

Chapter 6

The Link Layer and LANs

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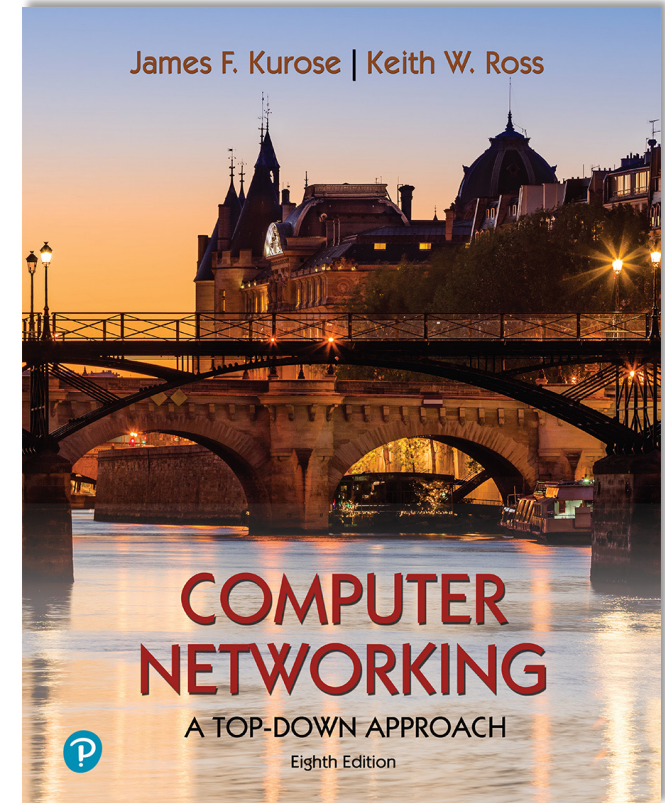
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*Computer Networking: A
Top-Down Approach*

8th edition

Jim Kurose, Keith Ross
Pearson, 2020

Link layer, LANs: roadmap

- introduction
- error detection, correction
- multiple access protocols
- **LANs**
 - addressing, ARP
 - Ethernet
 - **switches**
 - VLANs
- link virtualization: MPLS
- data center networking



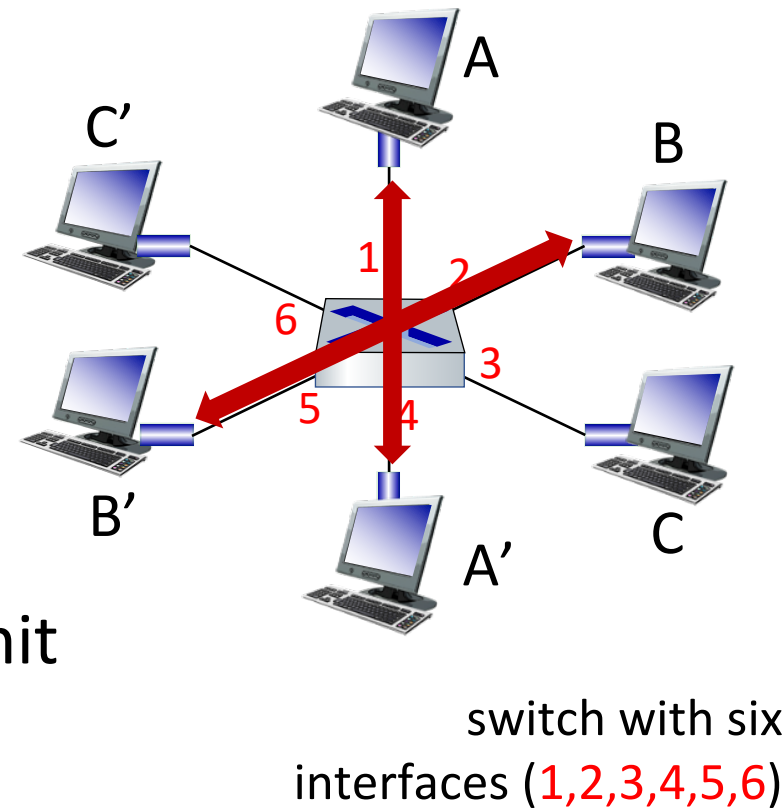
- a day in the life of a web request

Ethernet switch

- Switch is a **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 *unaware* of presence of switches
- **plug-and-play, self-learning**
 - switches do not need to be configured

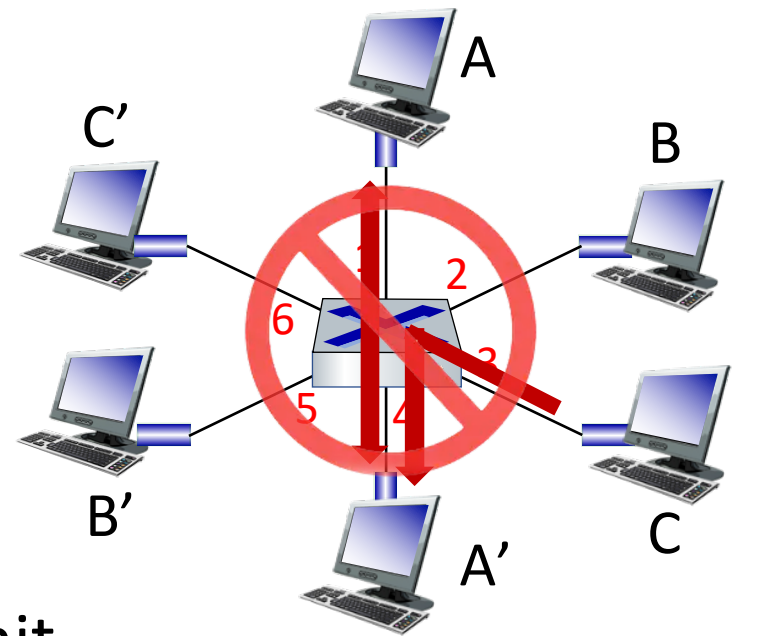
Switch: multiple simultaneous transmissions

- hosts have dedicated, direct connection to switch
- switches buffer packets
- Ethernet protocol used on *each* incoming link, so:
 - 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: multiple simultaneous transmissions

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- Ethernet protocol used on *each* incoming link, so:
 - no collisions; full duplex
 - each link is its own collision domain
- **switching:** A-to-A' and B-to-B' can transmit simultaneously, without collisions
 - but A-to-A' and C to A' can *not* happen simultaneously



Switch forwarding table

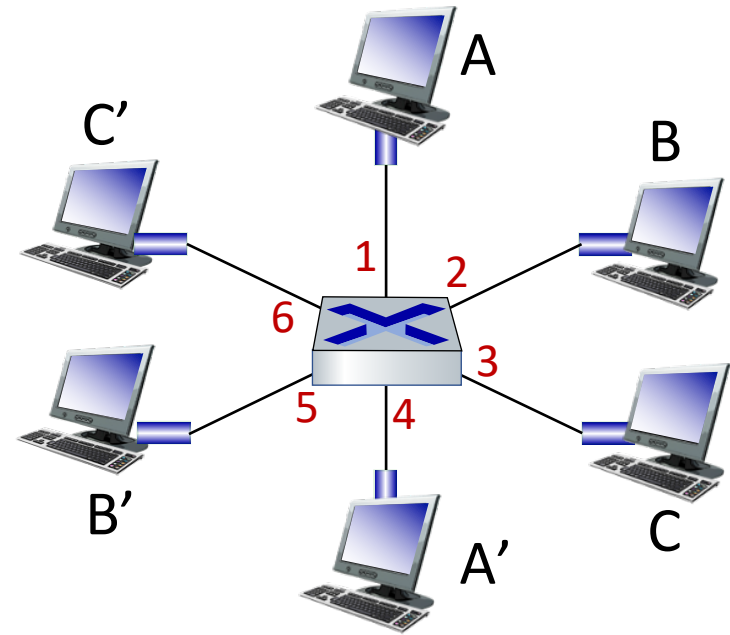
Q: how does switch know A' reachable via interface 4, B' reachable via interface 5?

A: each switch has a **switch table**, each entry:

- (MAC address of host, interface to reach host, time stamp)
- looks like a routing table!

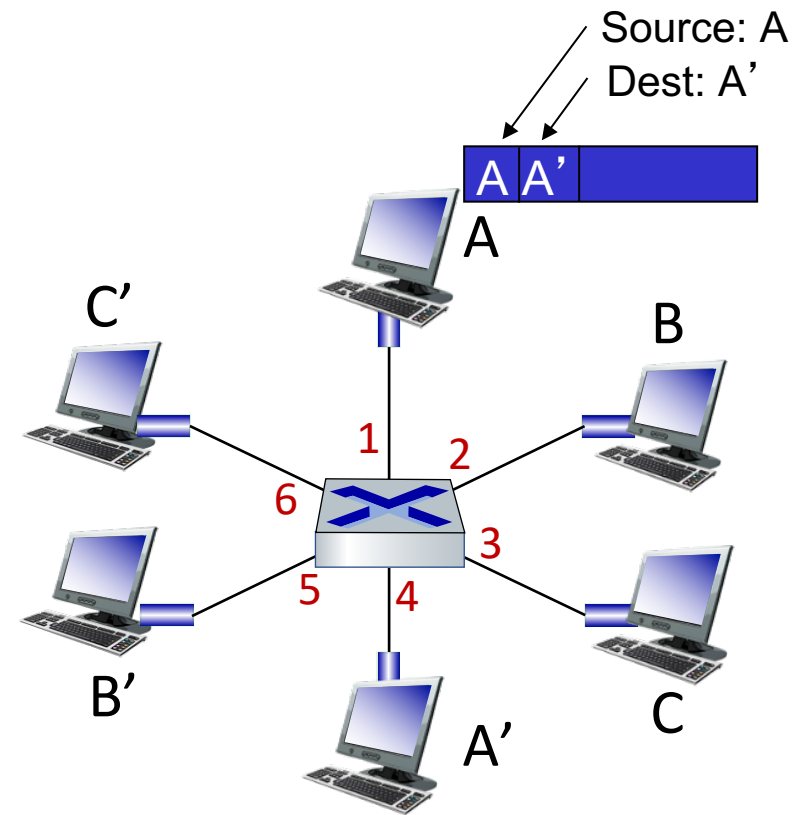
Q: how are entries created, maintained in switch table?

- something like a routing protocol?



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)*

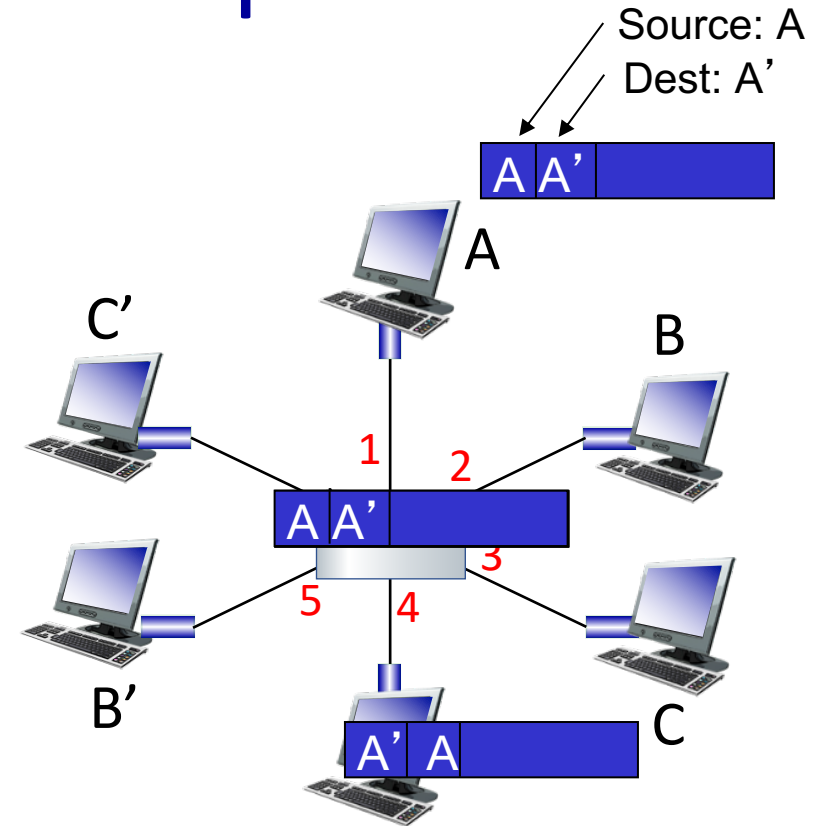
Switch: frame filtering/forwarding

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 */

Self-learning, forwarding: example

- frame destination, A',
location unknown: **flood**
- destination A location
known: **selectively send**
on just one link

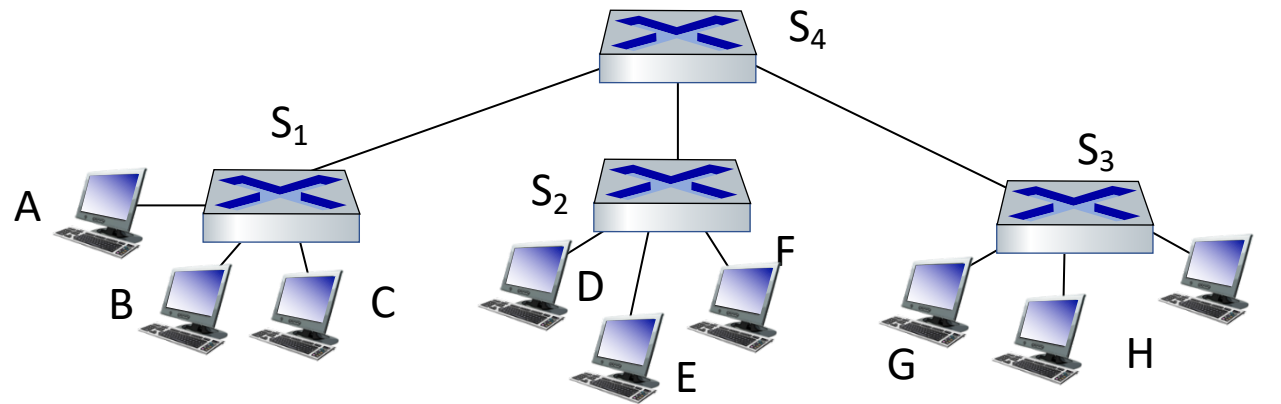


MAC addr	interface	TTL
A	1	60
A'	4	60

*switch table
(initially empty)*

Interconnecting switches

self-learning switches can be connected together:

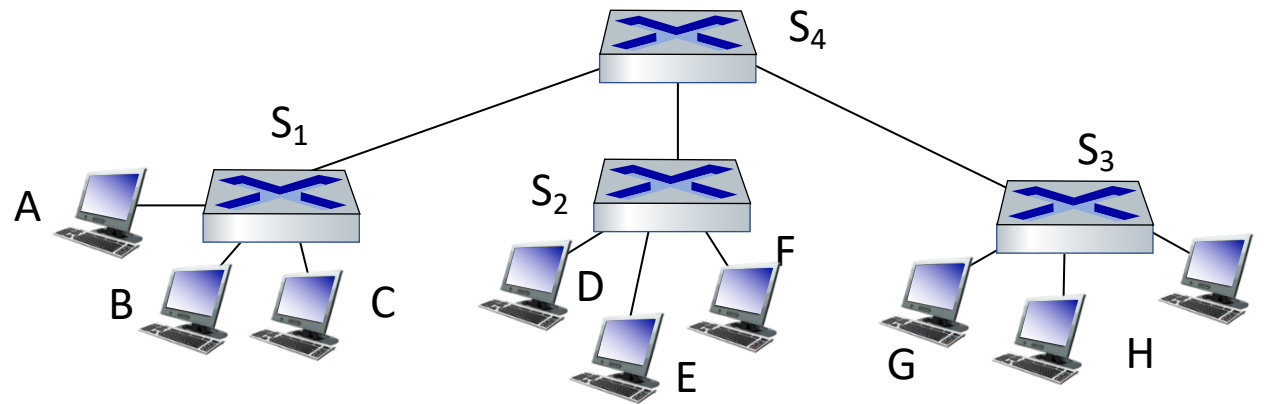


Q: sending from A to G - how does S_1 know to forward frame destined to G via S_4 and S_3 ?

- A: self learning! (works exactly the same as in single-switch case!)

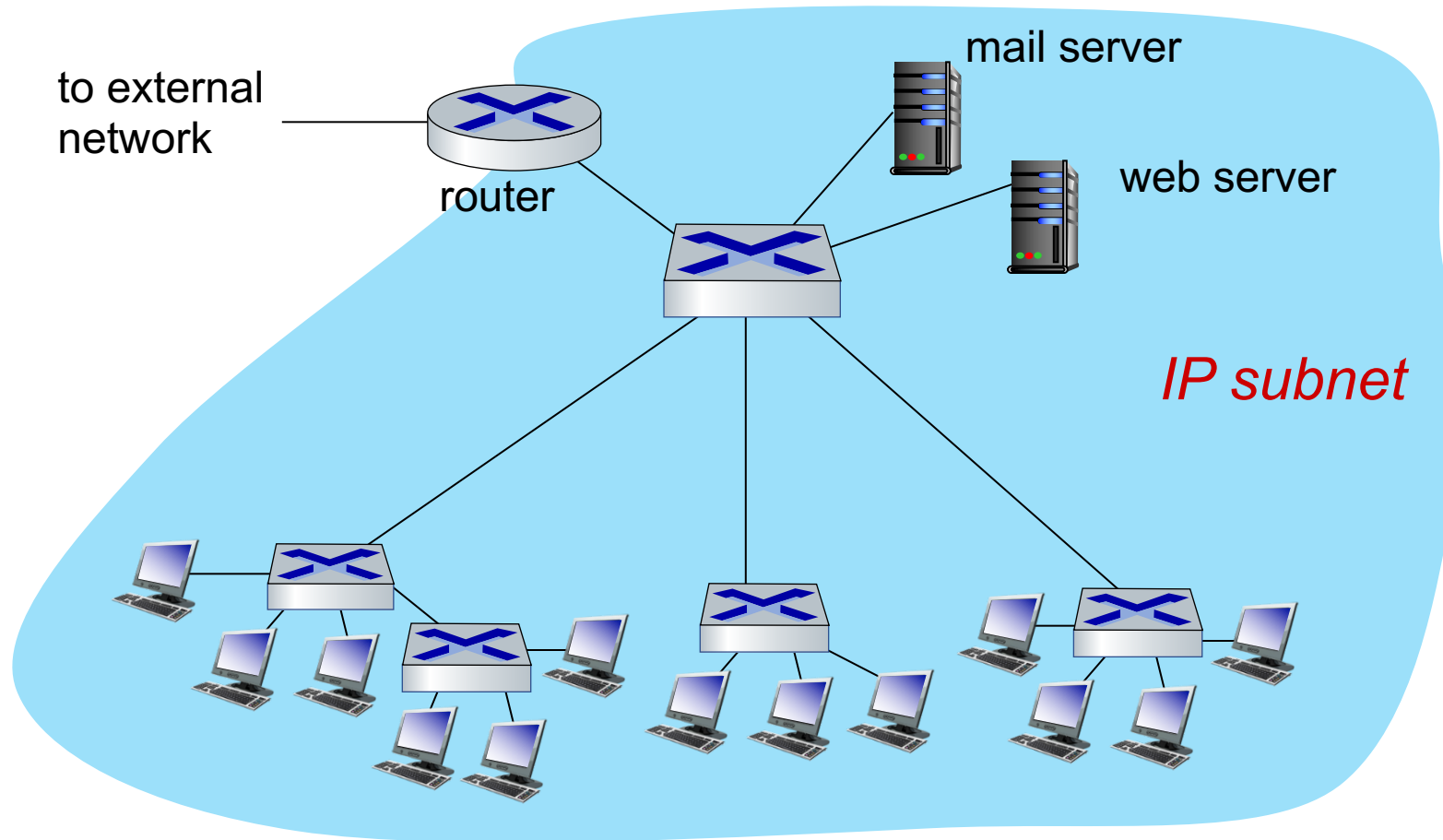
Self-learning multi-switch example

Suppose C sends frame to I, I responds to C



Q: show switch tables and packet forwarding in S₁, S₂, S₃, S₄

Small institutional network



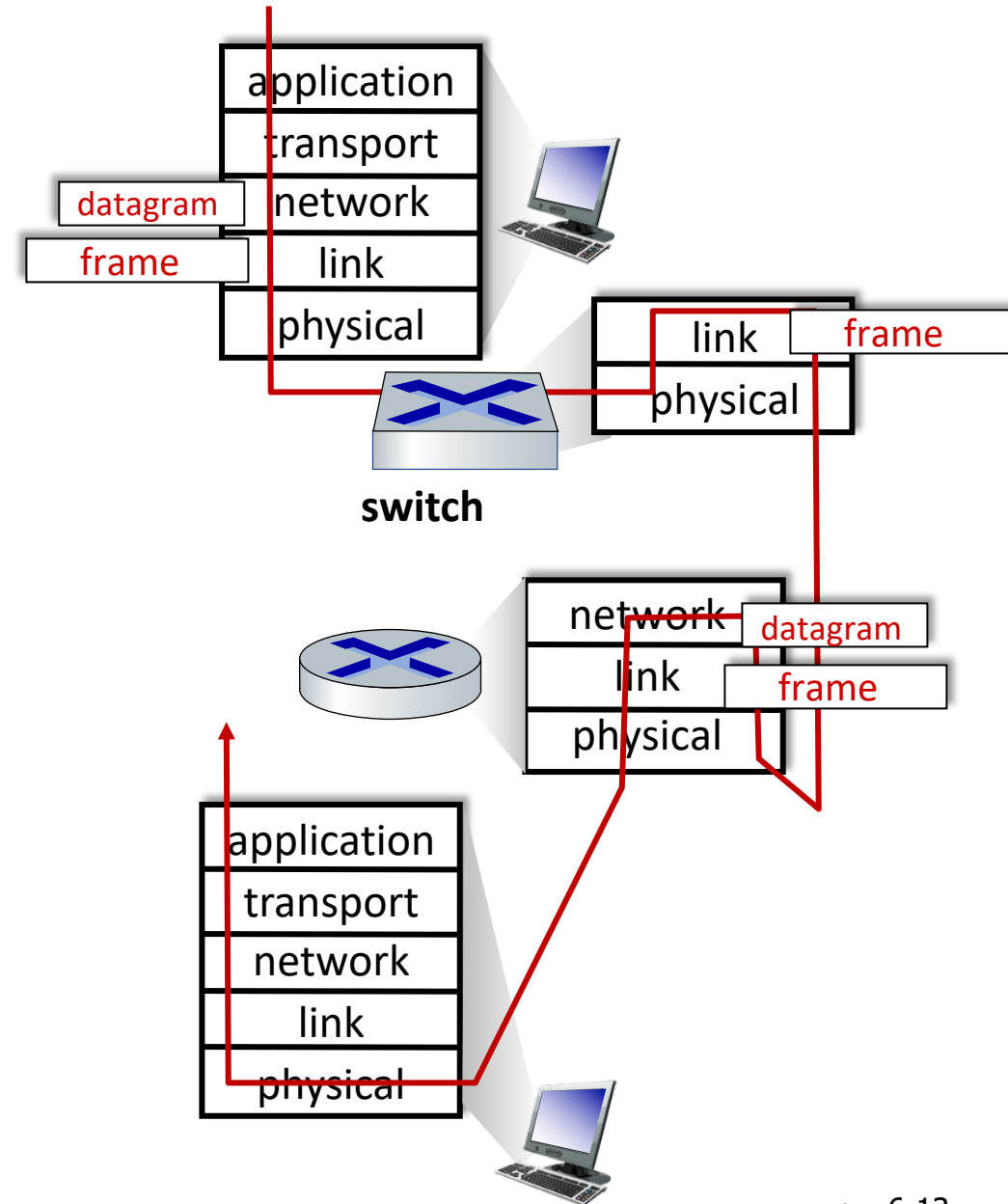
Switches vs. routers

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



Link layer, LANs: roadmap

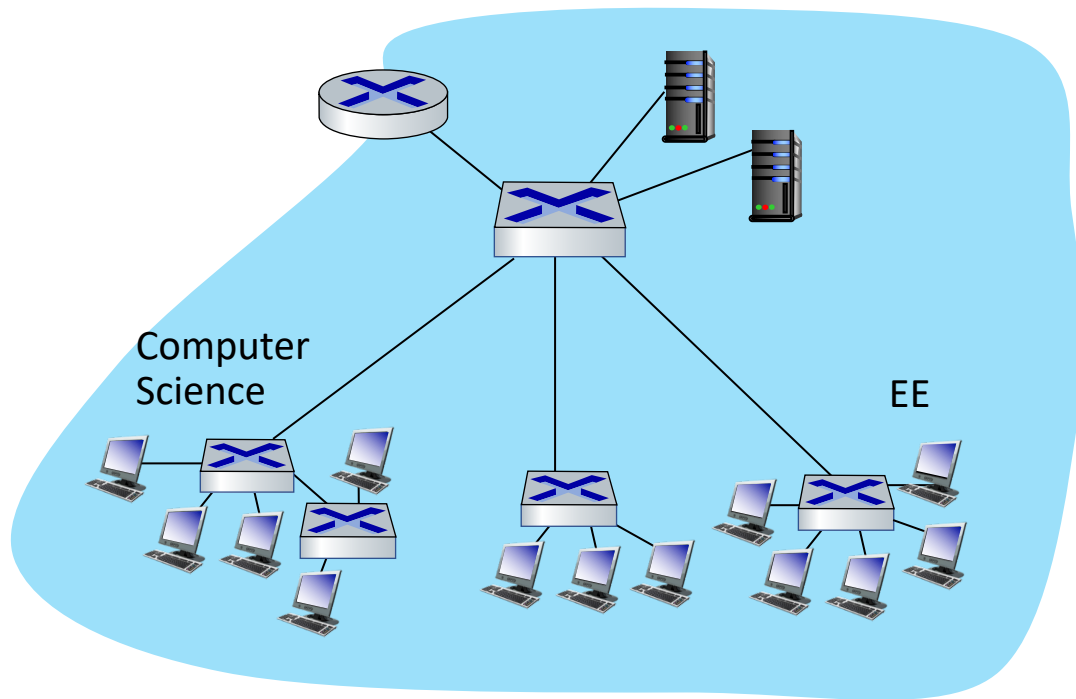
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Virtual LANs (VLANs): motivation

Q: what happens as LAN sizes scale, users change point of attachment?

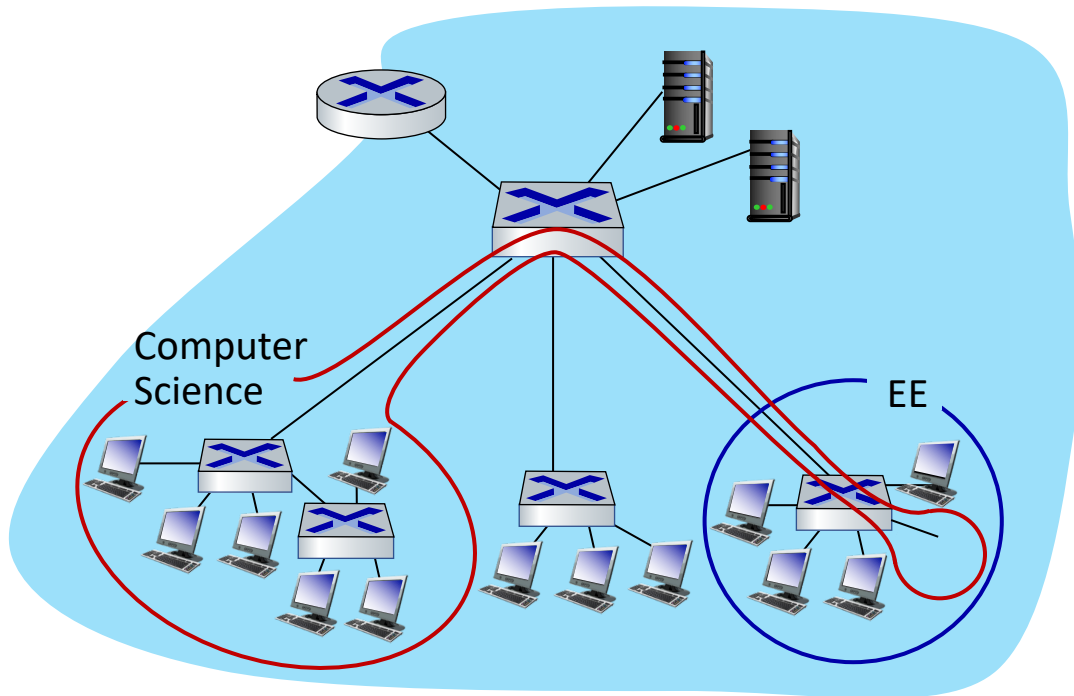


single broadcast domain:

- *scaling*: all layer-2 broadcast traffic (ARP, DHCP, unknown MAC) must cross entire LAN
- efficiency, security, privacy issues

Virtual LANs (VLANs): motivation

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single broadcast domain:

- *scaling*: all layer-2 broadcast traffic (ARP, DHCP, unknown MAC) must cross entire LAN
- efficiency, security, privacy, efficiency issues

administrative issues:

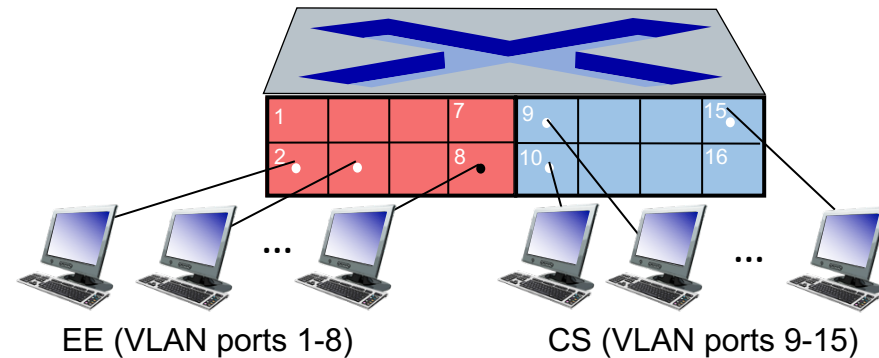
- CS user moves office to EE - *physically* attached to EE switch, but wants to remain *logically* attached to CS switch

Port-based VLANs

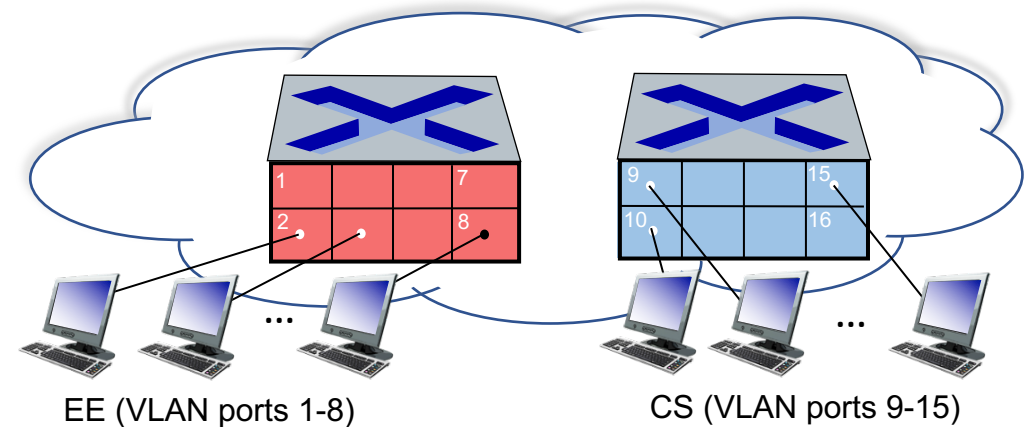
Virtual Local Area Network (VLAN)

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

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

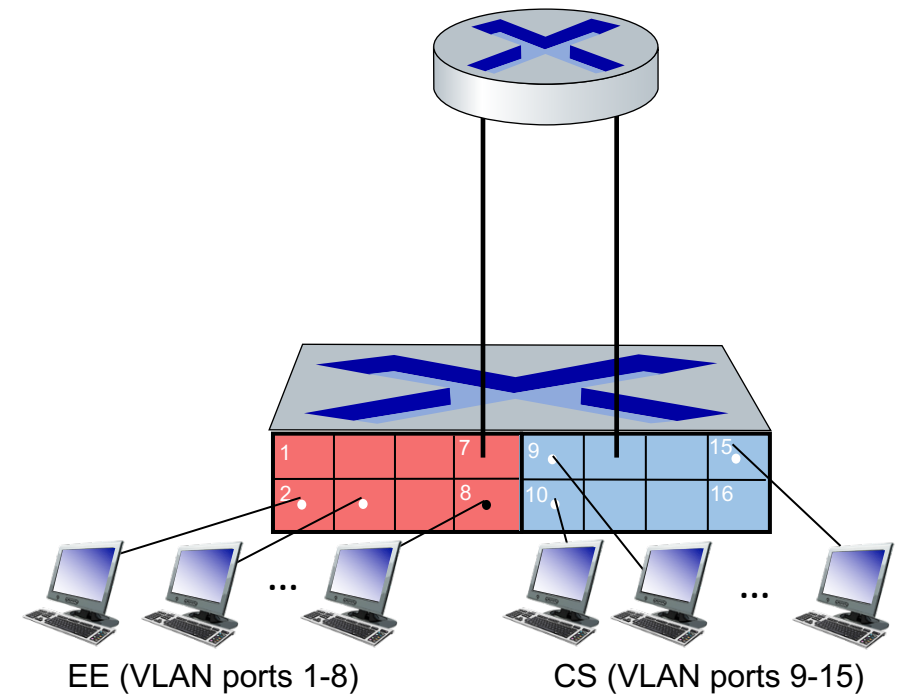


... operates as **multiple** virtual switches

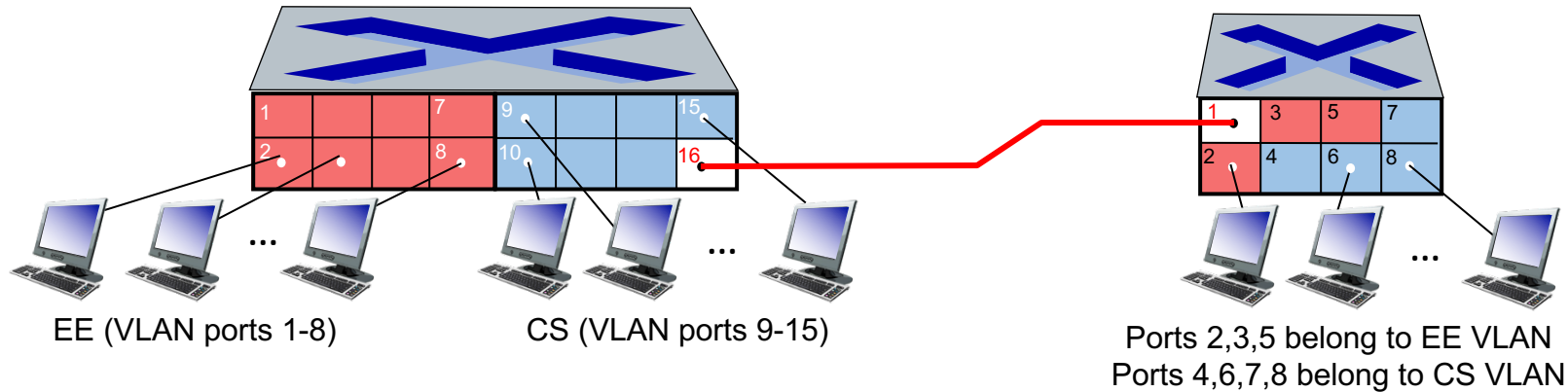


Port-based VLANs

- **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



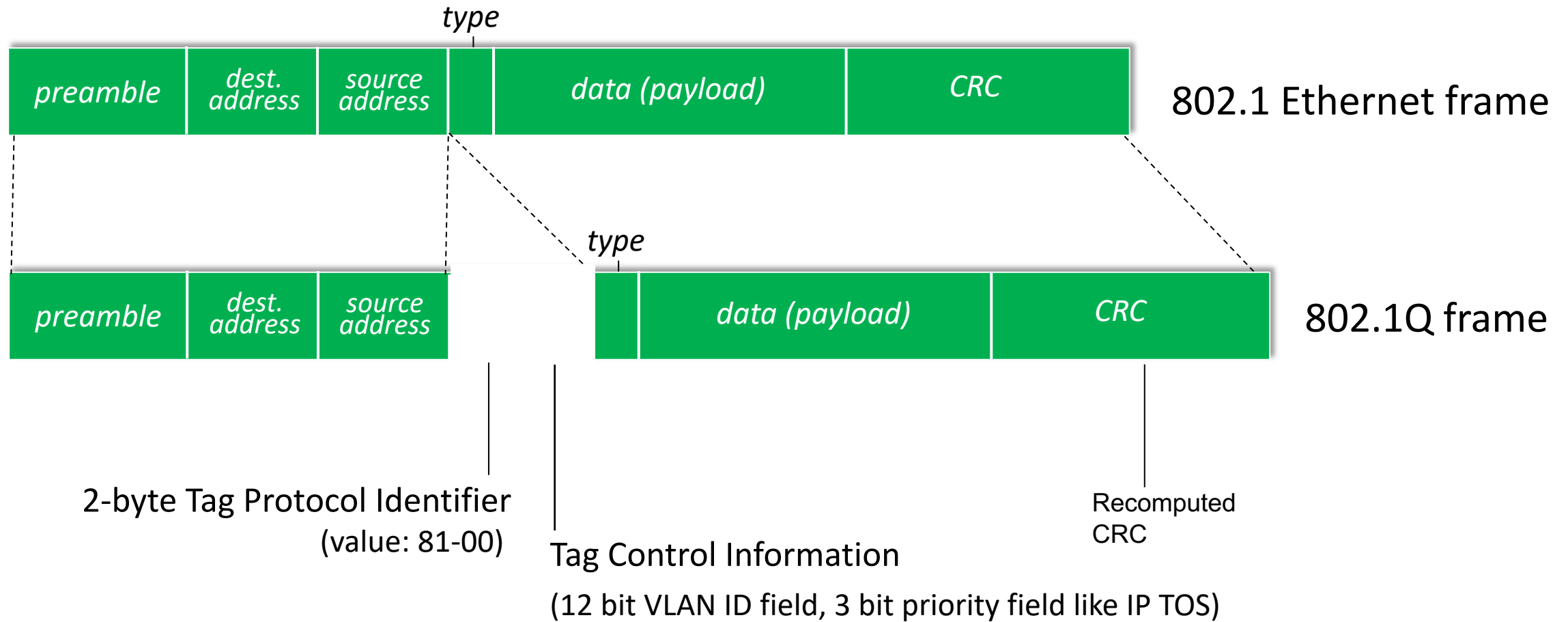
VLANs spanning multiple switches



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



Link layer, LANs: roadmap

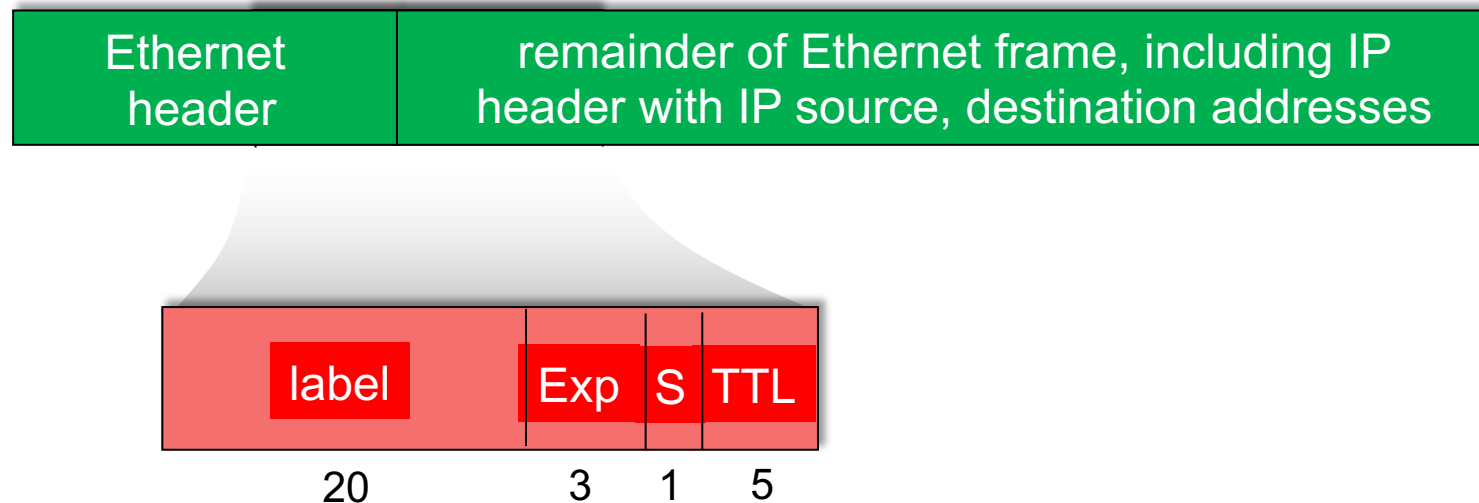
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Multiprotocol label switching (MPLS)

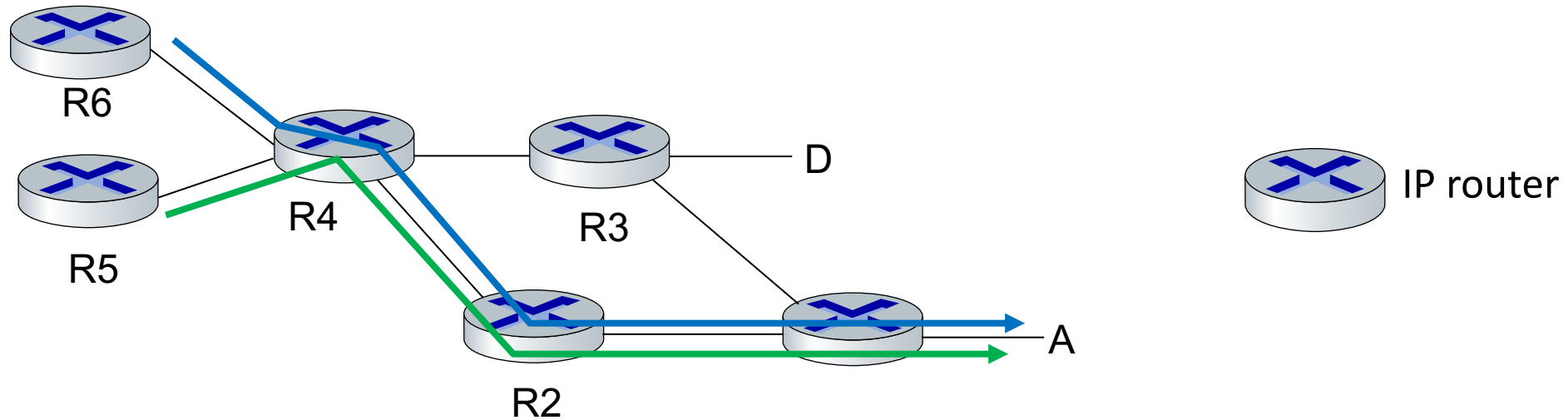
- **goal:** high-speed IP forwarding among network of MPLS-capable routers, using fixed length label (instead of shortest prefix matching)
 - faster lookup using fixed length identifier
 - borrowing ideas from Virtual Circuit (VC) approach
 - but IP datagram still keeps IP address!



MPLS capable routers

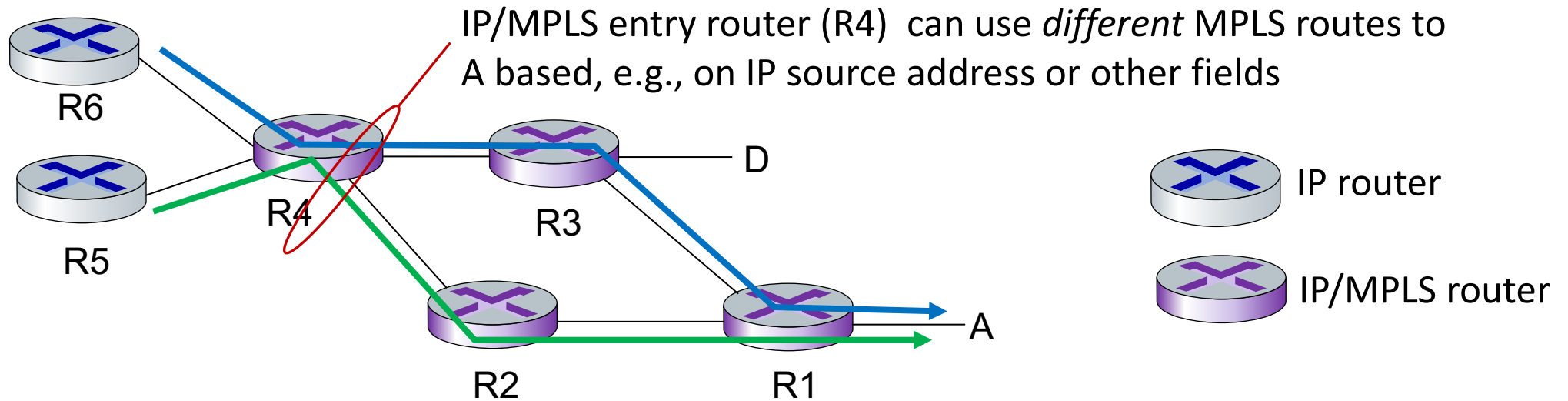
- a.k.a. label-switched router
- forward packets to outgoing interface based only on label value (*don't inspect IP address*)
 - MPLS forwarding table distinct from IP forwarding tables
- *flexibility*: MPLS forwarding decisions can *differ* from those of IP
 - use destination *and* source addresses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

MPLS versus IP paths



- **IP routing:** path to destination determined by destination address alone

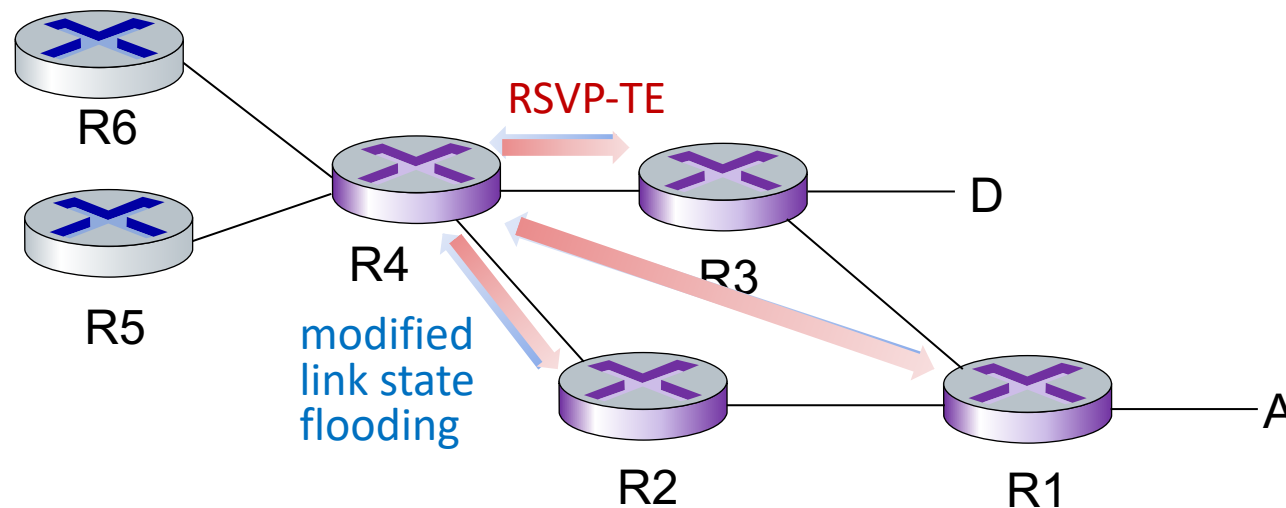
MPLS versus IP paths



- **IP routing:** path to destination determined by destination address alone
- **MPLS routing:** path to destination can be based on source *and* destination address
 - flavor of generalized forwarding (MPLS 10 years earlier)
 - *fast reroute*: precompute backup routes in case of link failure

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

