DATA COMMUNICATOIN NETWORKING

Instructor: Ouldooz Baghban Karimi

Course Book & Slides:
Computer Networking, A Top-Down Approach
By: Kurose, Ross

Course Overview

- **Basics of Computer Networks**
  - Internet & Protocol Stack
  - Application Layer
  - Transport Layer
  - Network Layer
  - Data Link Layer

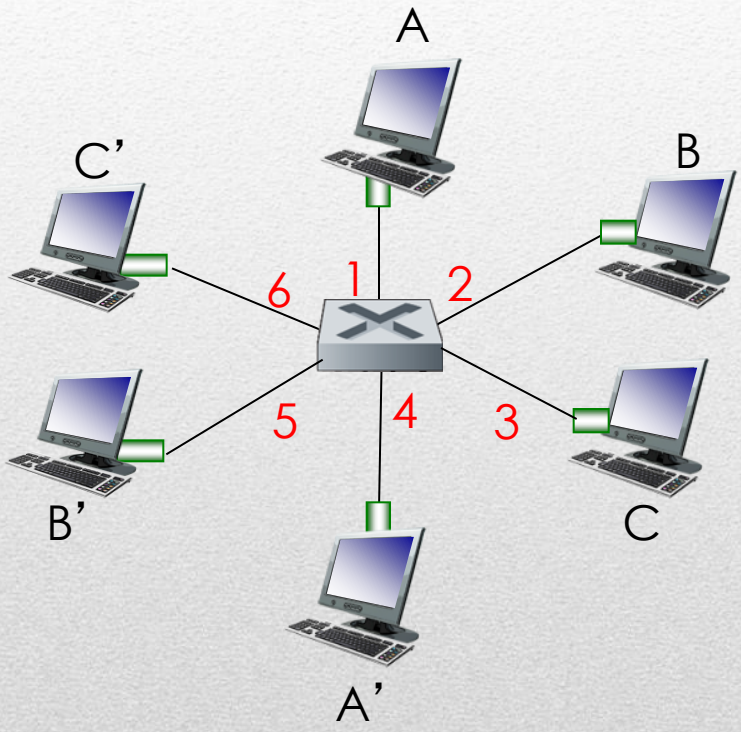
- **Advanced Topics**
  - Case Studies of Computer Networks
  - Internet Applications
  - Network Management
  - Network Security

Ethernet Switch

- **Link-layer device: takes an active role**
  - Store & forward Ethernet frames
  - Examine incoming frame's MAC address
  - Selectively forward frame to one-or-more outgoing links when frame is to be forwarded on segment
  - Uses CSMA/CD to access segment
- **Transparent**
  - Hosts are unaware of presence of switches
- **Plug-and-play**

Switch

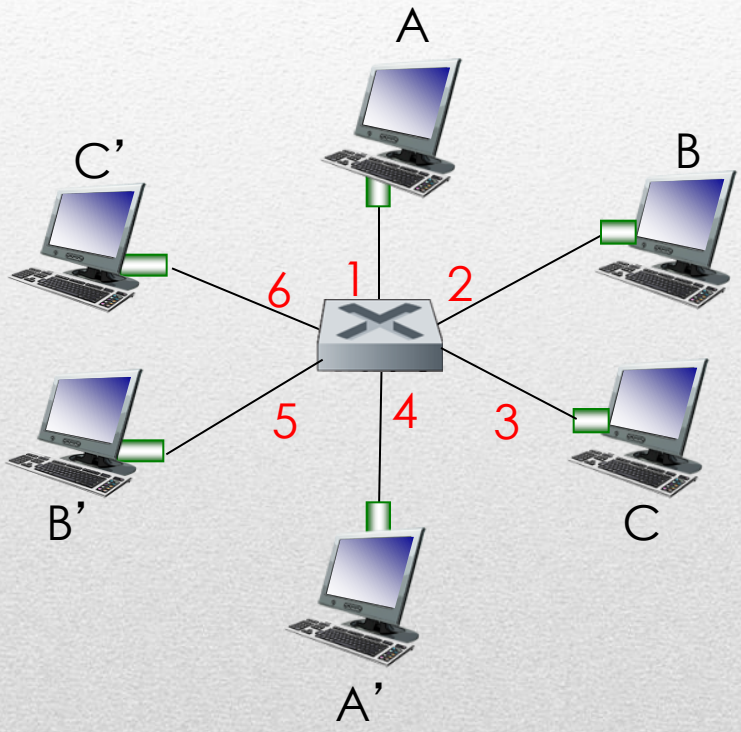
- Hosts have dedicated, direct connection to switch
- Switches buffer packets
- Ethernet protocol used on each incoming link, but no collisions
  - Full duplex
  - Each link is its own collision domain
- Switching
  - A-to-A' and B-to-B' can transmit simultaneously, without collisions



Switch with six interfaces (1,2,3,4,5,6)

Switch

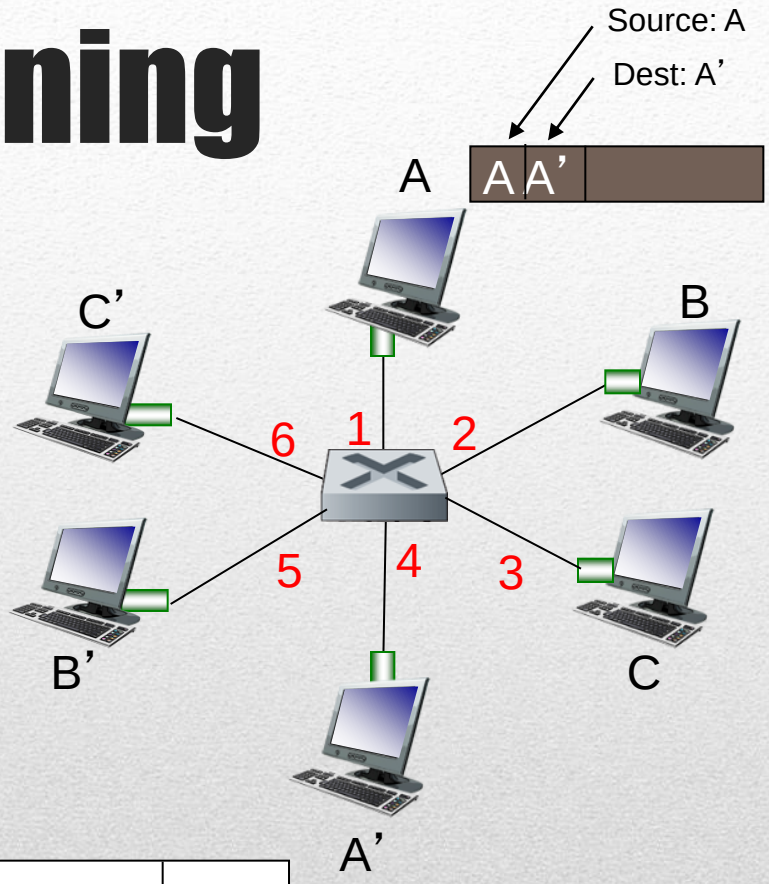
- **Hosts have dedicated, direct connection to switch**
- **Switches buffer packets**
  - Ethernet protocol used on each incoming link, but no collisions
  - Full duplex
  - Each link is its own collision domain
- **Switching**
  - A-to-A' and B-to-B' can transmit simultaneously, without collisions
  - Each switch has a switch table, each entry:
    - MAC address of host, interface to reach host, time stamp
    - Looks like a routing table!



Switch with six interfaces (1,2,3,4,5,6)

Switch: Self Learning

- Switch learns which hosts can be reached through which interfaces
  - When frame received, switch "learns" location of sender: incoming LAN segment
  - Records sender/location pair in switch table



MAC addr	interface	TTL
A	*1*	*60*

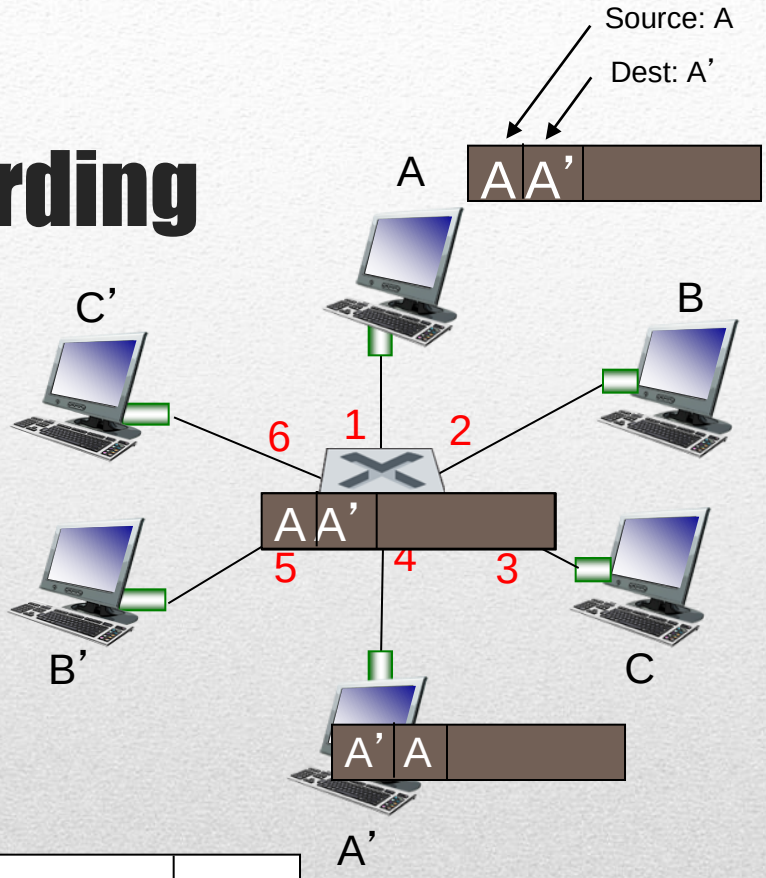
Switch table (initially empty)

Switch: Frame Filtering/Forwarding

When frame received at switch:

1. record incoming link, MAC address of sending host
2. index switch table using MAC destination address
3. if entry found for destination
   then {
   if destination on segment from which frame arrived
   then drop frame
   else forward frame on interface indicated by entry
   }
   else flood /* forward on all interfaces except arriving
   interface */

Switch:
Self Learning/Forwarding

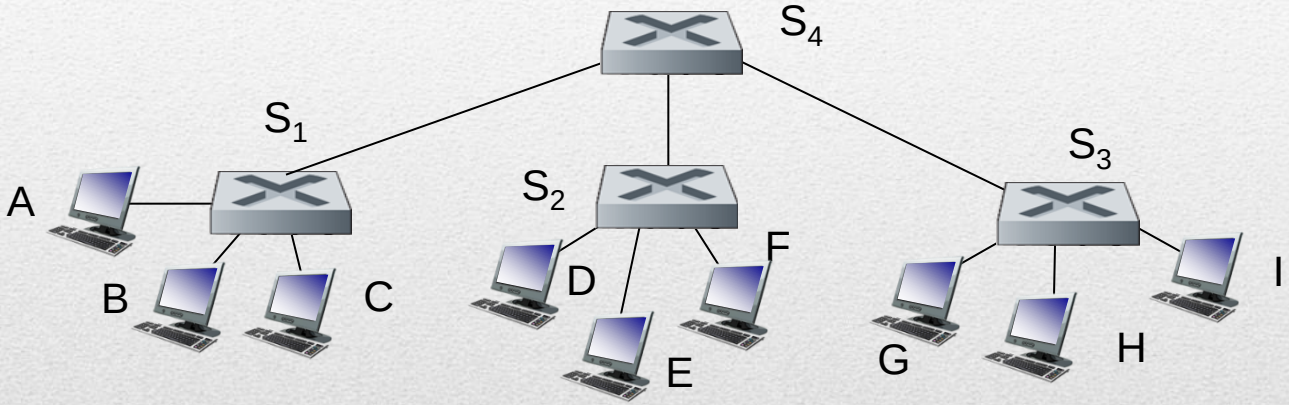


- Frame destination, A', location unknown: Flood
- Destination A location known: *Selectively just send on one link*

MAC addr	interface	TTL
A	*1*	*60*
A'	*4*	*60*

switch table (initially empty)

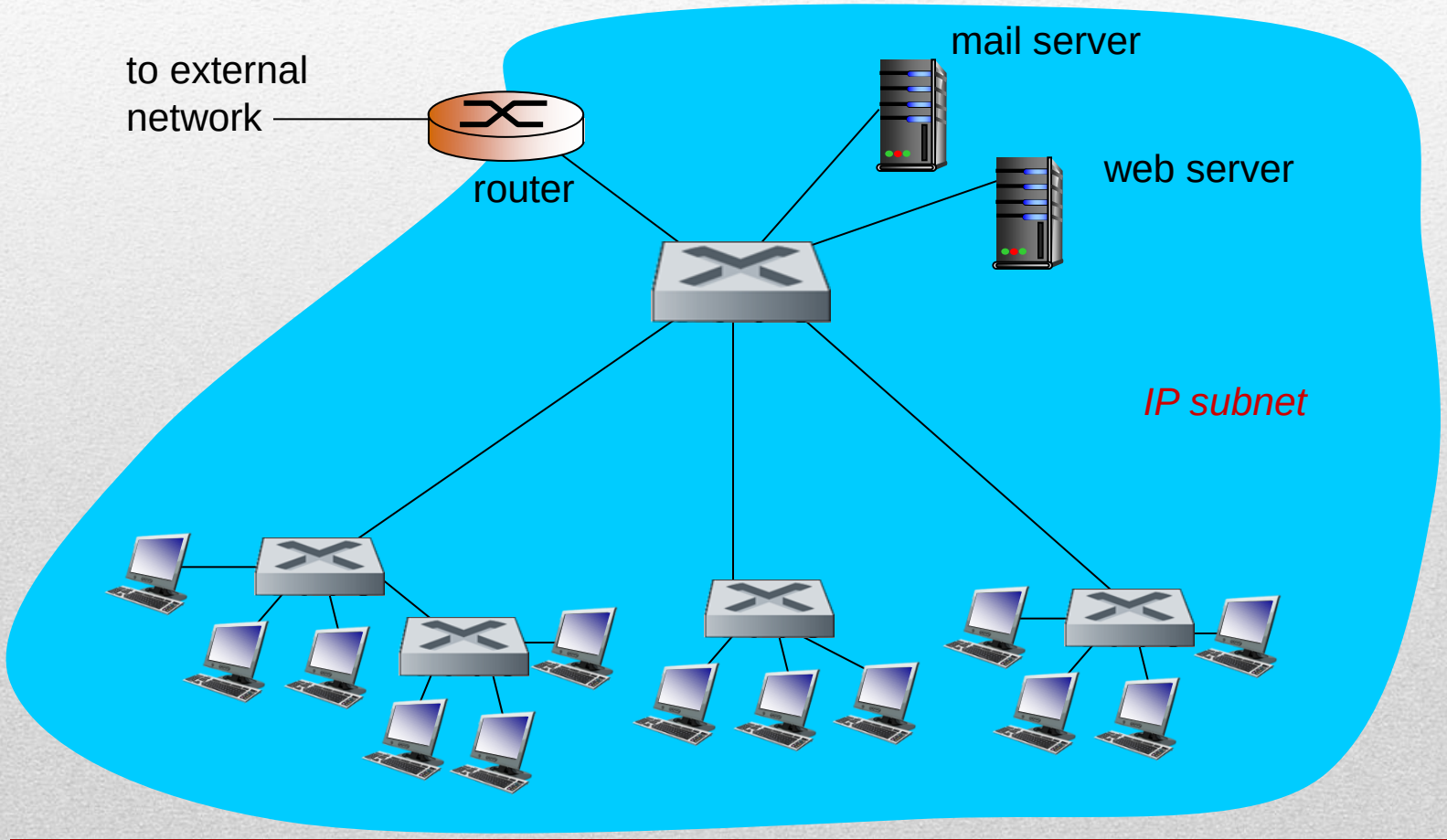
Interconnecting Switches



Q: Sending from A to G - how does S_1 know to forward frame destined to F via S_4 and S_3?

Self learning! Works exactly the same as in single-switch case!

Institutional Network



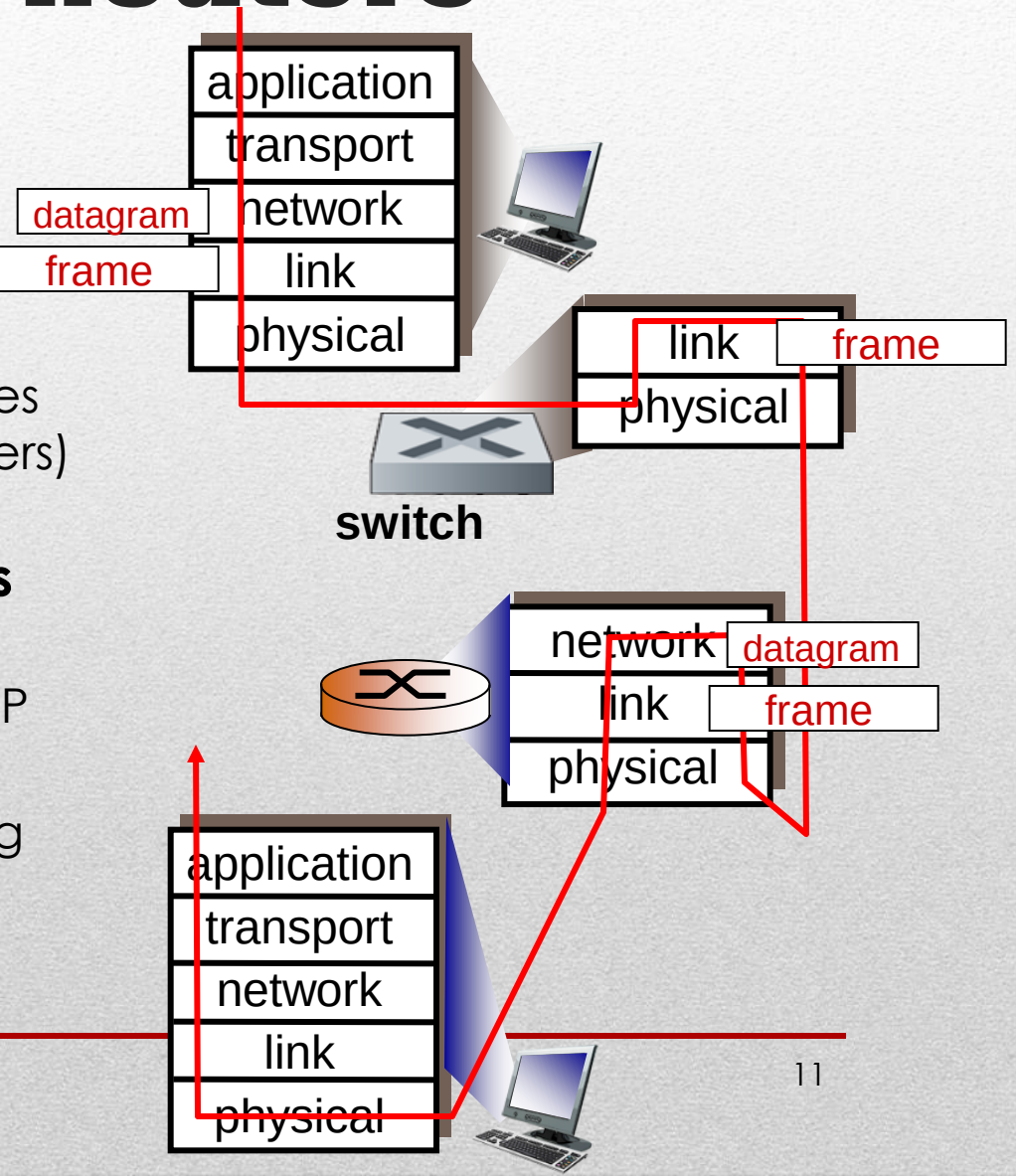
Switches vs. Routers

Both are store-and-forward

- Routers: network-layer devices (examine network layer headers)
- Switches: link-layer devices (examine link-layer headers)

Both have forwarding tables

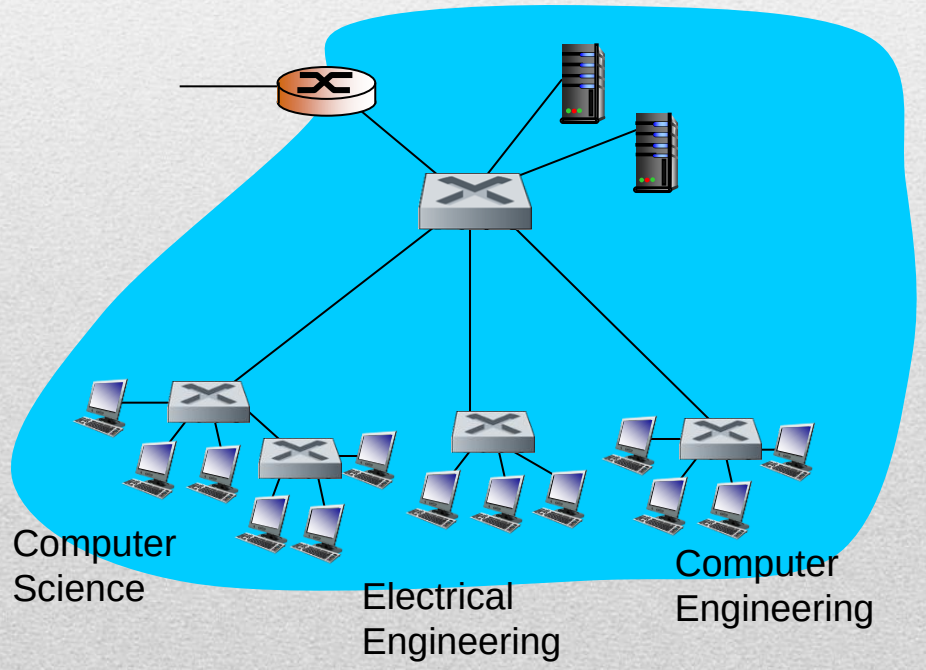
- Routers: compute tables using routing algorithms, IP addresses
- Switches: learn forwarding table using flooding, learning, MAC addresses



Switches vs. Routers

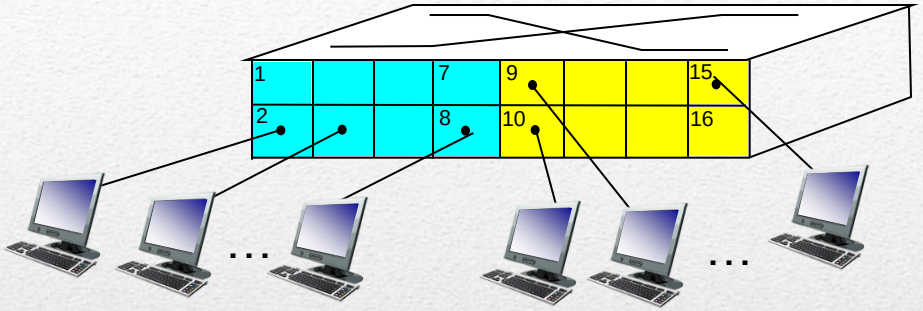
Consider

- CS user moves office to EE, but wants connect to CS switch?
- Single broadcast domain
  - All layer-2 broadcast traffic (ARP, DHCP, unknown location of destination MAC address) must cross entire LAN
  - Security/privacy, efficiency issues



VLANs

Port-based VLAN: switch ports grouped (by switch management software) so that *single* physical switch ……



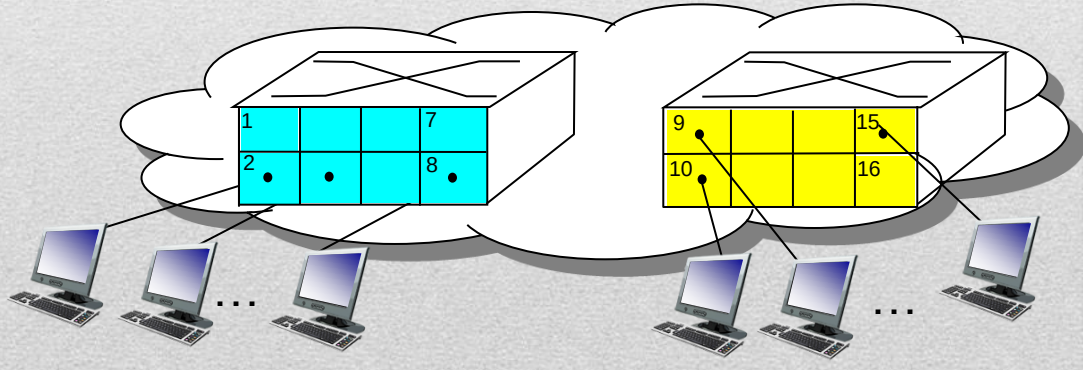
Electrical Engineering
(VLAN ports 1-8)

Computer Science
(VLAN ports 9-15)

Virtual Local Area Network

Switch(es) supporting VLAN capabilities can be configured to define multiple **virtual** LANS over single physical LAN infrastructure.

… operates as multiple virtual switches

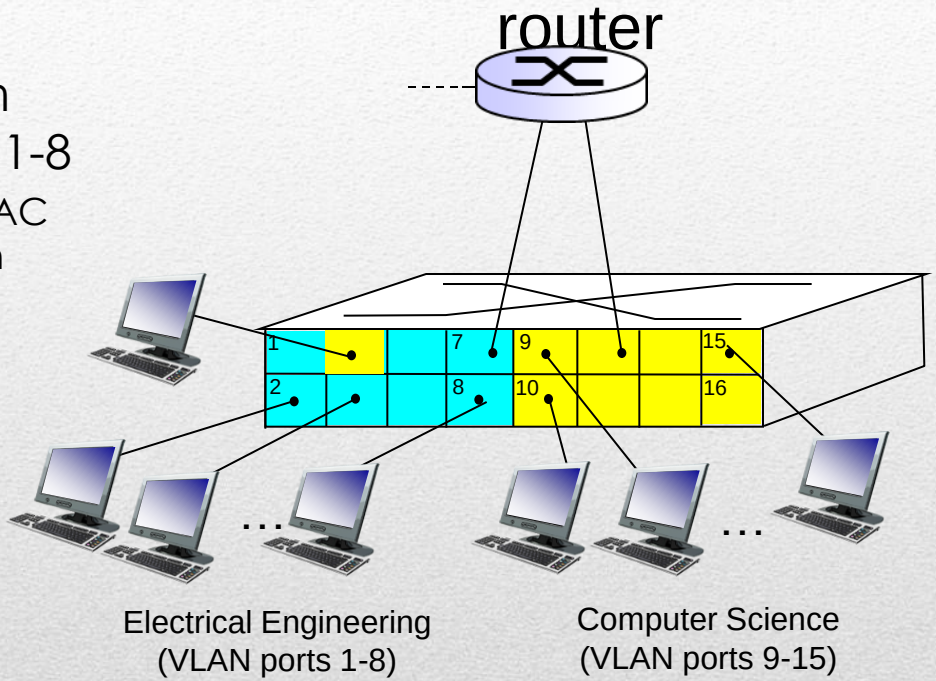


Electrical Engineering
(VLAN ports 1-8)

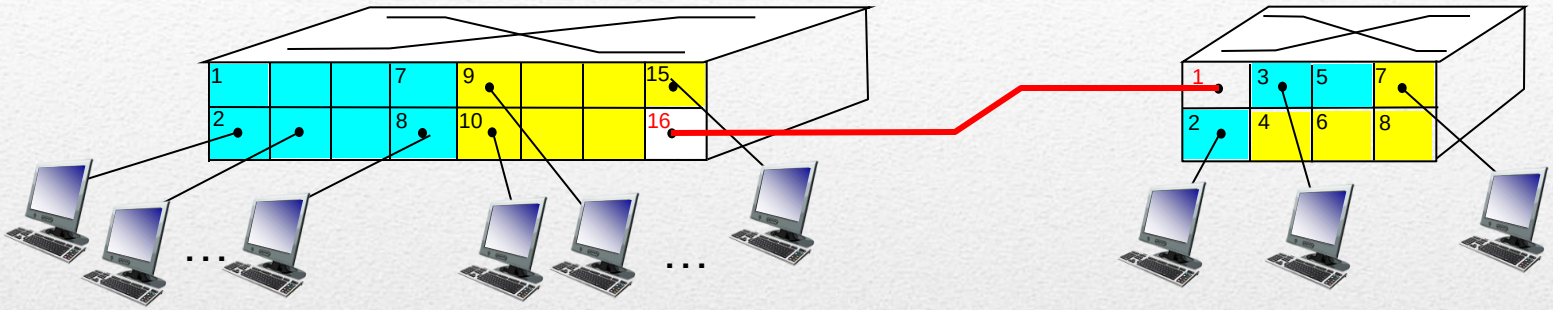
Computer Science
(VLAN ports 9-16)

Port Based VLANs

- Traffic isolation: frames to/from ports 1-8 can only reach ports 1-8
  - Can also define VLAN based on MAC addresses of endpoints, rather than switch port
- Dynamic membership: ports can be dynamically assigned among VLANs
- Forwarding between VLANS: done via routing (just as with separate switches)
  - In practice vendors sell combined switches plus routers



VLANs Spanning Multiple Switches



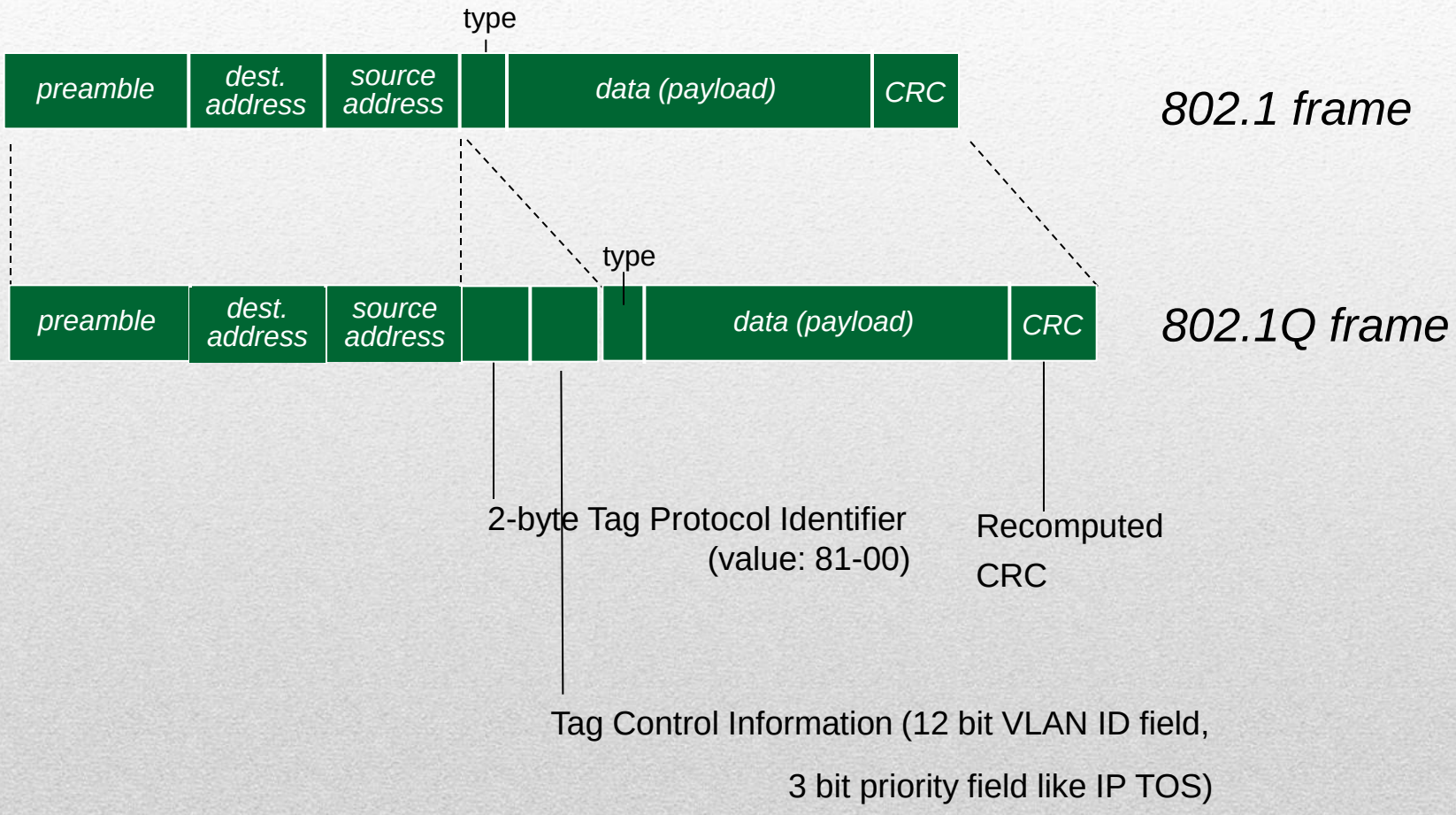
Electrical Engineering
(VLAN ports 1-8)

Computer Science
(VLAN ports 9-15)

Ports 2,3,5 belong to EE VLAN
Ports 4,6,7,8 belong to CS VLAN

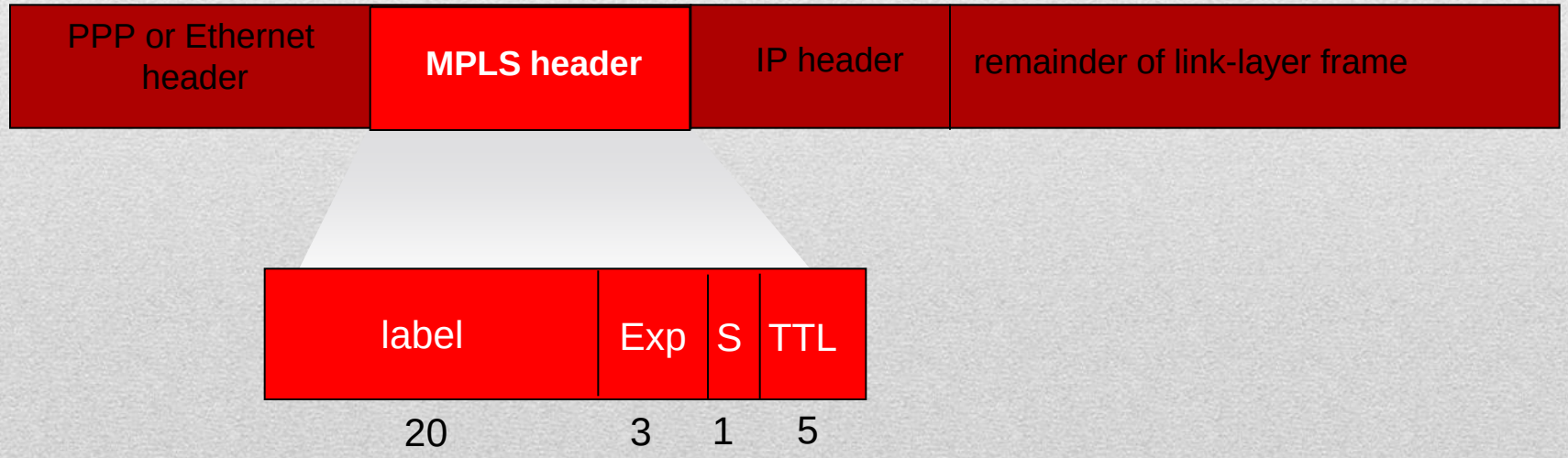
- Trunk port: carries frames between VLANS defined over multiple physical switches
  - Frames forwarded within VLAN between switches can't be vanilla 802.1 frames (must carry VLAN ID info)
  - 802.1q protocol adds/removed additional header fields for frames forwarded between trunk ports

802.1Q VLAN Frame Format



Multiprotocol Label Switching

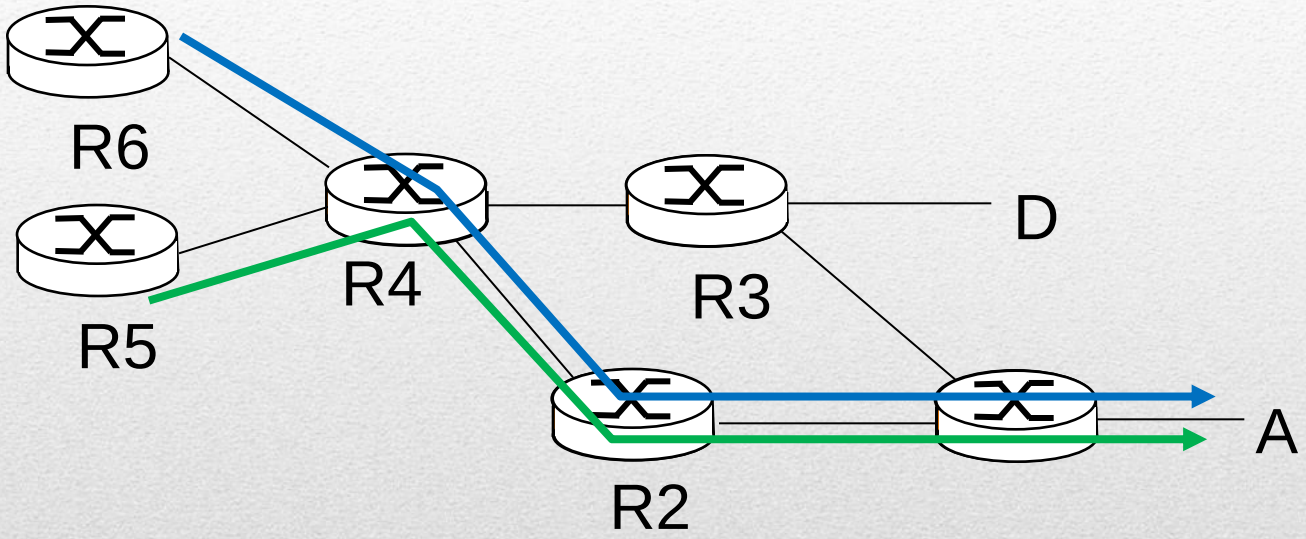
- Initial goal: high-speed IP forwarding using fixed length label (instead of IP address)
  - Fast lookup using fixed length identifier (rather than shortest prefix matching)
  - Borrowing ideas from Virtual Circuit (VC) approach
  - But IP datagram still keeps IP address!



MPLS Capable Routers

- a.k.a. label-switched router
- Forward packets to outgoing interface based only on label value (don't inspect IP address)
  - MPLS forwarding table distinct from IP forwarding tables
- Flexibility: MPLS forwarding decisions can differ from those of IP
  - Use destination and source addresses to route flows to same destination differently (traffic engineering)
  - Re-route flows quickly if link fails: pre-computed backup paths (useful for VoIP)

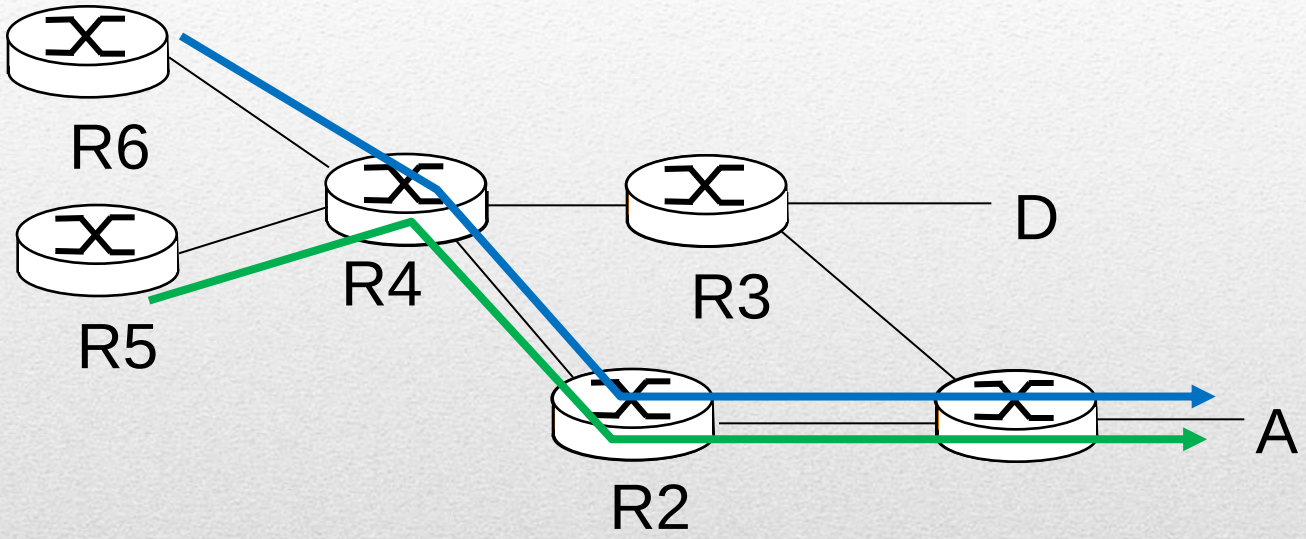
MPLS vs IP Path



IP routing: path to destination determined by destination address alone

IP router

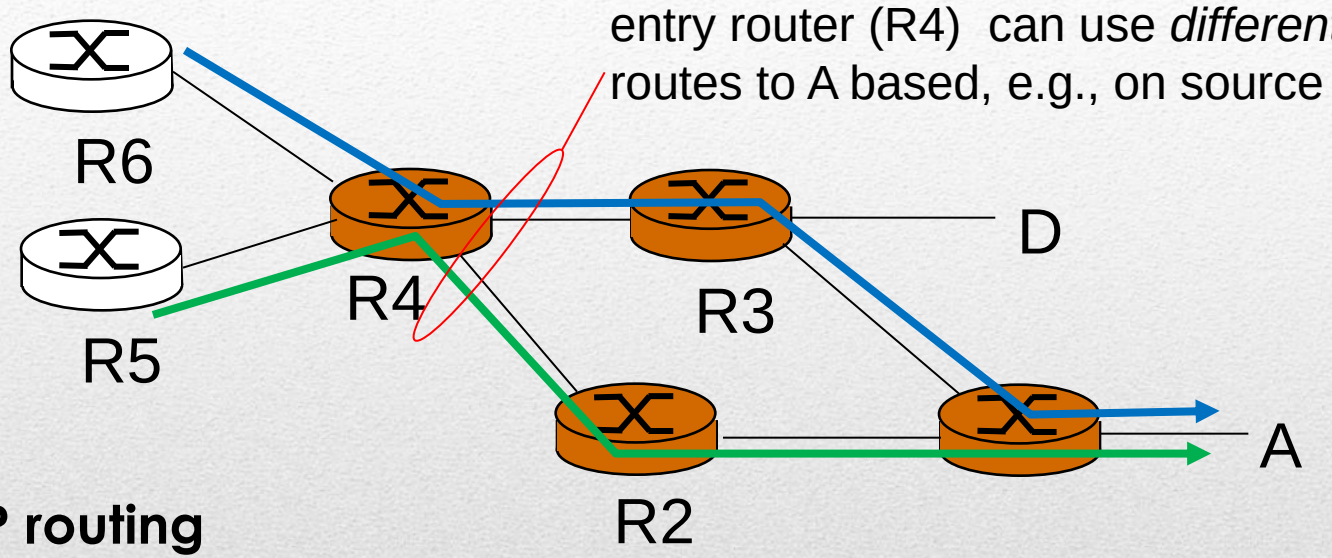
MPLS vs IP Path



IP routing: path to destination determined by destination address alone

IP router

MPLS vs IP Path



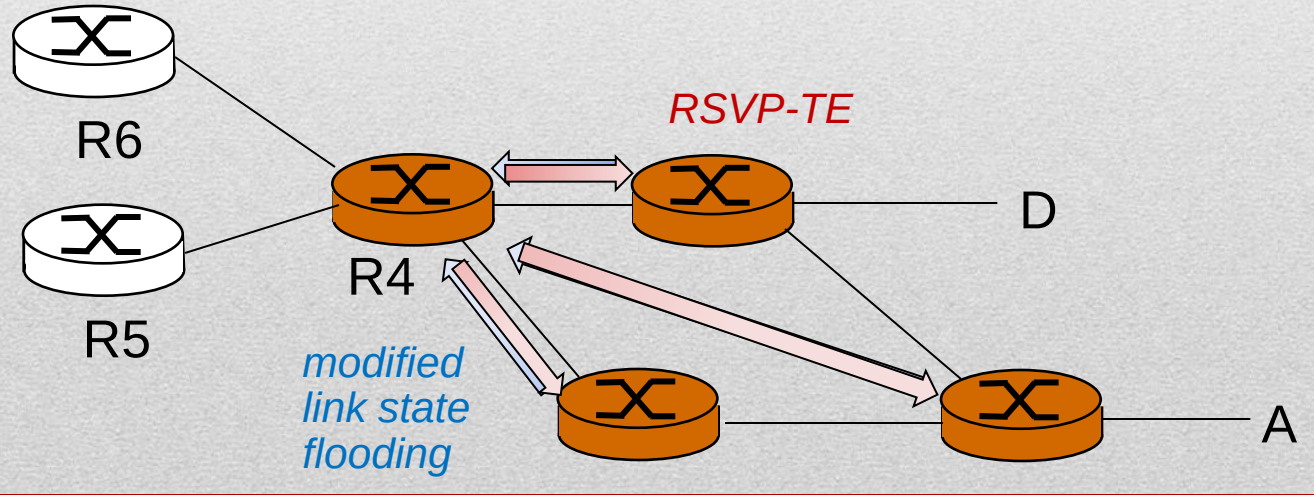
- **IP routing**
  - Path to destination determined by destination address alone
- **MPLS routing**
  - Path to destination can be based on source and destination address
  - Fast reroute: pre-compute backup routes in case of link failure

IP-only router

MPLS and IP router

MPLS Signaling

- Modify OSPF, IS-IS link-state flooding protocols to carry info used by MPLS routing,
  - e.g., link bandwidth, amount of "reserved" link bandwidth
  - Entry MPLS router uses RSVP-TE signaling protocol to set up MPLS forwarding at downstream routers



MPLS Forwarding Tables