CS450 Computer Networks

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CS450 Computer Networks
Lesson 17 Data Link Layer
Ethernet, Switches, VLANs, Data Center Networking

Do Less – accomplish more

Lesson 17: The Data Link Layer – Ethernet, switches, and VLANs

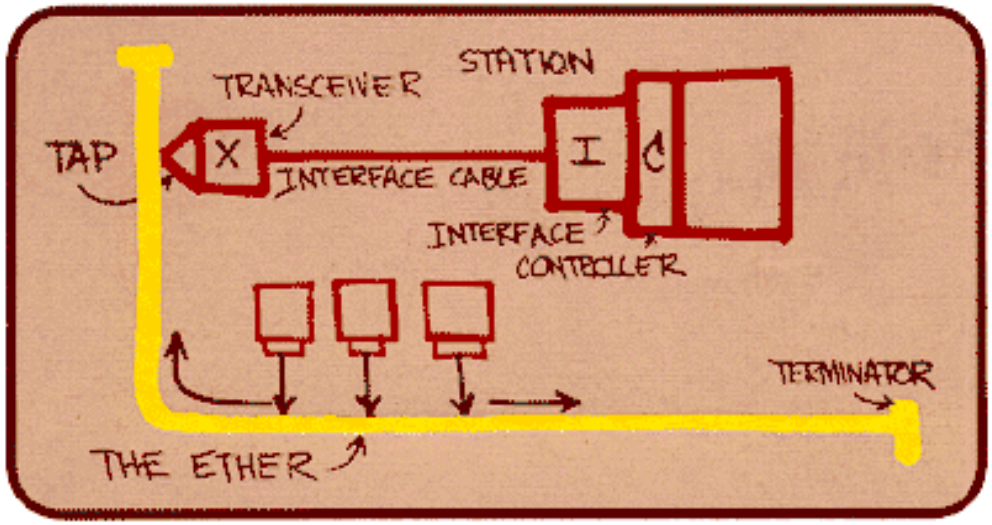
Our goals:

- Understand the implementation of the link layer services in Ethernet:
  - error detection, correction
  - sharing a broadcast channel: multiple access
  - link layer addressing
  - reliable data transfer, flow control
- Understand the uses of hubs, switches, and Virtual LANs

Ethernet

"dominant" wired LAN technology:

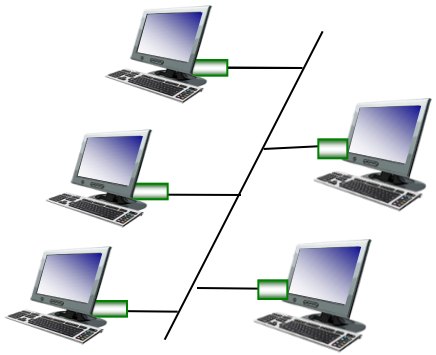
- Cheap - $20 for NIC
- first widely used LAN technology
- simpler, cheaper than token LANs and ATM
- kept up with speed race: 10 Mbps – 10 Gbps



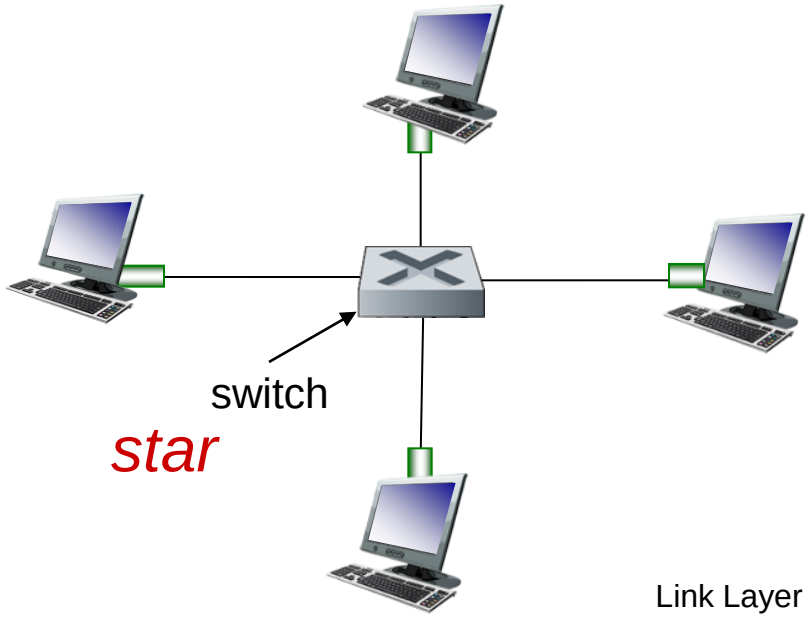
Metcalfe's Ethernet sketch

Ethernet: physical topology

- *bus:* popular through mid 90s
  - all nodes in same collision domain (can collide with each other)
- *star:* prevails today
  - active *switch* in center
  - each "spoke" runs a (separate) Ethernet protocol (nodes do not collide with each other)



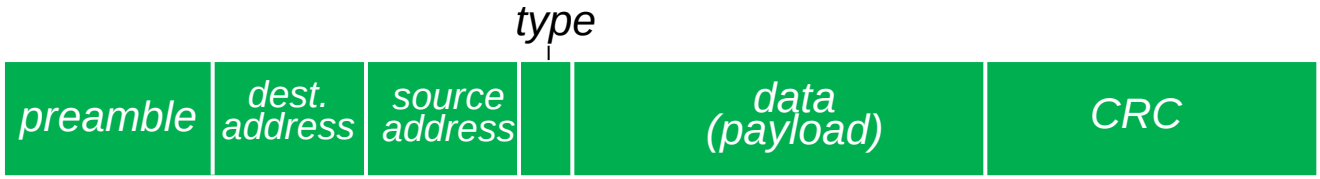
bus: coaxial cable



star

Ethernet frame structure

sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame

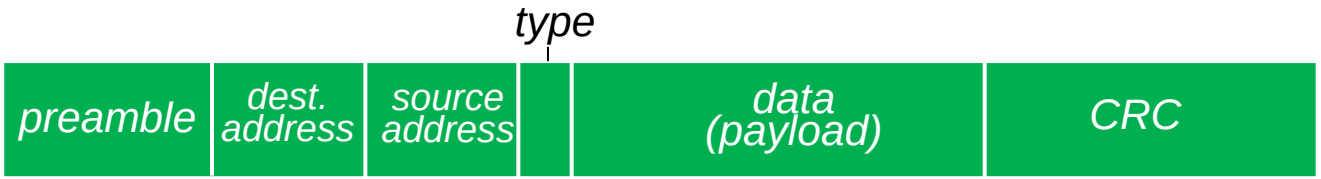


preamble:

- 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
- used to synchronize receiver, sender clock rates

Ethernet frame structure (more)

- *addresses:* 6 byte source, destination MAC addresses
  - if adapter receives frame with matching destination address, or with broadcast address (e.g. ARP packet), it passes data in frame to network layer protocol
  - otherwise, adapter discards frame
- *type:* indicates higher layer protocol (mostly IP but others possible, e.g., Novell IPX, AppleTalk)
- *CRC:* cyclic redundancy check at receiver
  - error detected: frame is dropped

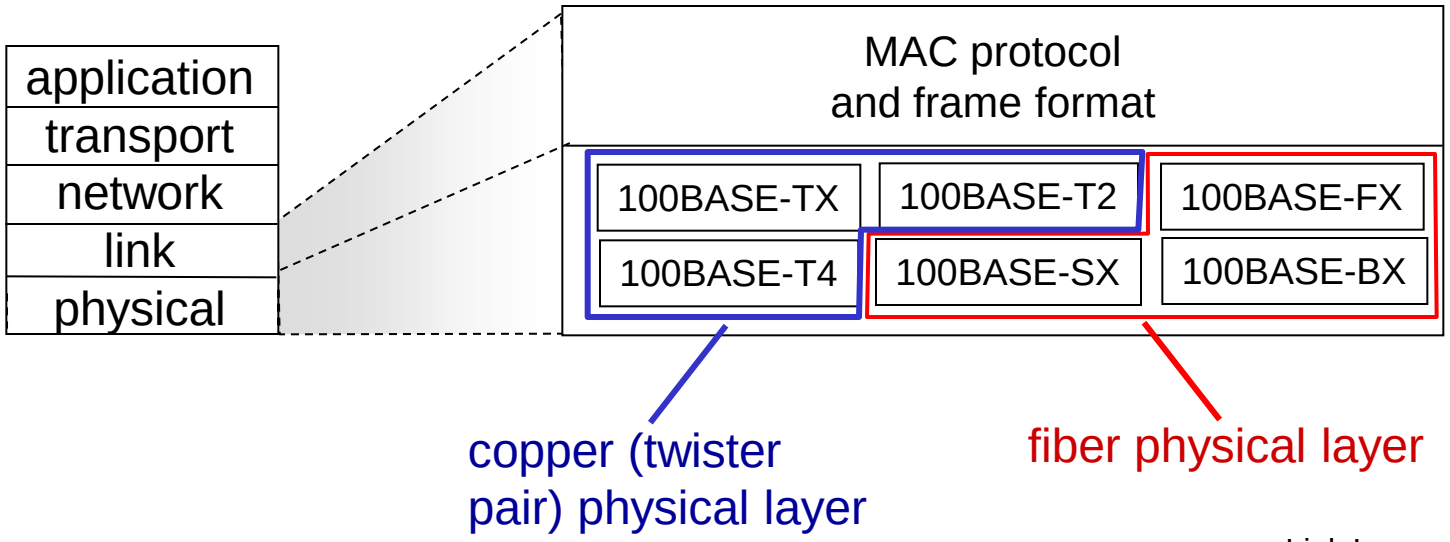


Ethernet: unreliable, connectionless

- *connectionless:* no handshaking between sending and receiving NICs
- *unreliable:* receiving NIC doesnt send acks or nacks to sending NIC
  - data in dropped frames recovered only if initial sender uses higher layer rdt (e.g., TCP), otherwise dropped data lost
- Ethernet's MAC protocol: unslotted *CSMA/CD wth binary backoff*

802.3 Ethernet standards: link & physical layers

- *many* different Ethernet standards
  - common MAC protocol and frame format
  - different speeds: 2 Mbps, 10 Mbps, 100 Mbps, 1Gbps, 10G bps
  - different physical layer media: fiber, cable

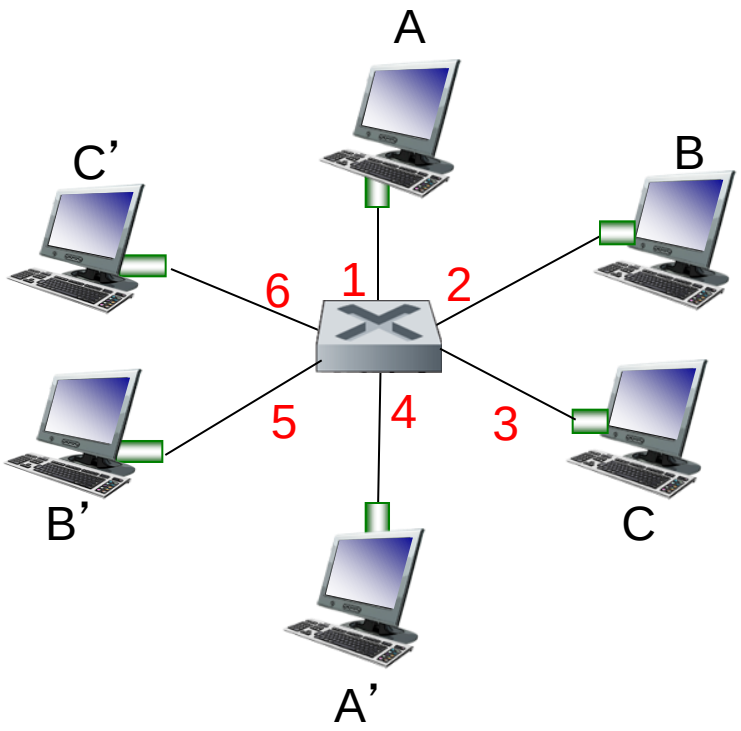


Ethernet switch

- 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, 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, 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)

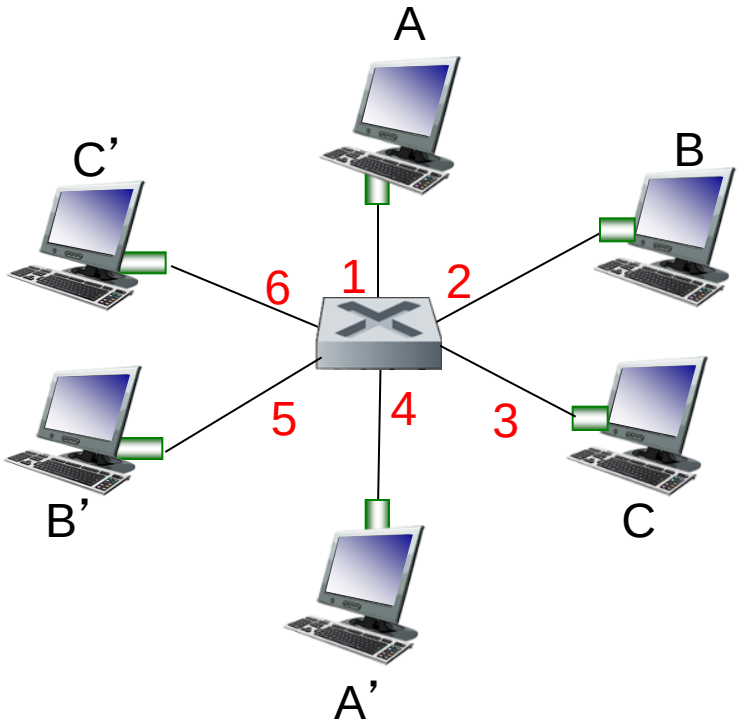
Switch forwarding table

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?

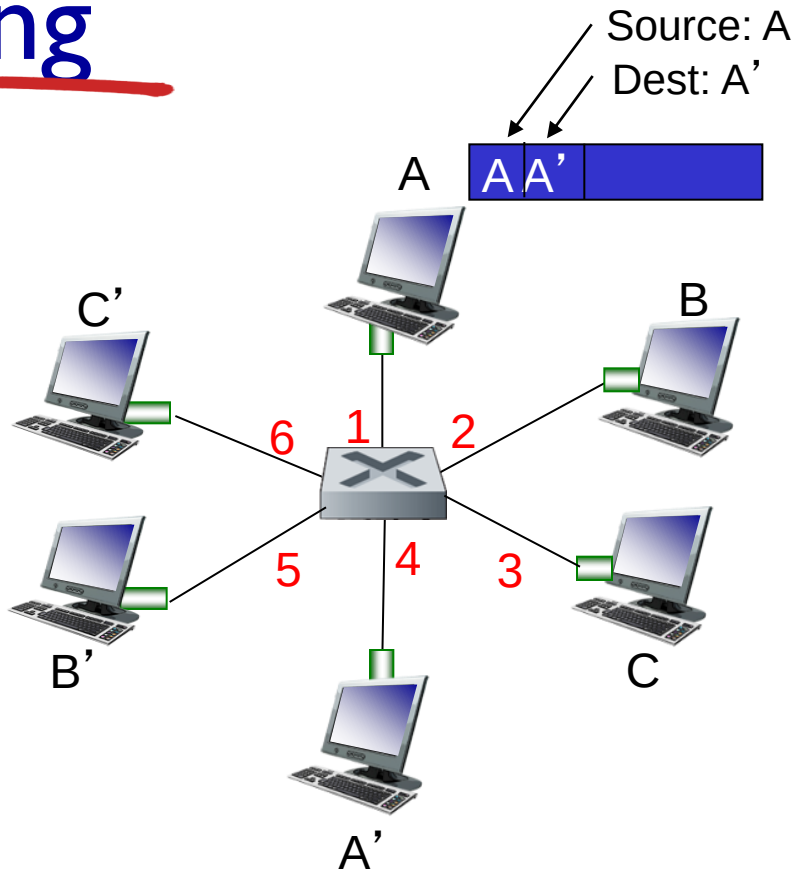
- *something like a routing protocol?*



switch 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)

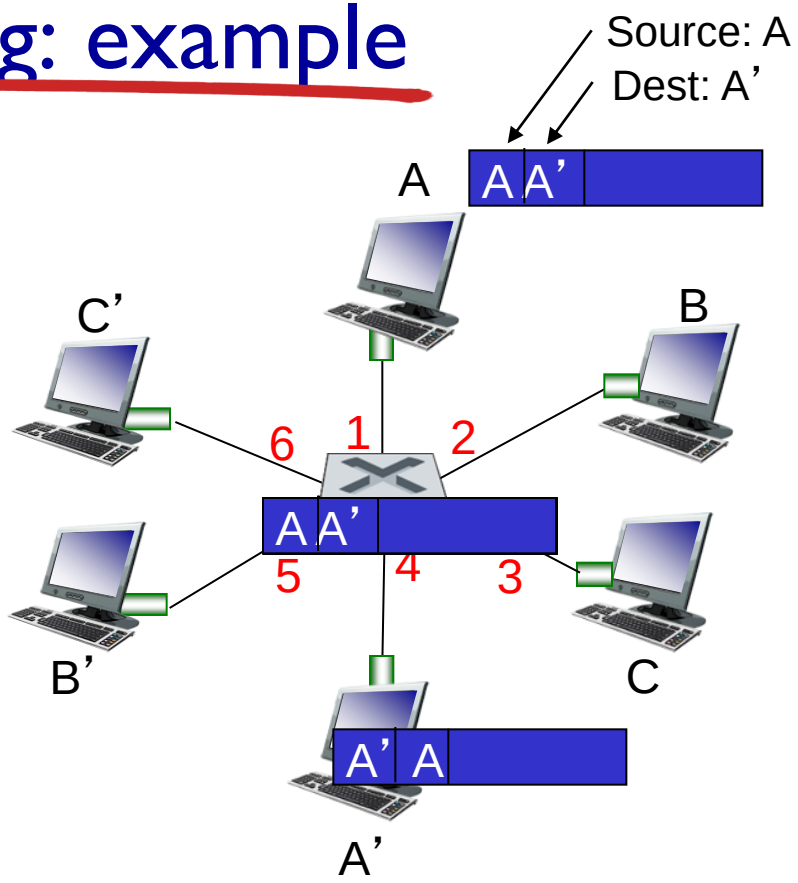
Switch: frame filtering/forwarding

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 */

Self-learning, forwarding: example

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

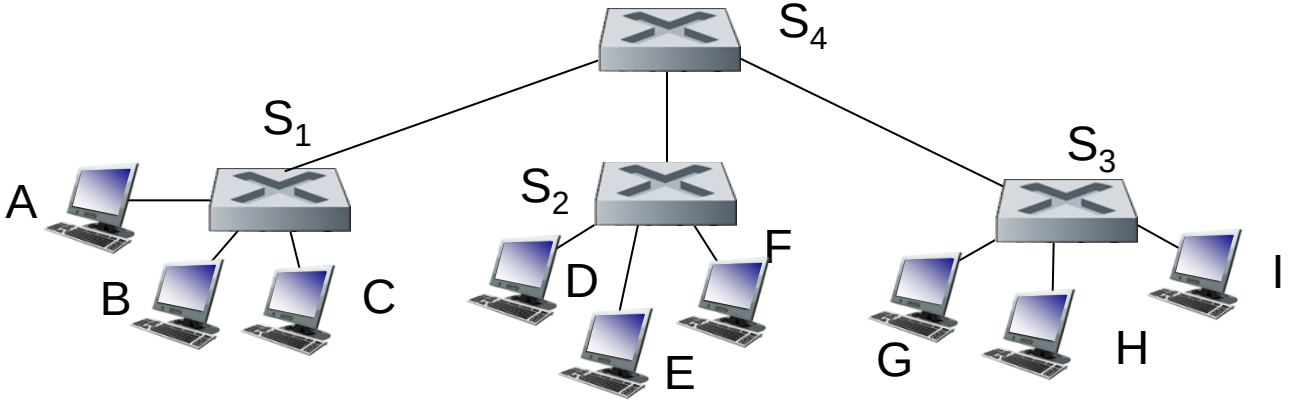


MAC addr	interface	TTL
A	*1*	*60*
A'	*4*	*60*

switch table (initially empty)

Interconnecting switches

- switches can be connected together

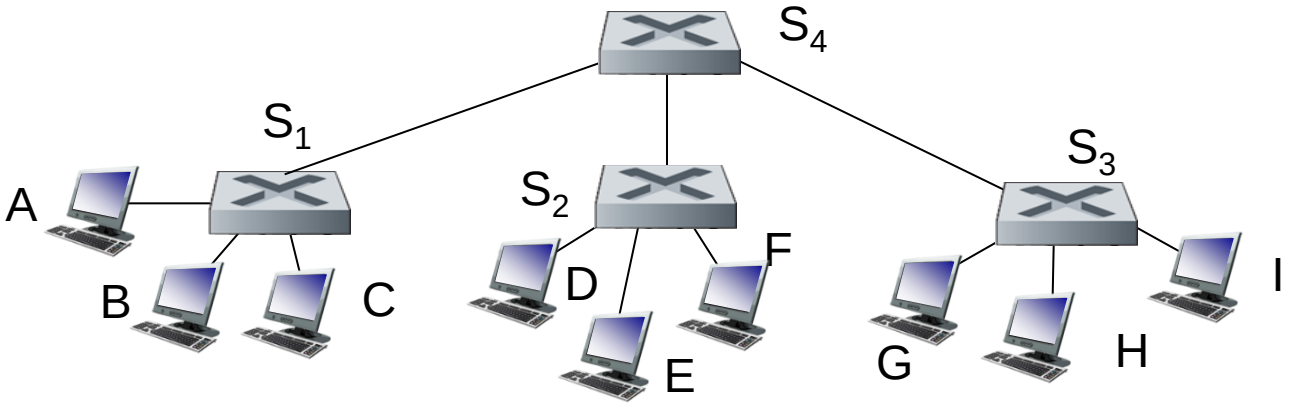


Q: sending from A to G - how does S_1 know to forward frame destined to F via S_4 and S_3?

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

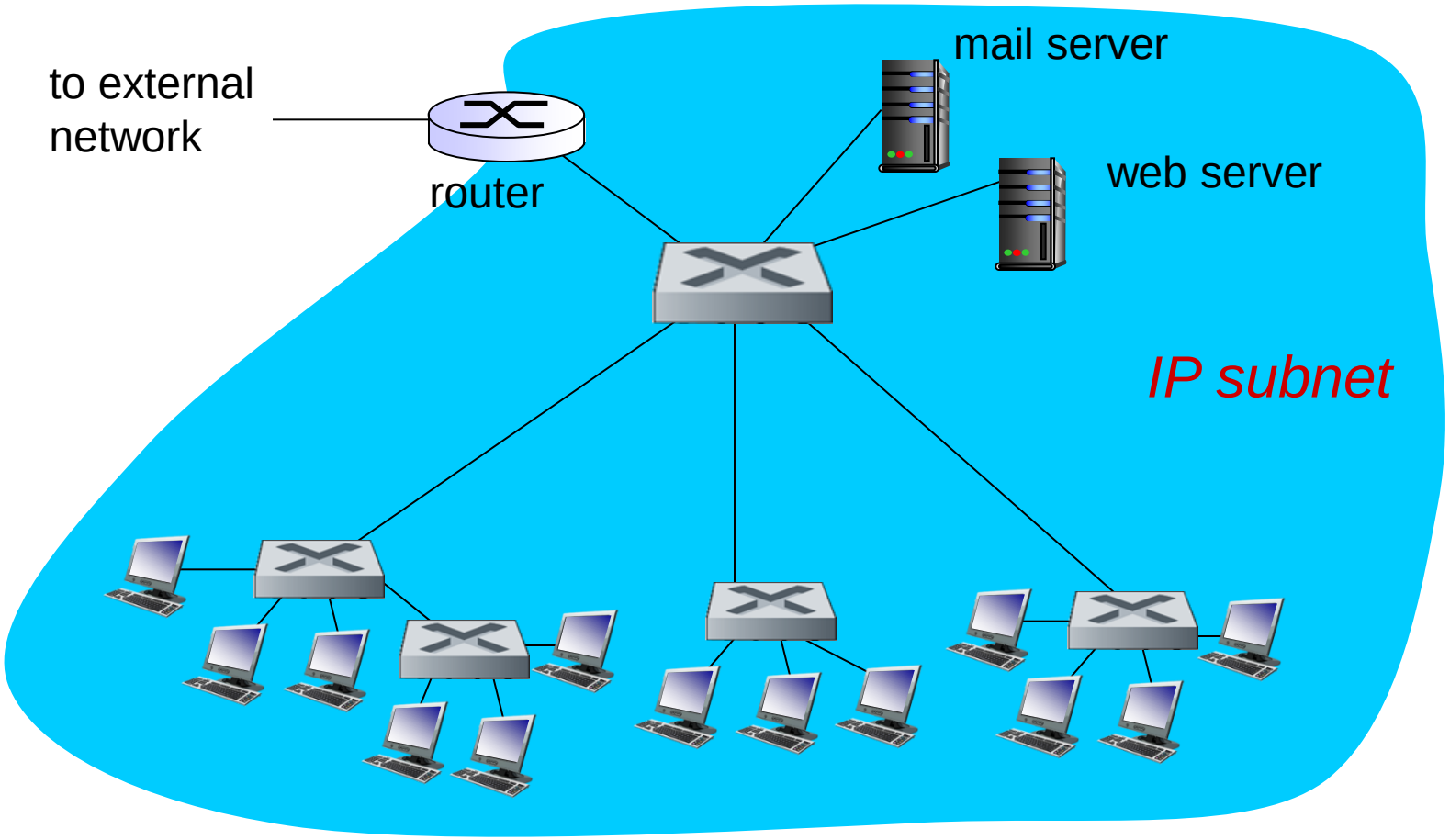
Self-learning multi-switch example

Suppose C sends frame to I, I responds to C



- *Q:* show switch tables and packet forwarding in S_1, S_2, S_3, S_4

Institutional network



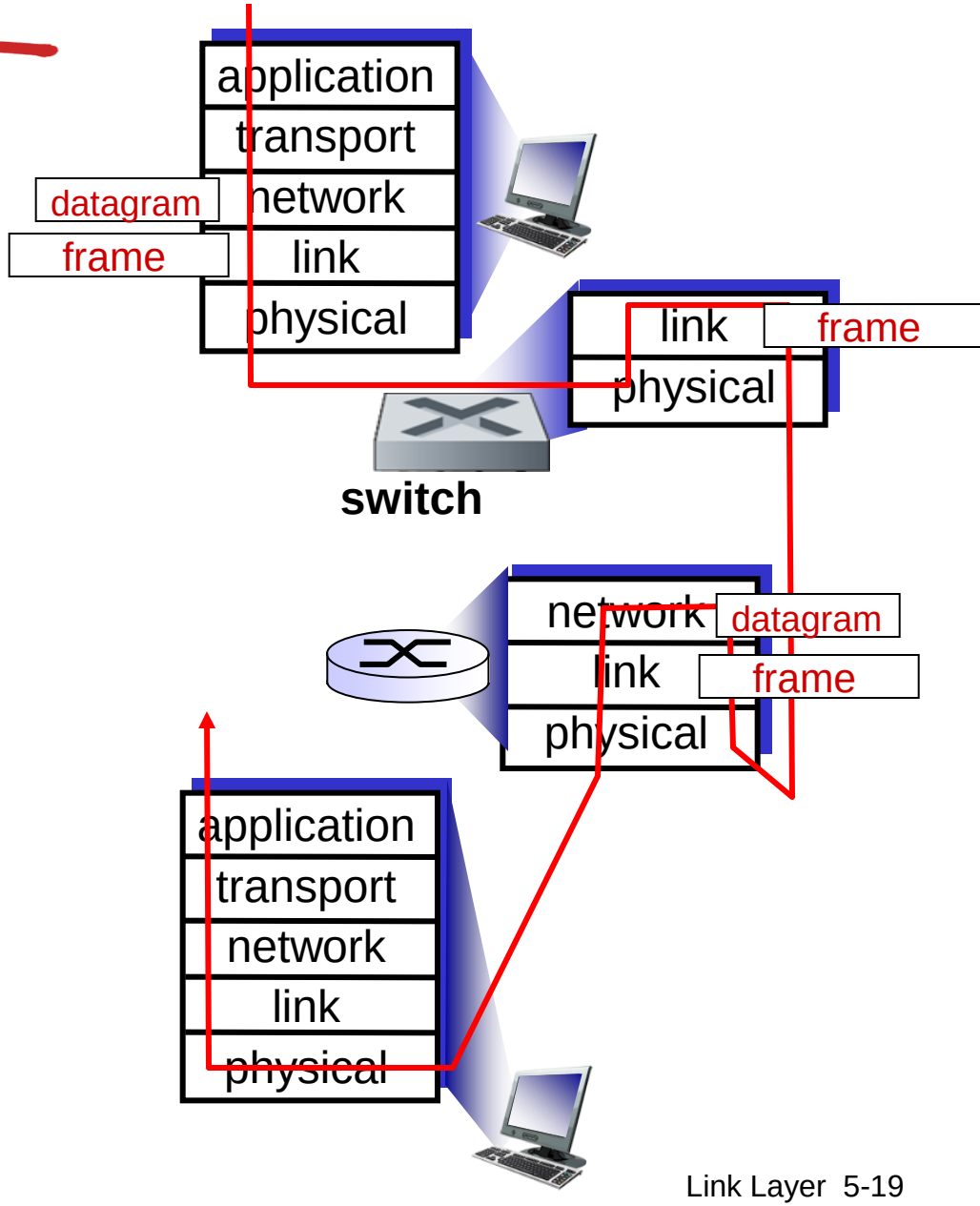
Switches vs. routers

both are store-and-forward:

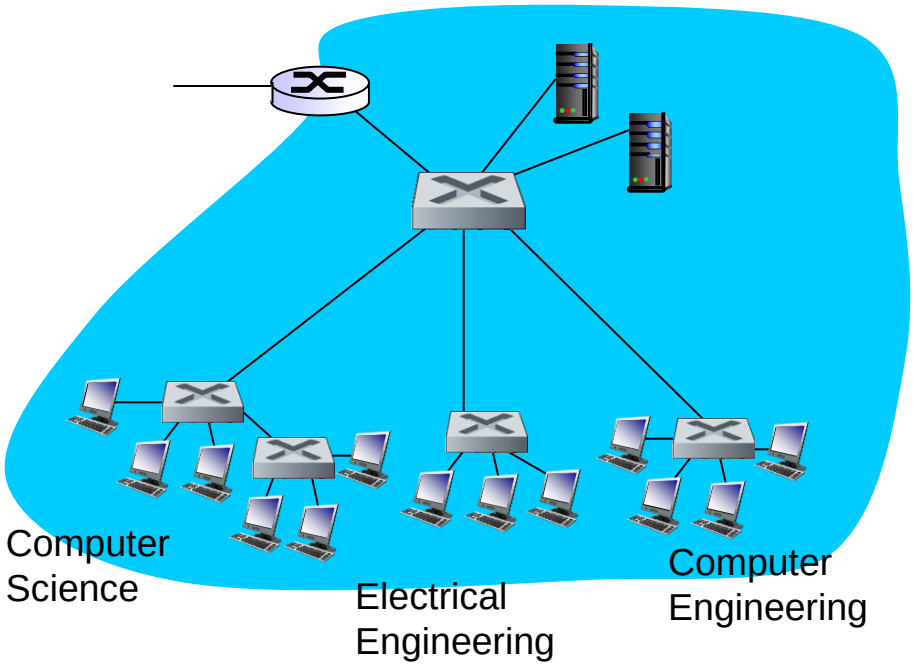
- *routers:* network-layer devices (examine network-layer headers)
- *switches*: link-layer devices (examine link-layer headers)

both have forwarding tables:

- *routers:* compute tables using routing algorithms, IP addresses
- *switches:* learn forwarding table using flooding, learning, MAC addresses



VLANs: motivation



consider:

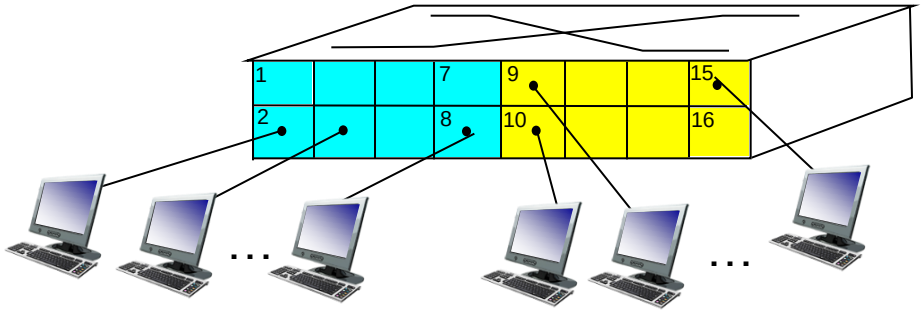
- CS user moves office to EE, but wants connect to CS switch?
- single broadcast domain:
  - all layer-2 broadcast traffic (ARP, DHCP, unknown location of destination MAC address) must cross entire LAN
  - security/privacy, efficiency issues

VLANs

Virtual Local Area Network

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

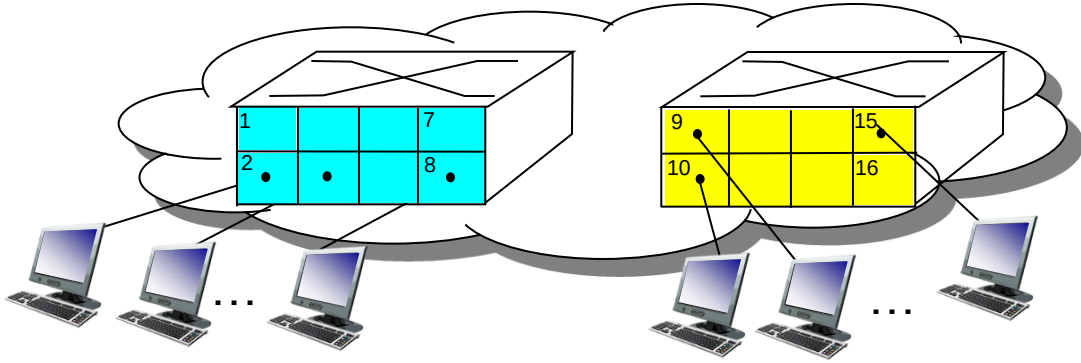
port-based VLAN: switch ports grouped (by switch management software) so that *single* physical switch ……



Electrical Engineering (VLAN ports 1-8)

Computer Science (VLAN ports 9-15)

… operates as *multiple* virtual switches

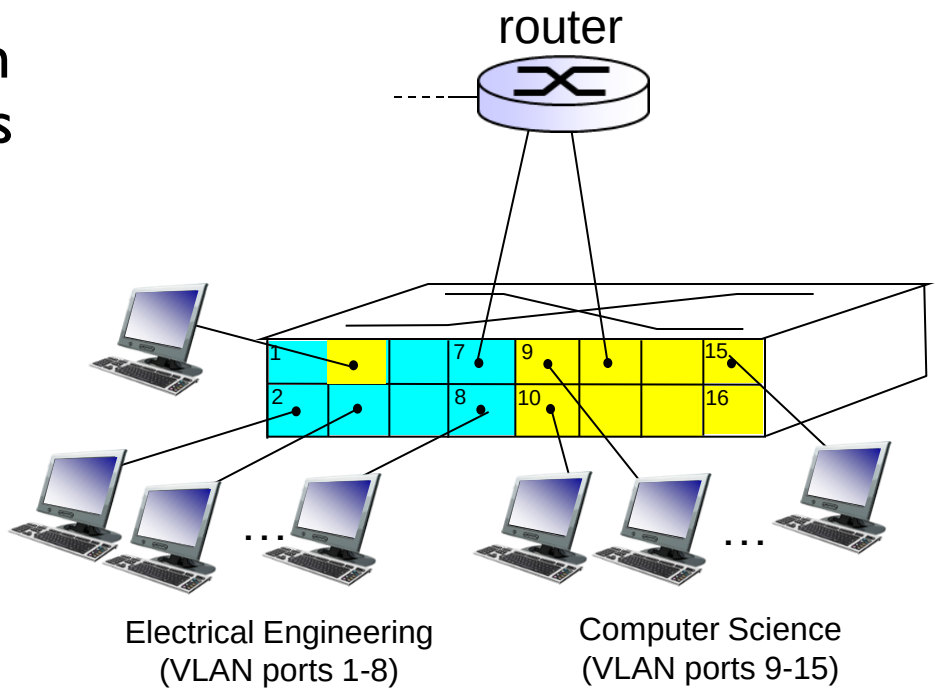


Electrical Engineering (VLAN ports 1-8)

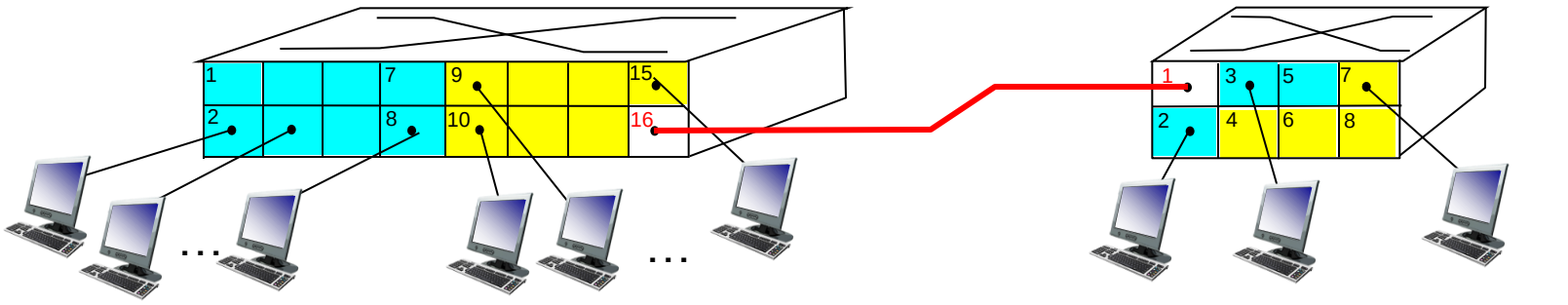
Computer Science (VLAN ports 9-16)

Port-based VLAN

- *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



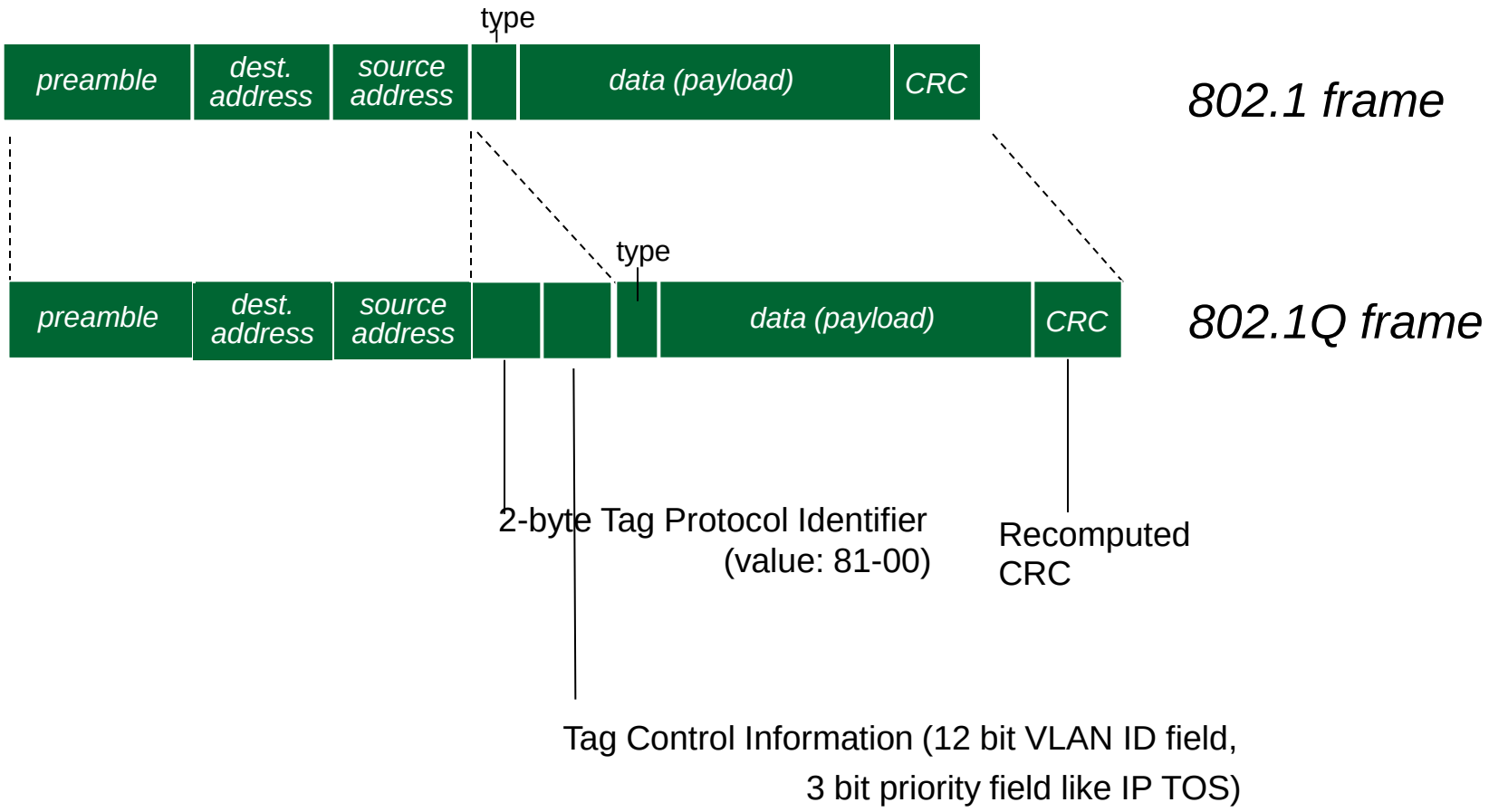
Electrical Engineering
(VLAN ports 1-8)

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



Data center networks

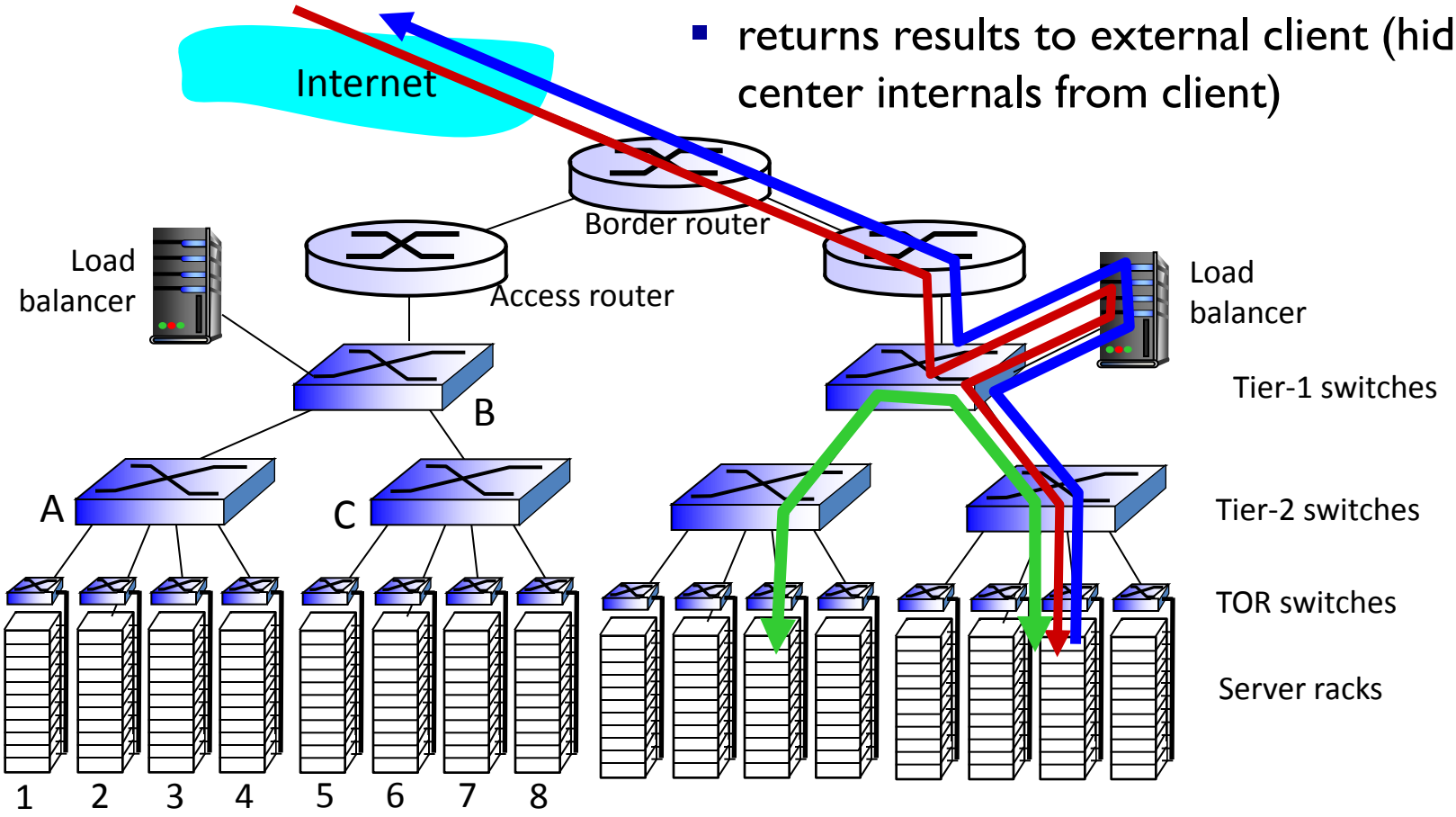
- 10's to 100's of thousands of hosts, often closely coupled, in close proximity:
  - e-business (e.g. Amazon)
  - content-servers (e.g., YouTube, Akamai, Apple, Microsoft)
  - search engines, data mining (e.g., Google)
- challenges:
  - multiple applications, each serving massive numbers of clients
  - managing/balancing load, avoiding processing, networking, data bottlenecks

Inside a 40-ft Microsoft container, Chicago data center

Data center networks

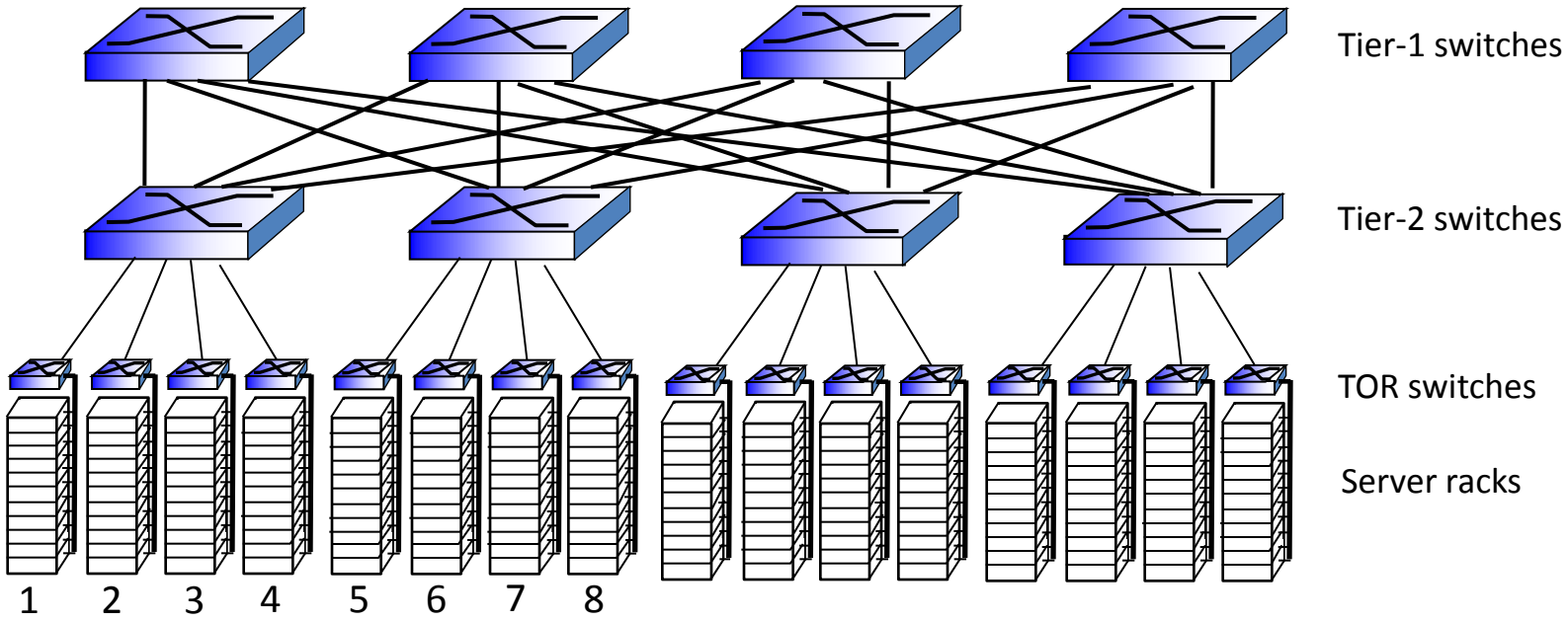
load balancer: application-layer routing

- receives external client requests
- directs workload within data center
- returns results to external client (hiding data center internals from client)



Data center networks

- rich interconnection among switches, racks:
  - increased throughput between racks (multiple routing paths possible)
  - increased reliability via redundancy



Lesson 17: The Data Link Layer – Summary

- Ethernet is the dominant LAN technology. It has evolved very effectively (over 30 years!) to meet the needs of growing networks.
- Generally, you will find switches and routers deployed using Ethernet that eliminate collisions between hosts.
- VLANs are a good example of common networks used in the industry to minimize administration and hardware costs.
- Data Center Networks – a new area for network throughput and reliability optimization