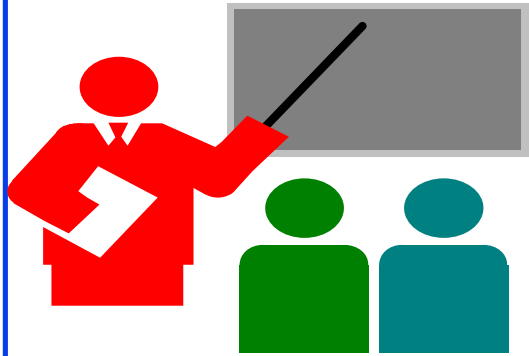


# MPLS on ATM: Issues

- ❑ VCI field is sufficient for one level tagging  
VPI may be used for the 2nd level
- ❑ LSR switches need to participate in network layer routing protocols (OSPF, BGP)
- ❑ Multiple tags per destination may be used to avoid frame merging
- ❑ VPI/VCI space may be segmented for label switching and normal ATM switching

# Other Issues

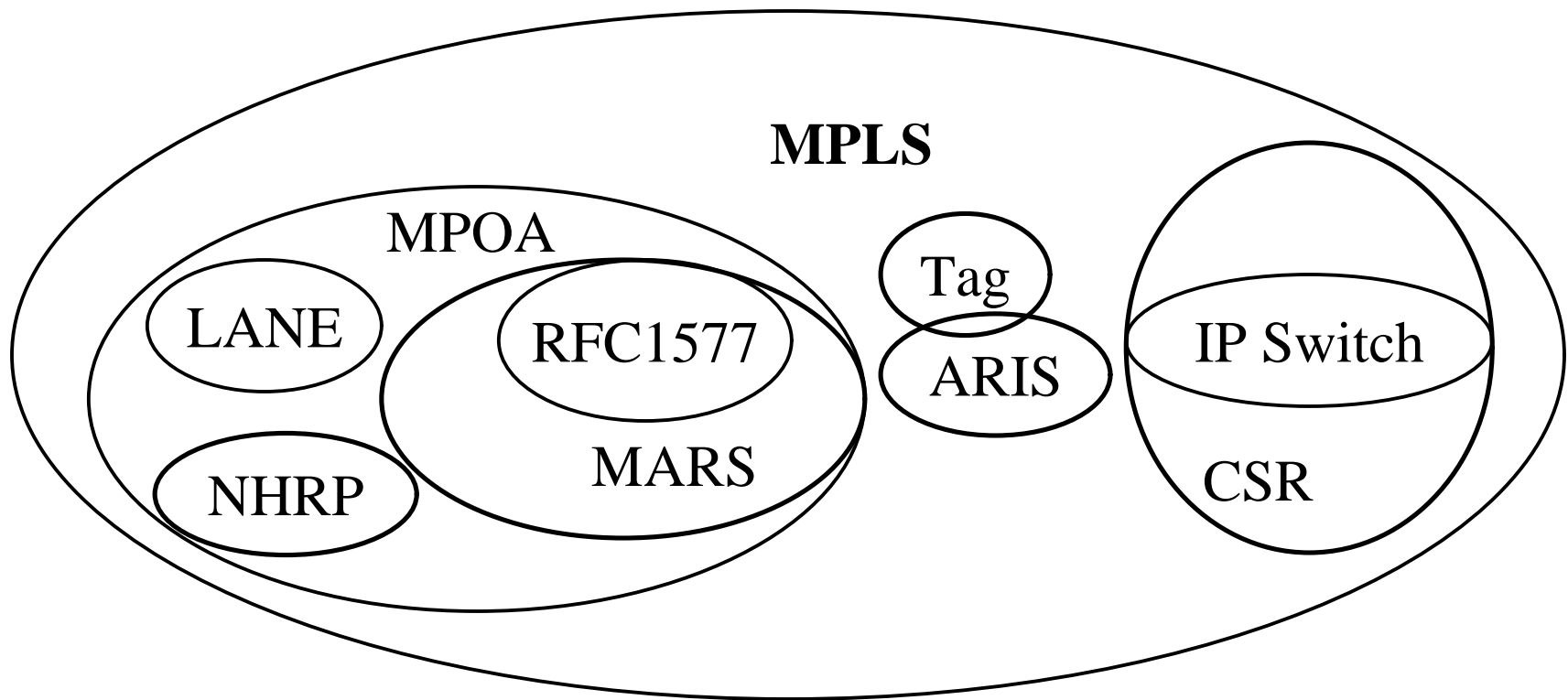
- ❑ Loop prevention, detection, survival
- ❑ Multicast:  
Multiple entries in label information base
- ❑ Multipath: Streams going to the same destination but different sources/port # may be assigned separate labels.
- ❑ Host involvement: Label-enabled hosts will avoid first hop reassembly
- ❑ Security: Label swapping may be terminated before firewall



# Summary

- ❑ IP Switching: Traffic-based, per-hop VCs, downstream originated
- ❑ CSR: Traffic-based, VCs (VCID), originated by downstream/upstream/both
- ❑ Tag switching: Topology based, one VC per route
- ❑ ARIS: Topology based, one VC per egress router
- ❑ MPLS combines various features of IP switching, CSR, Tag switching, ARIS

# Summary (Cont)



# Key References

- ❑ For a detailed list of references see [http://www.cis.ohio-state.edu/~jain/refs/atm\\_refs.htm](http://www.cis.ohio-state.edu/~jain/refs/atm_refs.htm)
- ❑ "A Framework for Multiprotocol Label Switching", 05/12/1997, <http://www.internic.net/internet-drafts/draft-ietf-mpls-framework-00.txt>
- ❑ RFC 2098, "Toshiba's Router Architecture Extensions for ATM : Overview", 02/04/1997, 18 pp., <http://ds.internic.net/rfc/rfc2098.txt>

# References (Cont)

- ❑ RFC 2105, "Cisco Systems' Tag Switching Architecture Overview", 02/06/1997, 13 pp., <http://ds.internic.net/rfc/rfc2105.txt>
- ❑ "ARIS: Aggregate Route-Based IP Switching", 03/26/1997, <http://www.internic.net/internet-drafts/draft-viswanathan-aris-overview-00.txt>
- ❑ Multiprotocol Label Switching (mpls) working group at IETF. Email: [mpls-request@cisco.com](mailto:mpls-request@cisco.com)

# Current Schedule

6/24/97	Course Overview
6/26/97	Networking Trends and their impact
7/1/97	ATM Networks - An Introduction
7/3/97	LAN Emulation and ATM Emulation
7/8/97	MARS, NHRP, MPOA, IP Switching
7/10/97	Multiprotocol Label Switching
<b>7/15/97</b>	<b>Quiz 1 (No Mbone transmission)</b>
7/17/97	Virtual LANs
7/22/97	<b>No Class</b>

# Schedule (Cont)

7/24/97 Gigabit Ethernet

7/29/97 Multimedia: Compression Standards

**7/31/97 Quiz 2 (No MBone transmission)**

8/5/97 Multimedia over IP: RSVP, RTP

8/7/97 Wireless LANs and WANs

8/12/97 Residential broadband: Cable Modems, xDSL

8/14/97 Mobile Networking: Mobile IP, Wireless ATM

**8/19/97 Quiz 3 (No MBone transmission)**

8/21/97 Graduating Seniors' grades due

# Credits

This MBone transmission was made possible by:

- ❑ Mark Fullmer, OSU/UTS
- ❑ Mike Iverson, OSU/UTS
- ❑ Mike Douglas, OSU/UTS
- ❑ Jayaraman Iyer, OSU/CIS
- ❑ Sohail Munir, OSU/CIS