

CMPE 150/L : Introduction to Computer Networks

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Lecture 18

Final project demo

- ❑ Please do the demo THIS week to the TAs.
- ❑ Or you are allowed to use screenshots for demo. However the screenshots MUST be consistent to your program results, or you cannot get demo points

Next lecture

- ❑ Final review of the course
- ❑ Summarize important knowledge points that will be covered in the final examination.

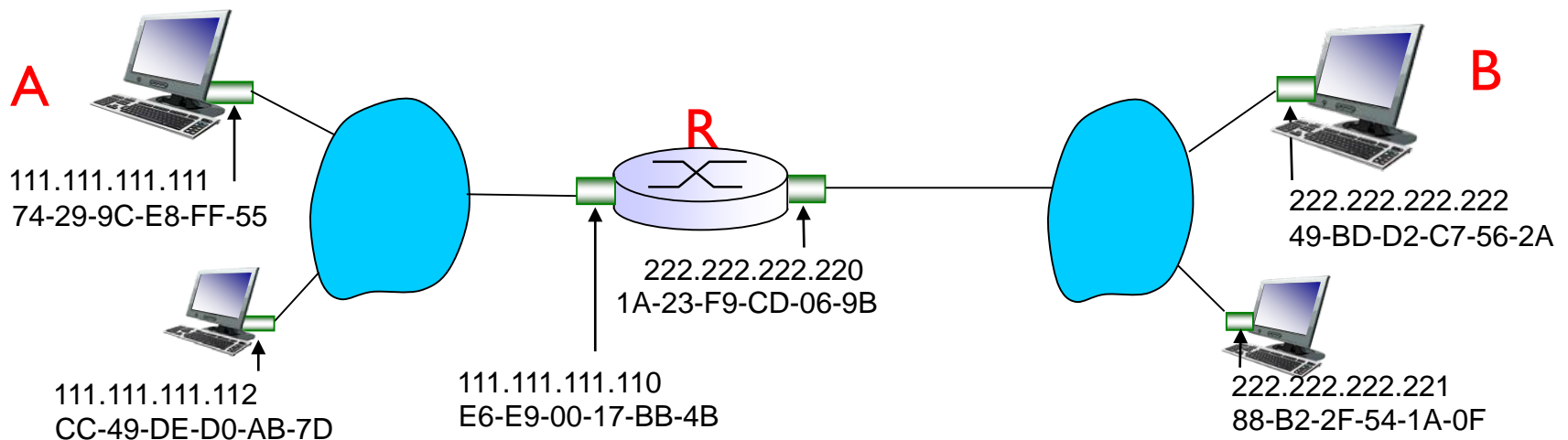
Course evaluation

- I will finish the lecture 15 mins earlier and you may use the time for course evaluation.

Addressing: routing to another LAN

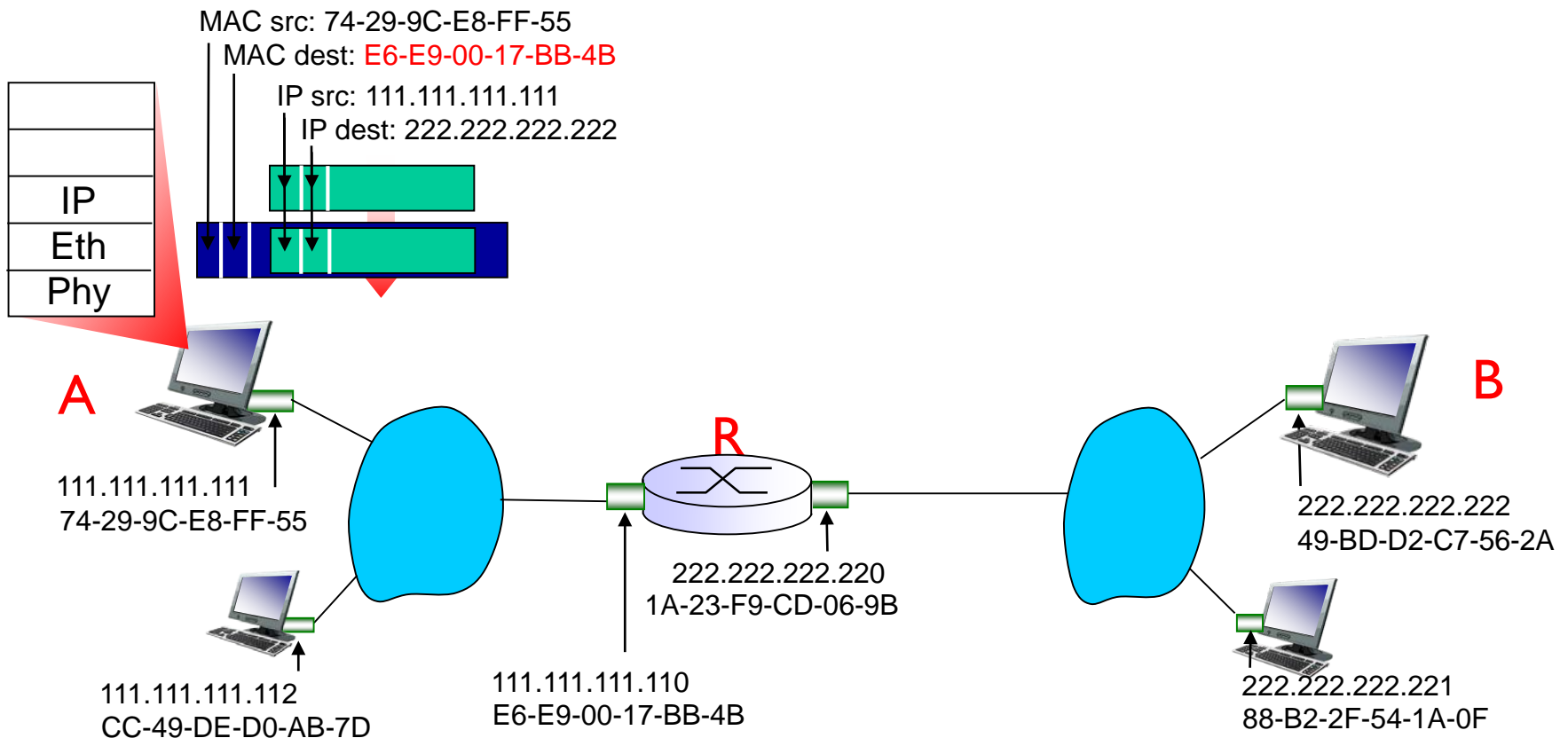
walkthrough: **send datagram from A to B via R**

- focus on addressing – at IP (datagram) and MAC layer (frame)
- assume A knows B's IP address
- assume A knows IP address of first hop router, R (how?)
 - DHCP
- assume A knows R's MAC address (how?)
 - ARP



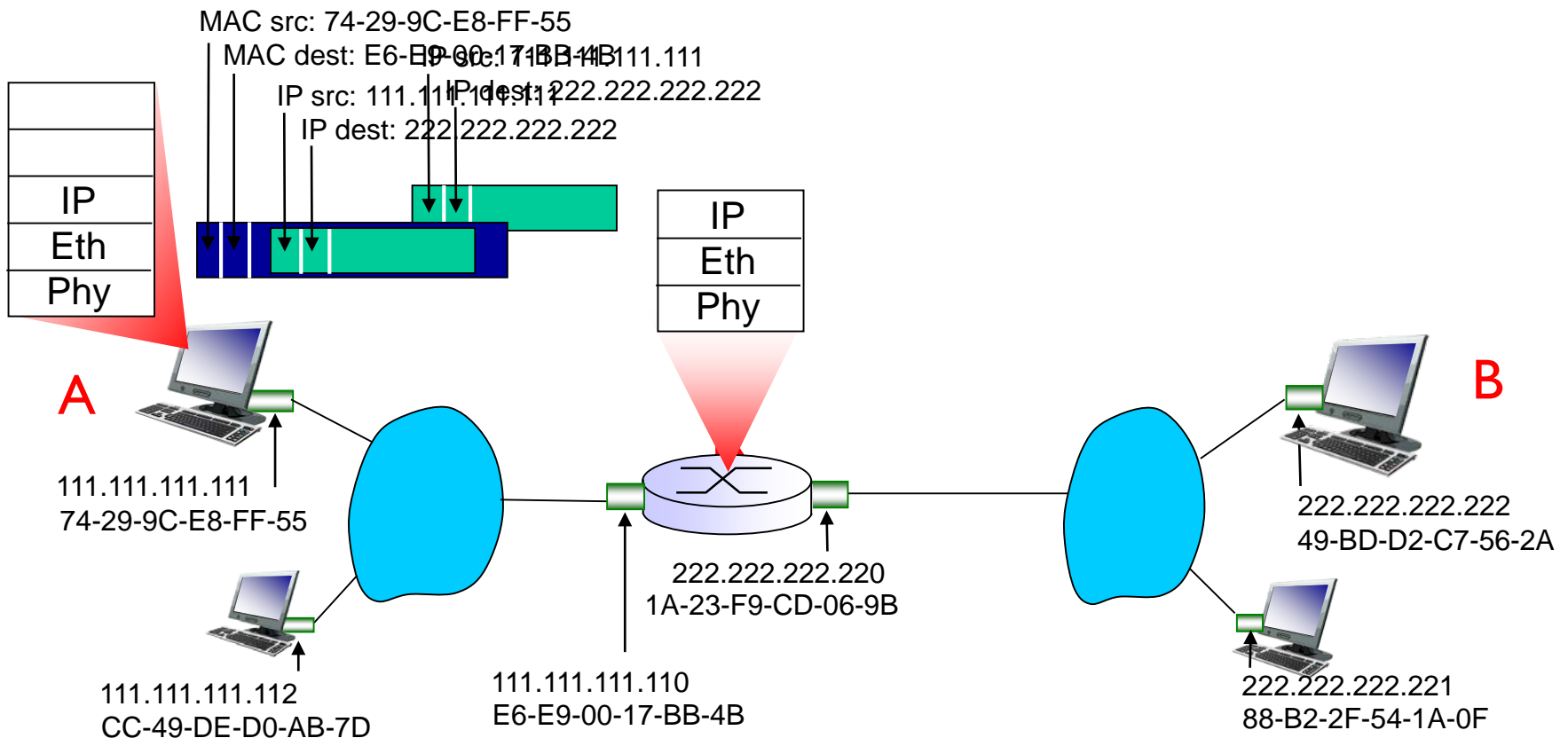
Addressing: routing to another LAN

- ❖ A creates IP datagram with IP source A, destination B
- ❖ A creates link-layer frame with R's MAC address as dest, frame contains A-to-B IP datagram



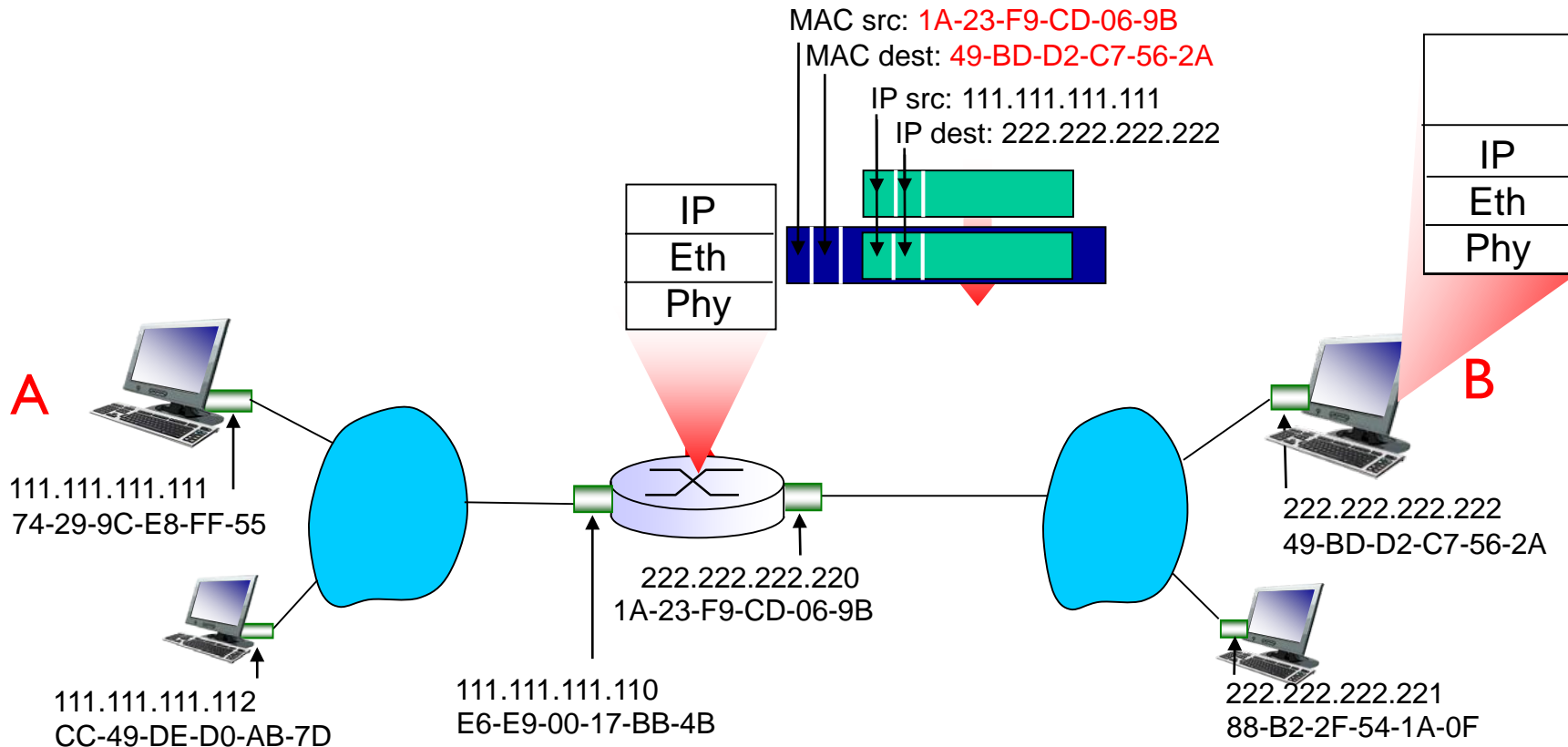
Addressing: routing to another LAN

- ❖ frame sent from A to R
- ❖ frame received at R, datagram removed, passed up to IP



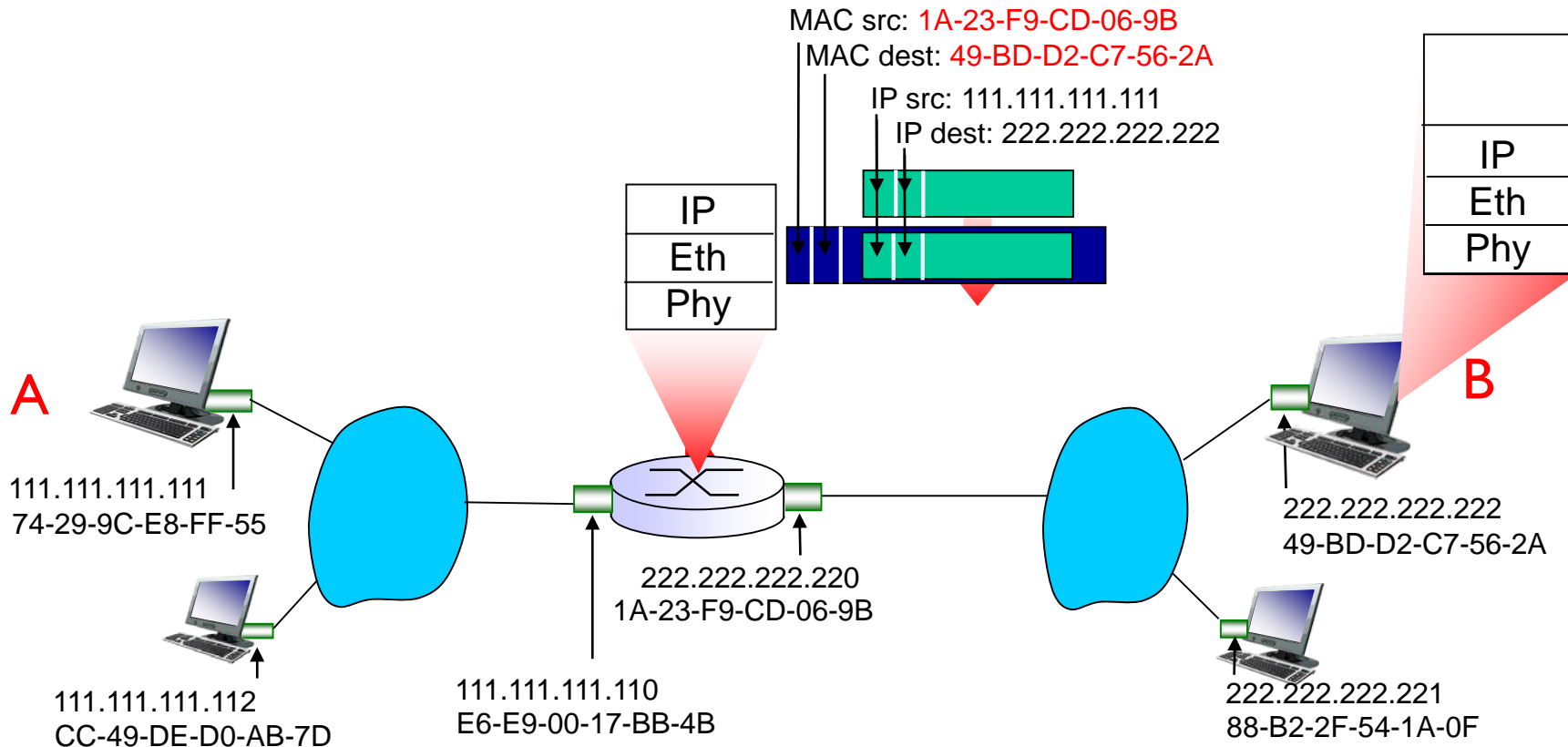
Addressing: routing to another LAN

- ❖ R forwards datagram with IP source A, destination B
- ❖ R creates link-layer frame with B's MAC address as dest, frame contains A-to-B IP datagram



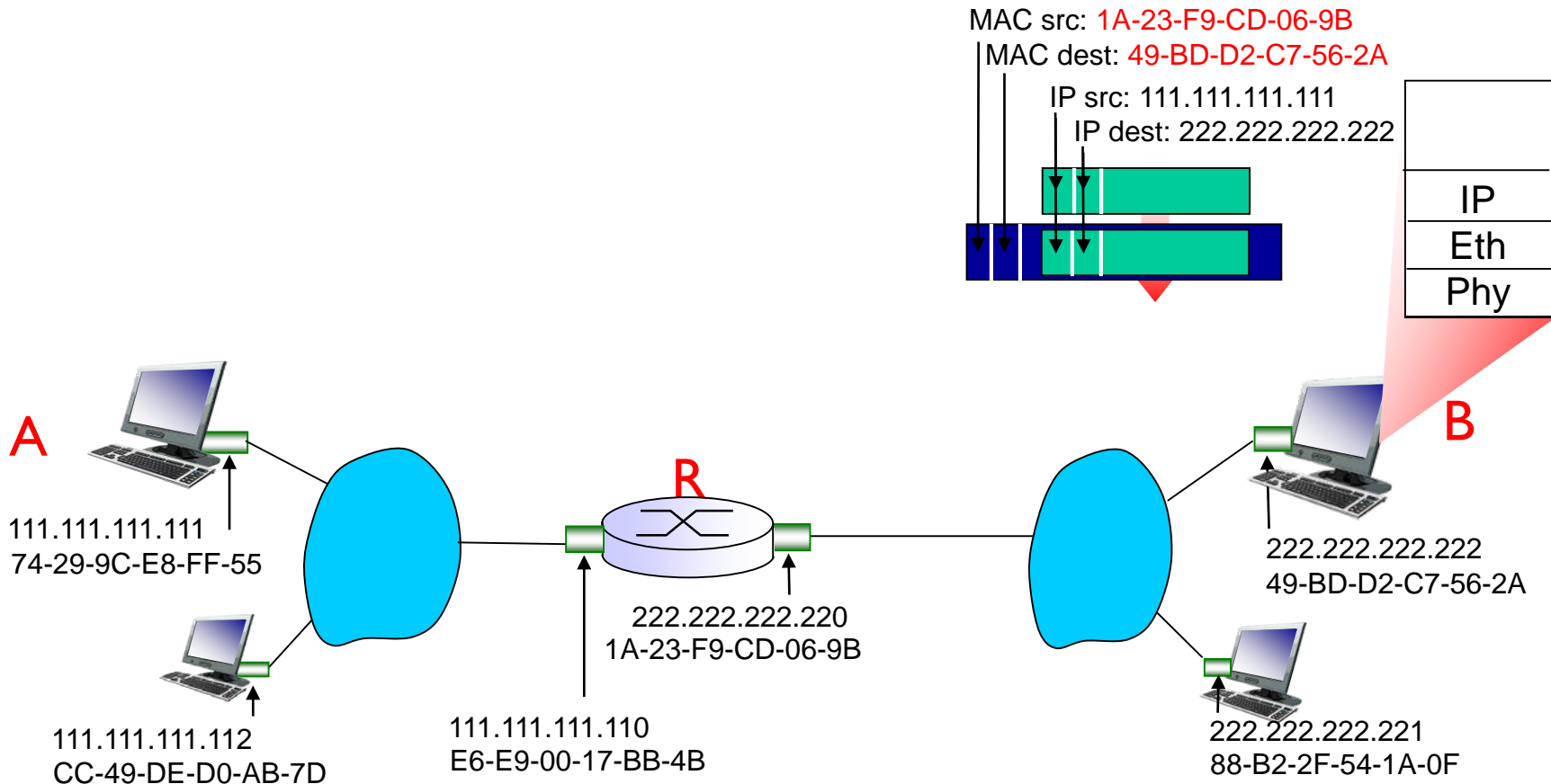
Addressing: routing to another LAN

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Addressing: routing to another LAN

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Link layer, LANs: outline

5.1 introduction, services

5.2 error detection,
correction

5.3 multiple access
protocols

5.4 LANs

- addressing, ARP
- Ethernet
- switches

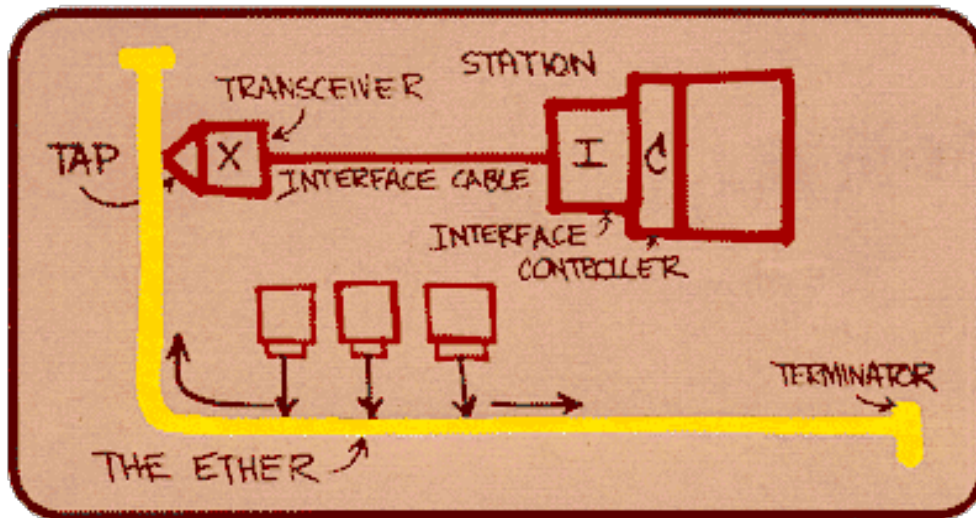
5.5 data center
networking

5.6 a day in the life of a
web request

Ethernet

“dominant” wired LAN technology:

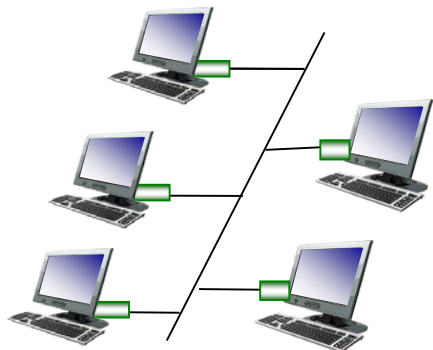
- ❖ cheap \$20 for NIC
- ❖ first widely used LAN technology
- ❖ simpler, cheaper than token LANs and ATM
- ❖ kept up with speed race: 10 Mbps – 10 Gbps



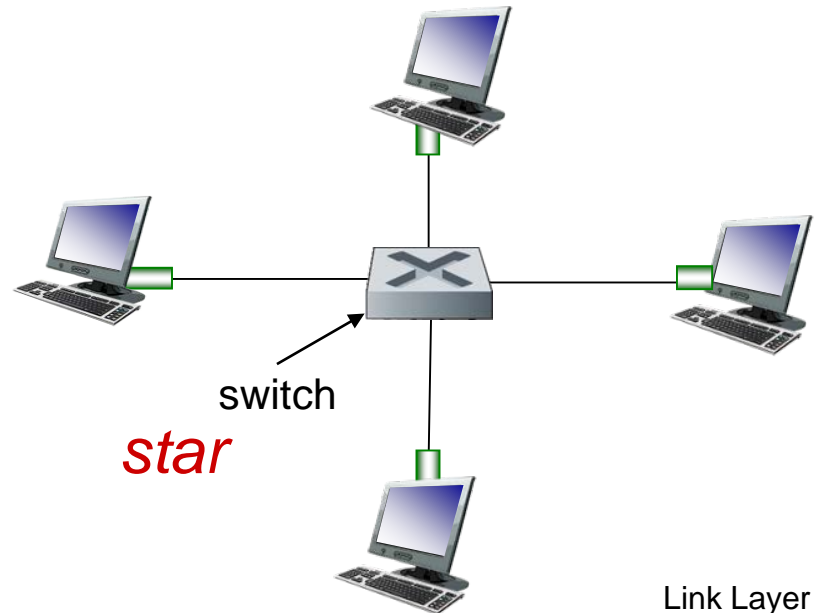
Metcalfe's Ethernet sketch

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



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

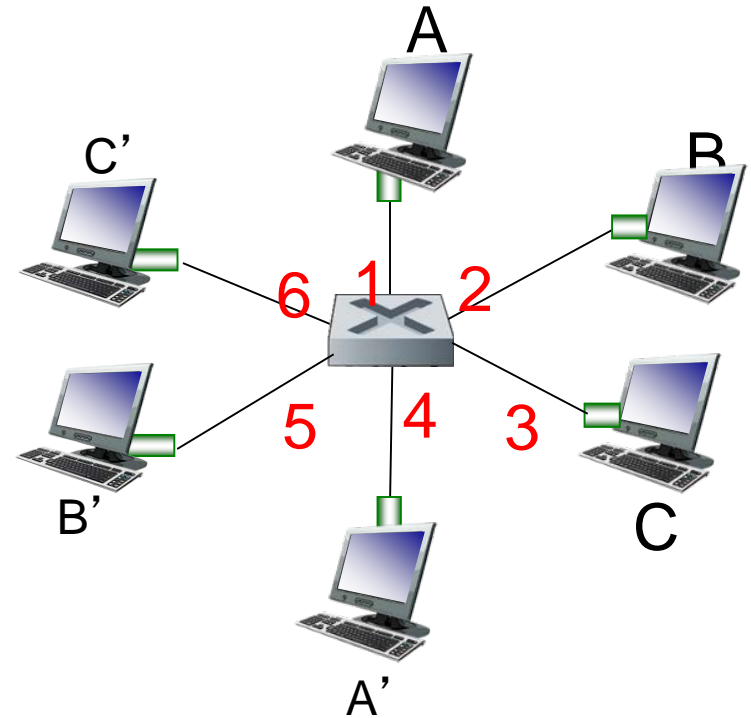
- ❖ *connectionless*: no handshaking between sending and receiving NICs
- ❖ *unreliable*: receiving NIC doesn't send acks or nacks to sending NIC
 - data in dropped frames recovered only if initial sender uses higher layer rdt (e.g., TCP), otherwise dropped data lost
- ❖ Ethernet's MAC protocol: unslotted *CSMA/CD with binary backoff*

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)

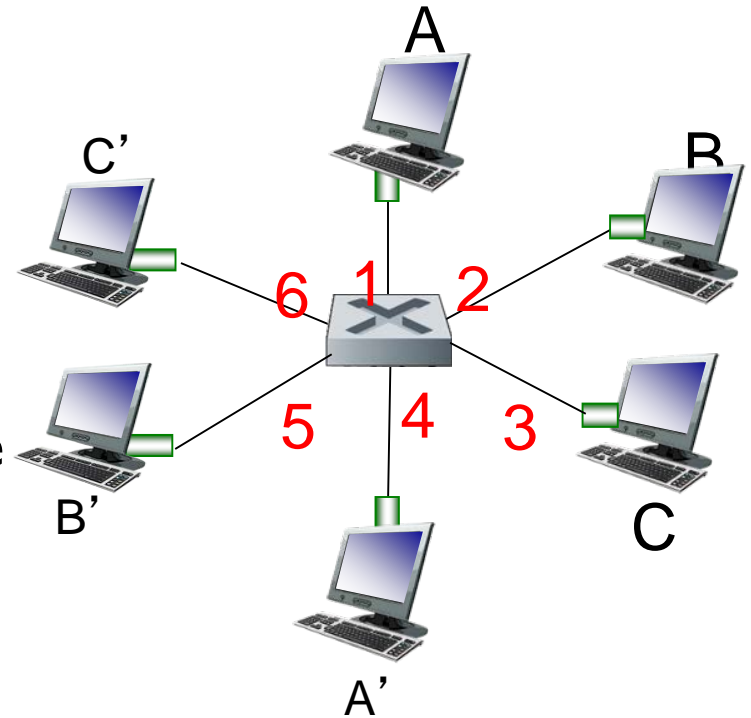
Switch forwarding table

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?

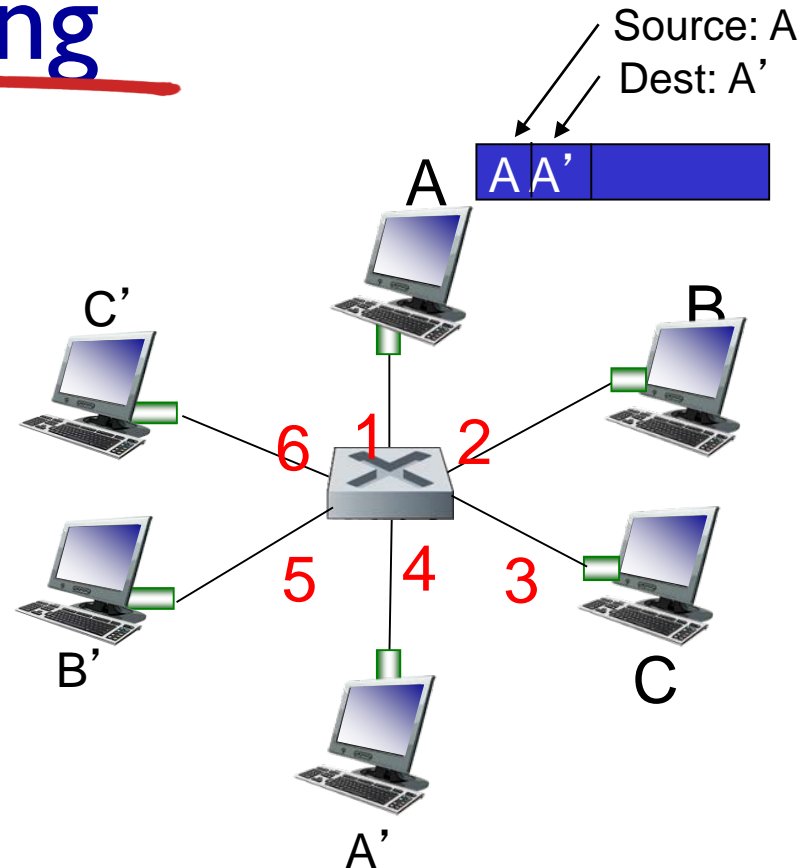
- something like a routing protocol?



*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

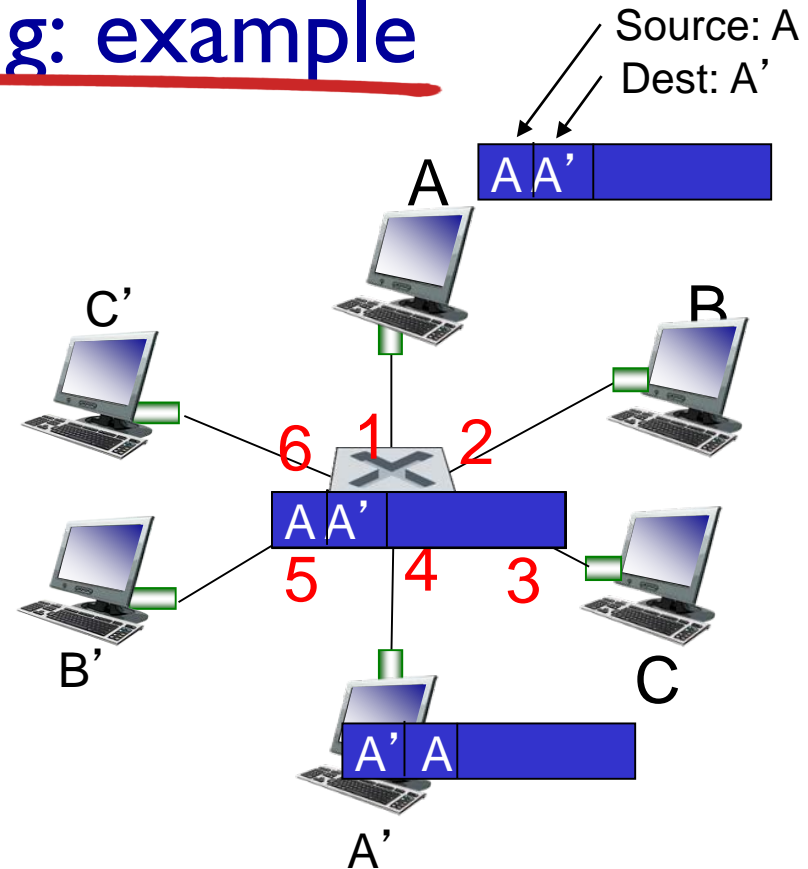
else forward frame on interface indicated by entry

}

else flood /* forward on all interfaces except arriving
interface */

Self-learning, forwarding: example

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

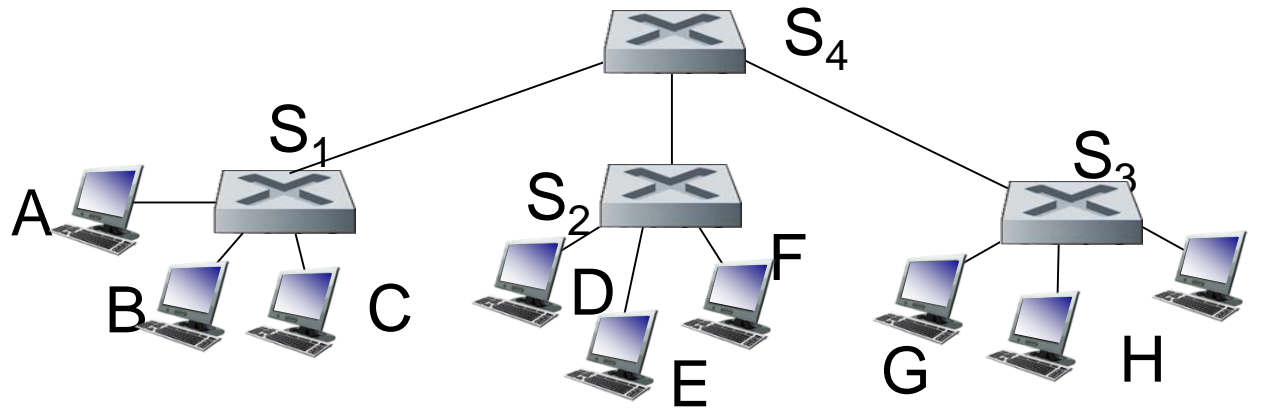


MAC addr	interface	TTL
A	1	60
A'	4	60

*switch table
(initially empty)*

Interconnecting switches

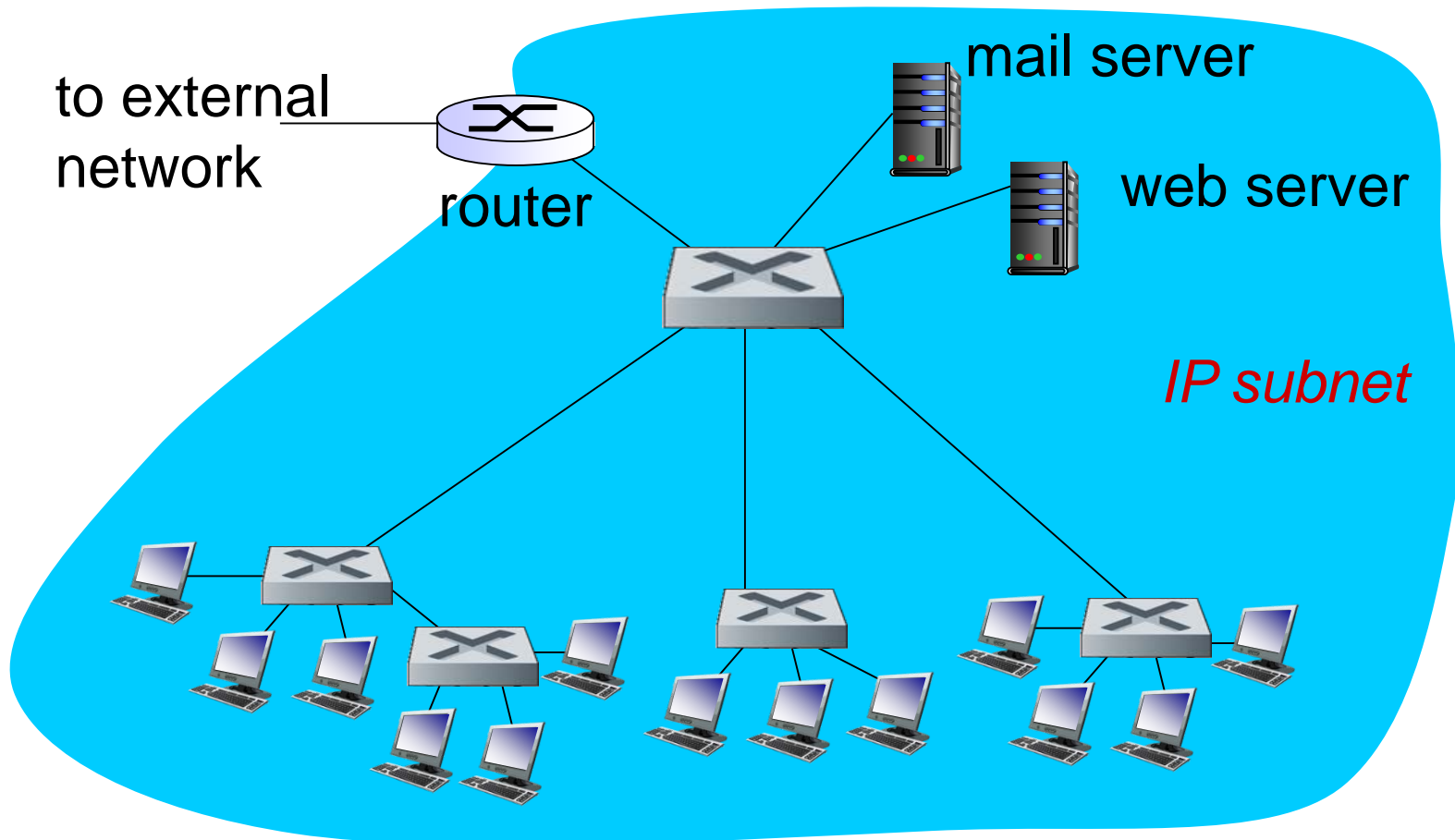
- ❖ switches can be connected together



Q: sending from A to G - how does S₁ know to forward frame destined to F via S₄ and S₃?

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

Institutional network



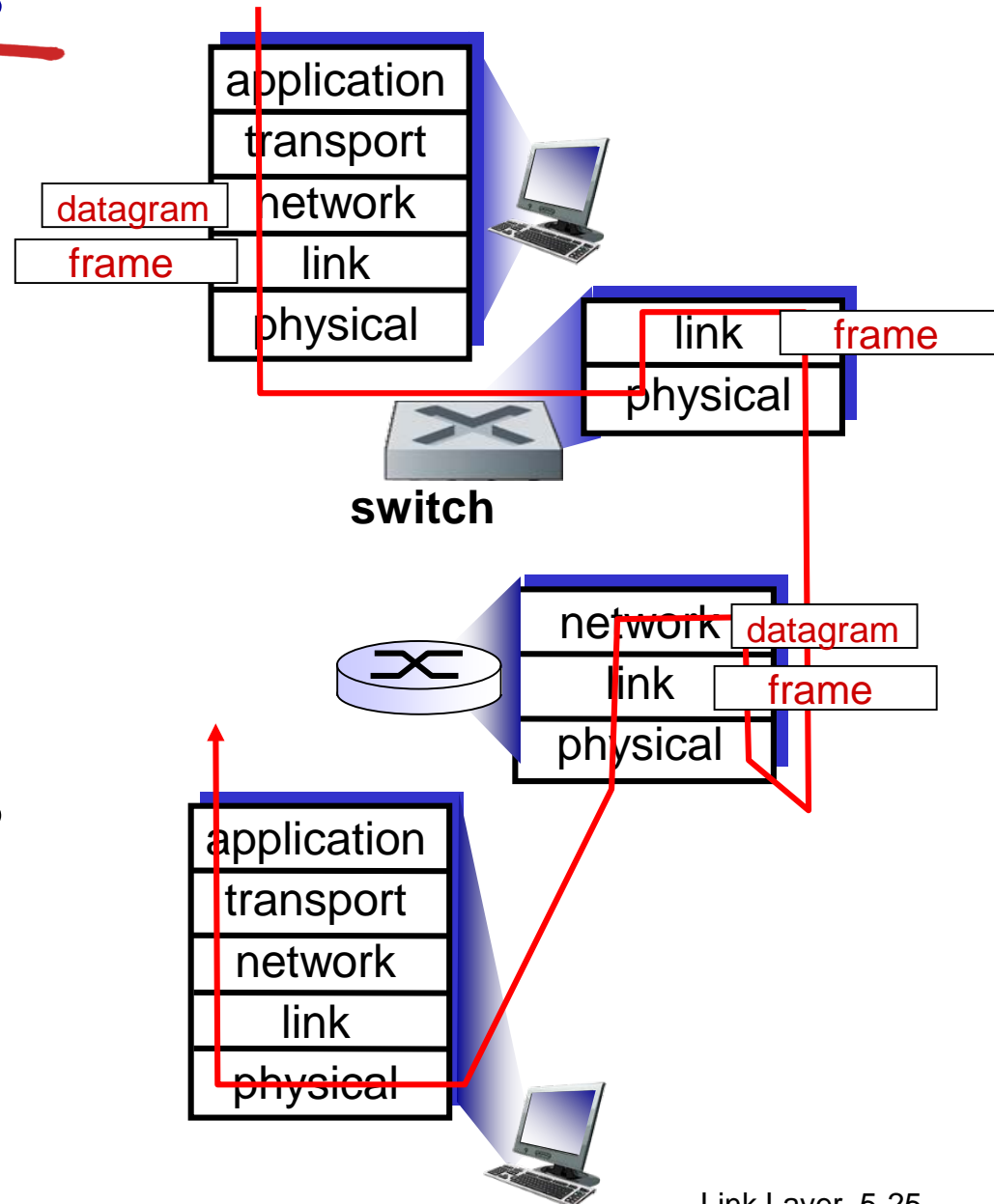
Switches vs. routers

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



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5.6 data center
networking

5.7 a day in the life of a
web request

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

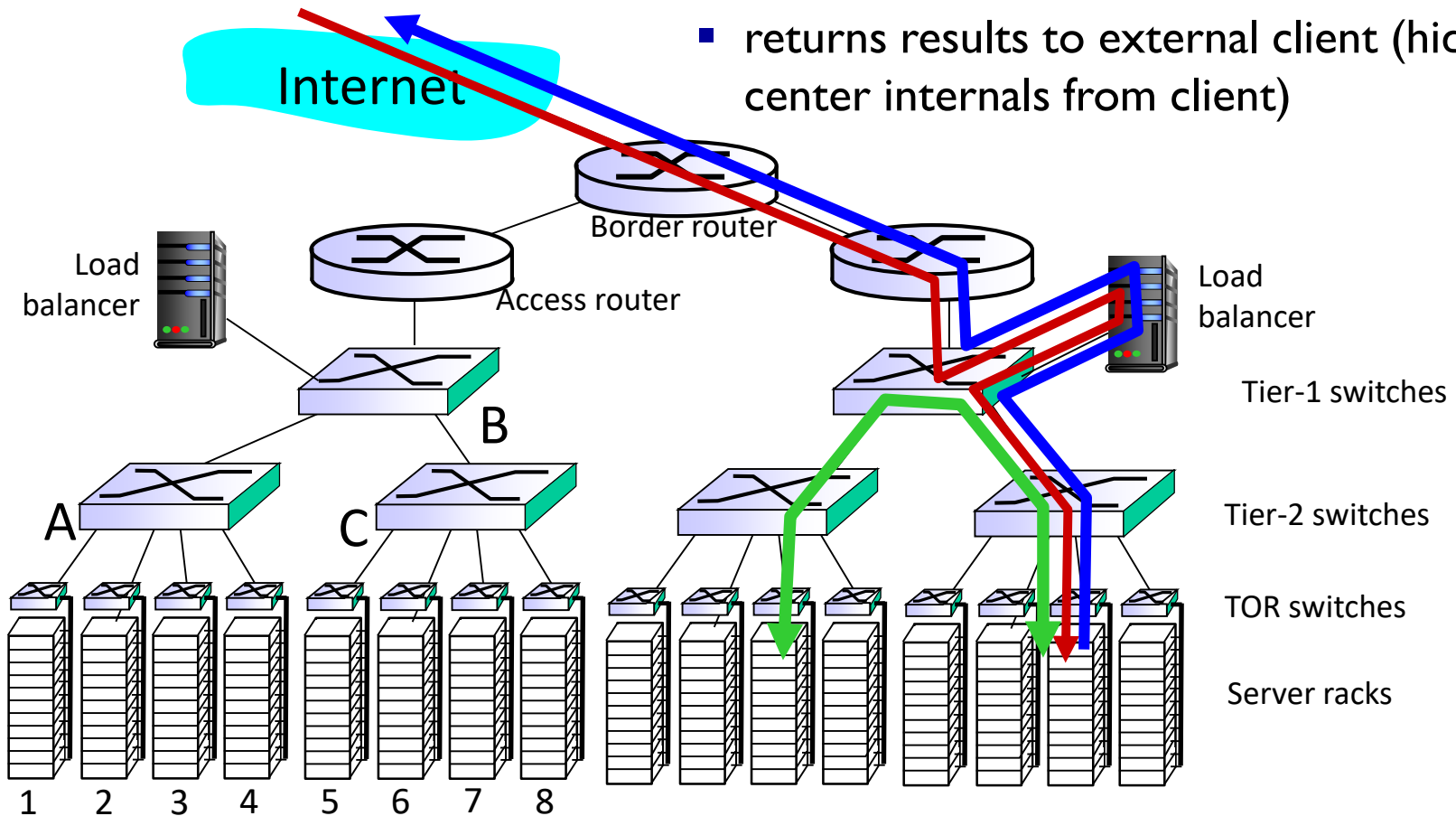


Inside a 40-ft Microsoft container,
Chicago data center

Data center networks

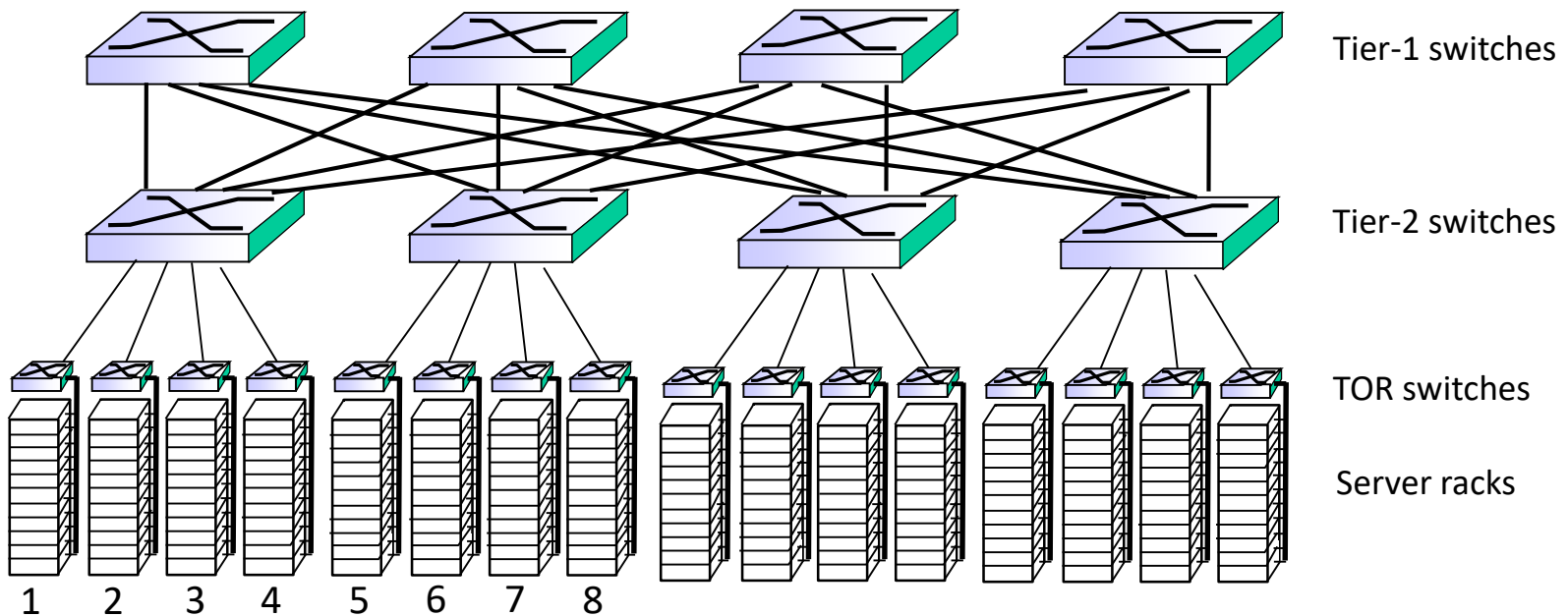
load balancer: application-layer routing

- 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



Next class

Finish Chapter 5 and final review