CS 43: Computer Networks
Switches and LANs

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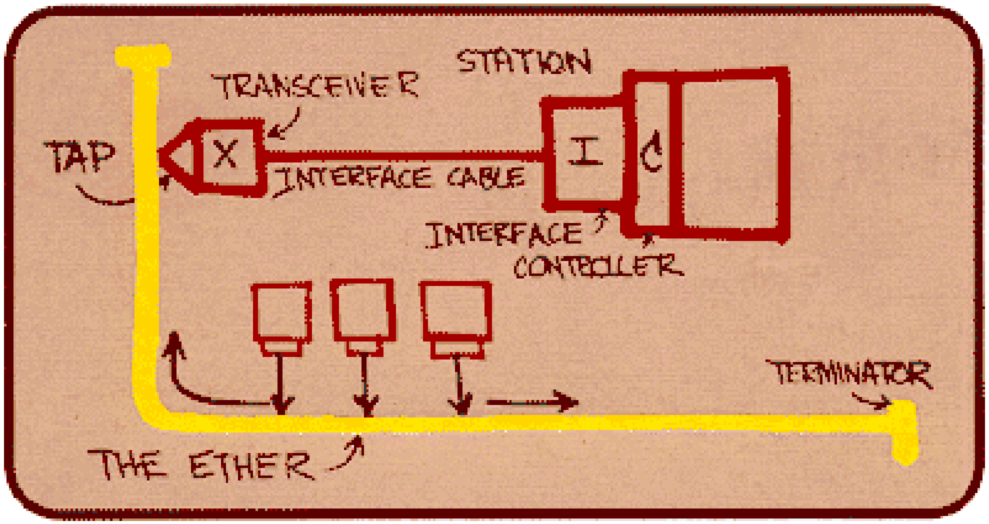
Ethernet



Metcalfe's Ethernet sketch

"Dominant" wired LAN technology:

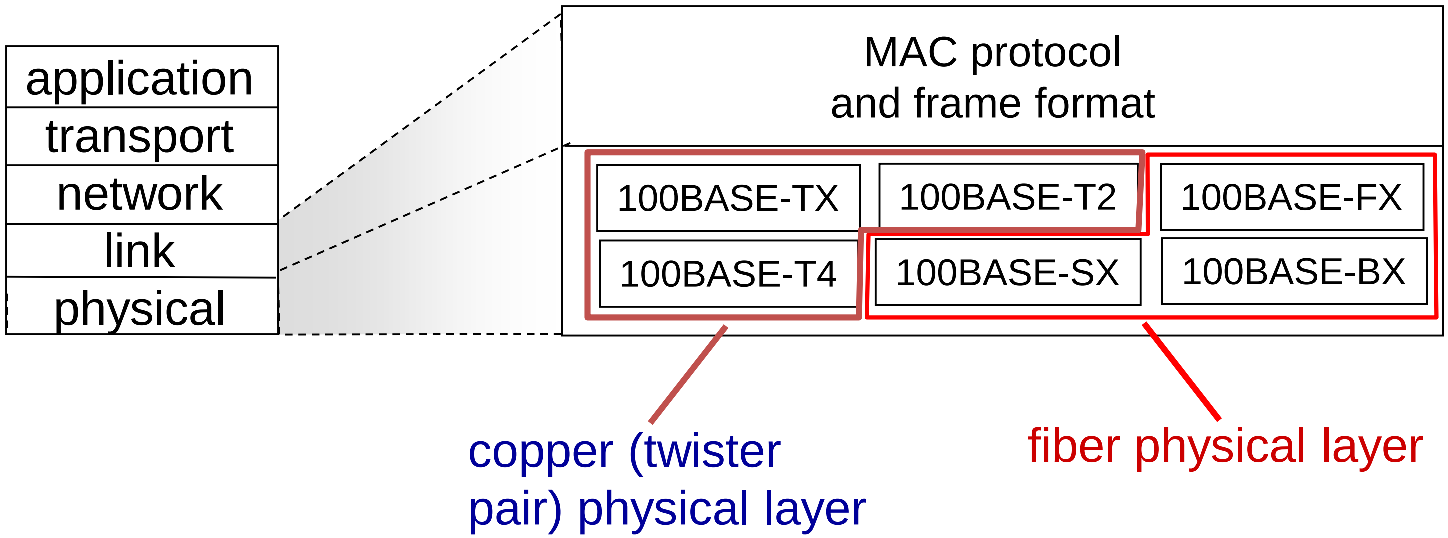
- cheap $20 for NIC
- first widely used LAN technology
- simpler, cheaper than token LANs and ATM
- kept up with speed race: 10 Mbps – 10 Gbps

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 reliable delivery (e.g., TCP), otherwise dropped data lost
- Ethernet's MAC protocol: *CSMA/CD with binary exponential backoff*

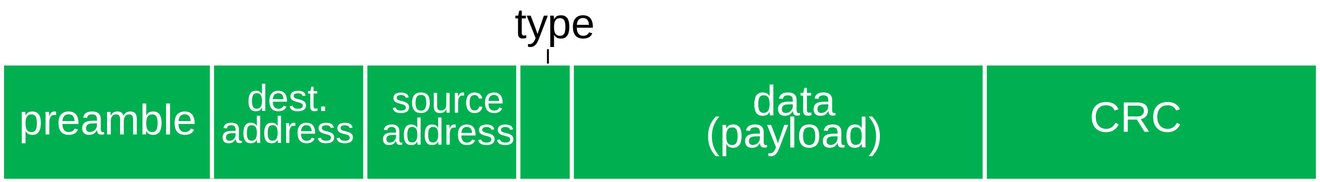
802.3 Ethernet standards: link & physical layers

- *Many* different Ethernet standards
  - Common MAC protocol and frame format
  - Speeds: 2 Mbps, 10 Mbps, 100 Mbps, 1Gbps, 10Gbps
  - Physical layer media: fiber, copper cable



Ethernet frame structure

Sender 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

Clock Synching

- Bits represented as voltages, either low or high
- We will read one bit per clock cycle

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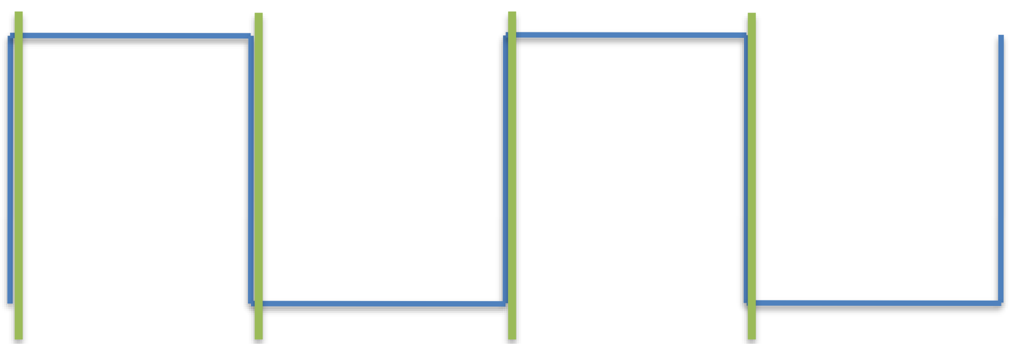
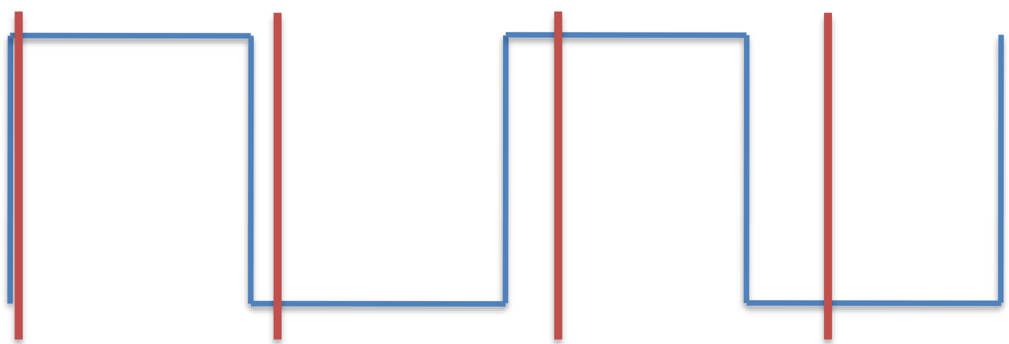


Ideal receiver: Sample signal at regular interval.

For 1 Gbps Ethernet, ~1 nanosecond interval.

Clock Synching

- Bits represented as voltages, either low or high
- We will read one bit per clock cycle



Problem: receiver clock may not agree with sender!

Preamble let's receiver see several 0 -> 1 -> 0 -> ... transitions.

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

A quick lab note…

- You will NOT see the preamble in the frames you receive.
  - (It also doesn't count as part of the 1500 byte MTU)
- There are header structs defined in sr_protocol.h.
- First task upon receiving a packet: "Is this for me?"
  - Compare dest address of packet against address of interface that received it.
  - Function already exists for this (ether_to_me)

MAC Addresses

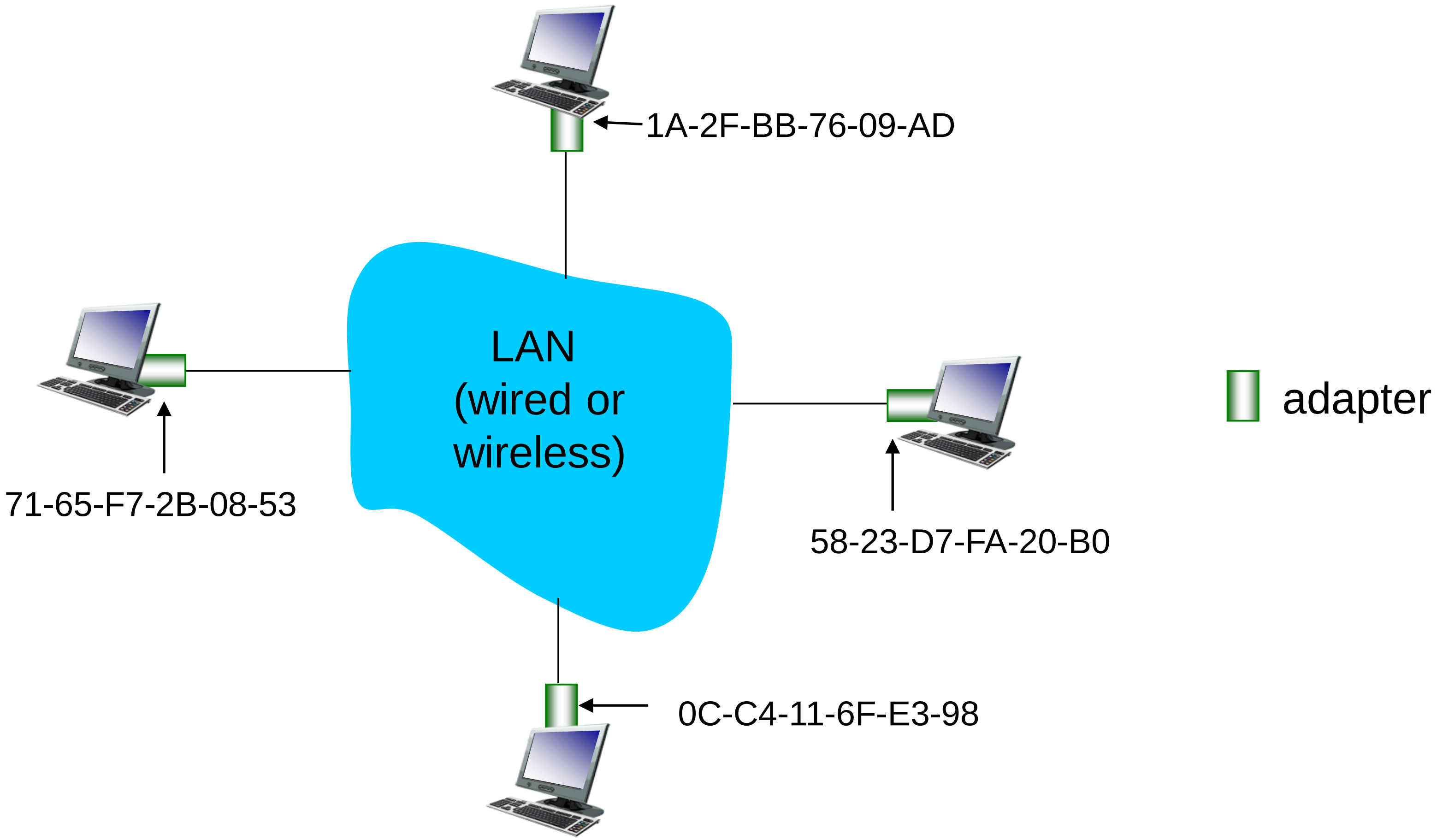
- 32-bit IP address:
  - *network-layer* address for interface
  - used by network layer for end-to-end routing

- MAC (or LAN or physical or Ethernet) address:
  - function: *used locally to get a frame from one interface to another physically-connected interface (same sub-network)*
  - 48 bit MAC address (for most LANs) burned in NIC ROM, also (usually) software settable
  - e.g.: 1A-2F-BB-76-09-AD

    hexadecimal (base 16) notation
    (each digit represents 4 bits)

MAC Addresses

Each interface/adapter on LAN has unique *MAC* address

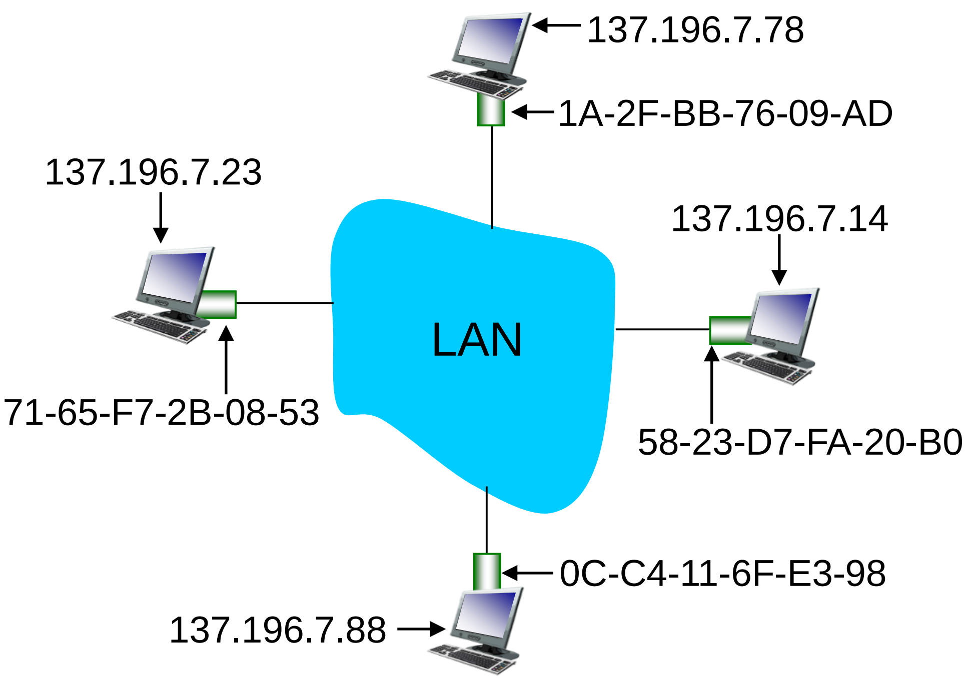


MAC Addresses

- MAC address allocation administered by IEEE
- Manufacturer buys portion of MAC address space (to assure uniqueness)
- Analogy:
  - MAC address: like Social Security Number
  - IP address: like postal address
- MAC flat address ➜ portability
  - can move LAN card from one LAN to another
- IP hierarchical address *not* portable
  - address depends on IP subnet to which node is attached

ARP: Address Resolution Protocol

Question: how to determine interface's MAC address, knowing its IP address?



ARP table: each IP node (host, router) on LAN has table

- IP/MAC address mappings for some LAN nodes:

  < IP address; MAC address; TTL>

- TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)

ARP protocol & LAN communication

- A wants to send datagram to B. A knows B’s IP address.
  - B’s MAC address not in A’s ARP table.

- A broadcasts ARP query packet, containing B's IP address
  - dest Ethernet address = FF-FF-FF-FF-FF-FF
  - all nodes on LAN receive ARP query, most ignore it

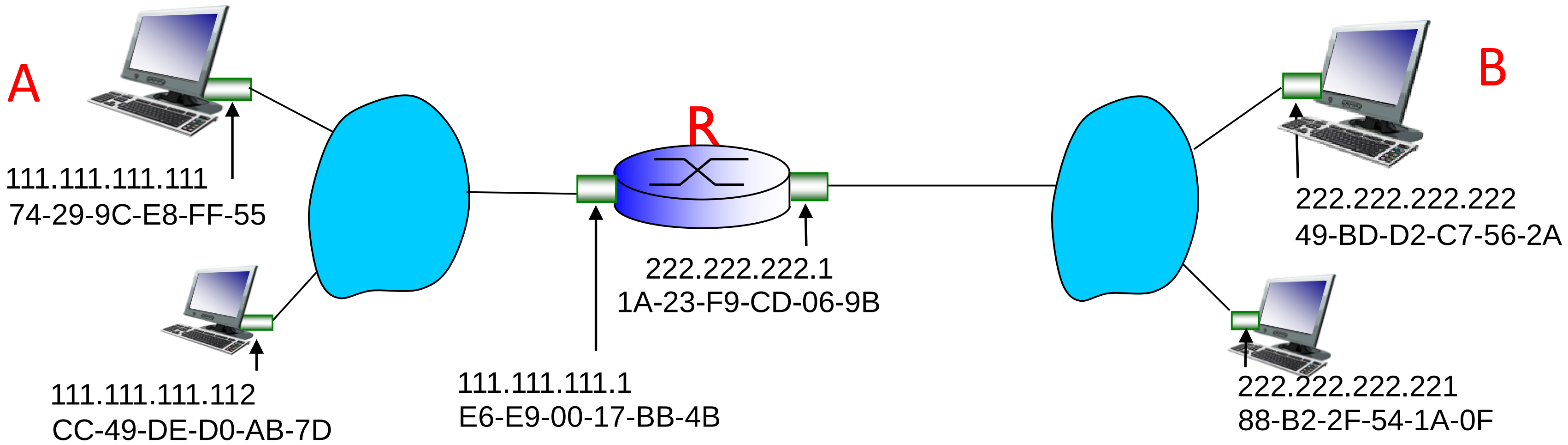
- B receives ARP packet, replies to A with its (B's) MAC address
  - frame sent to A’s MAC address (unicast)

- A caches IP-to-MAC address pair in its ARP table until timeout
  - soft state: times out unless refreshed, can be reacquired

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 (e.g., DNS lookup is done)
- Note: there's a router here, these are separate subnets

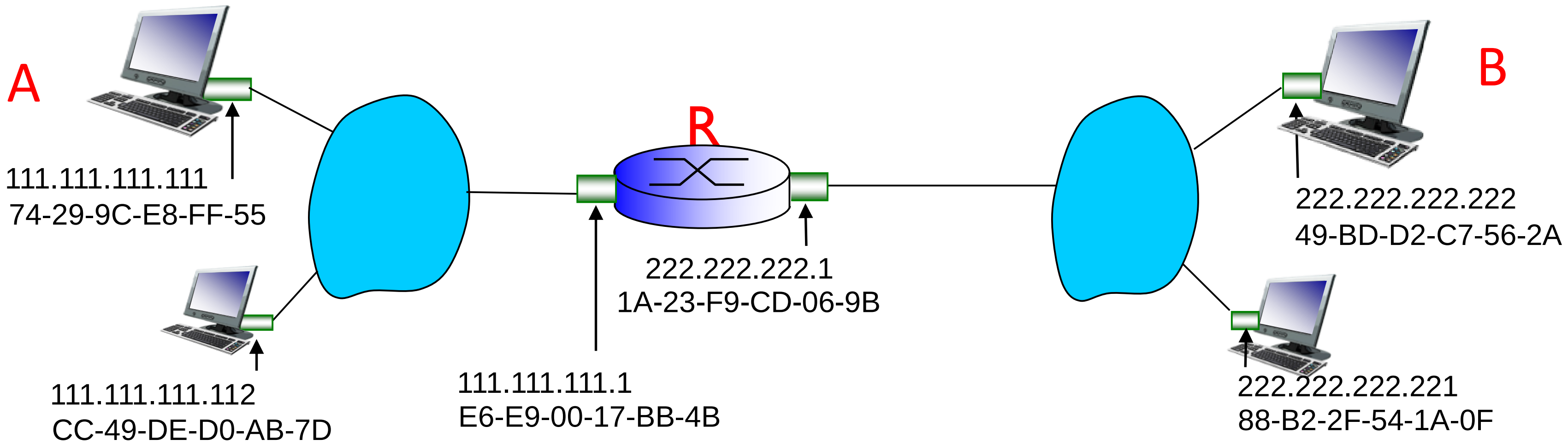


Addressing: routing to another LAN

Walkthrough: send datagram from A to B via R

- Who do we address the datagram to (IP destination)?

- Who do we forward it to on the first hop?



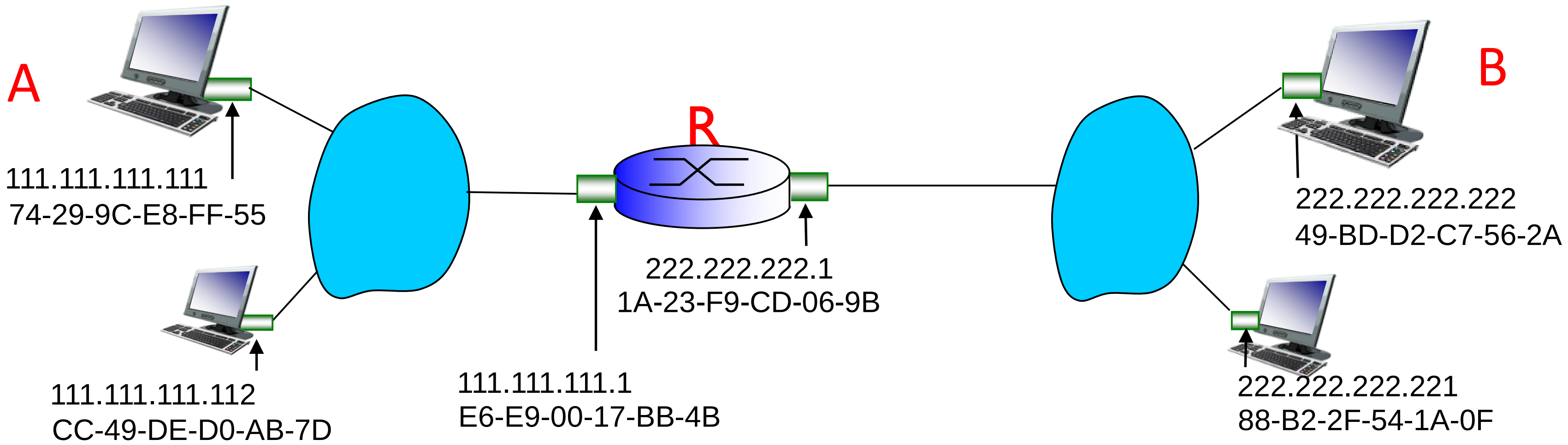
How does A learn the IP address of R?

A. ARP

B. DHCP

C. IP

D. Routing protocol



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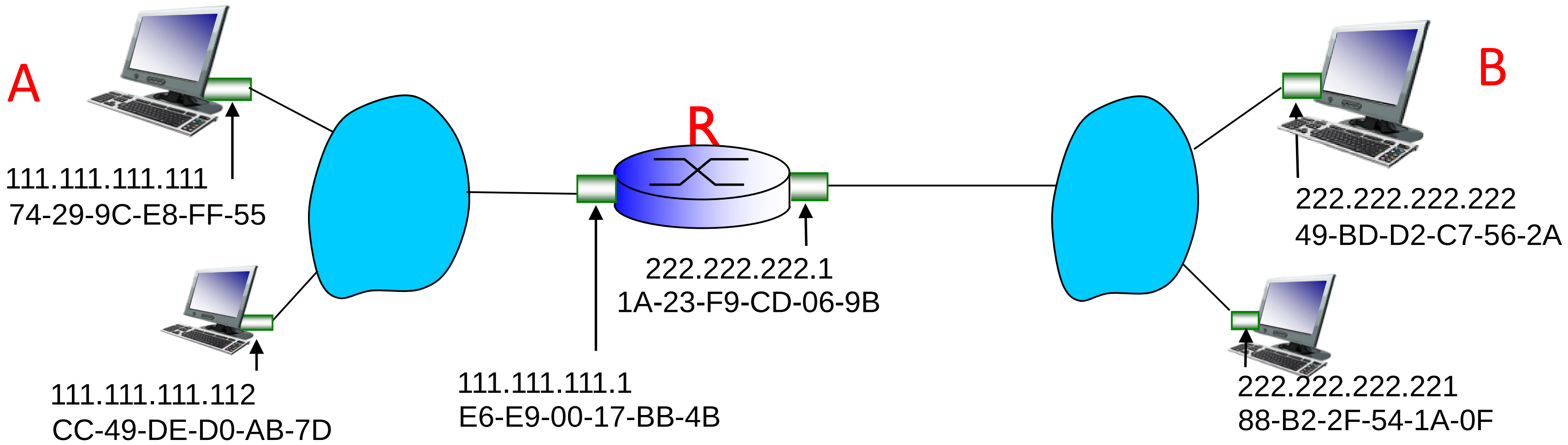
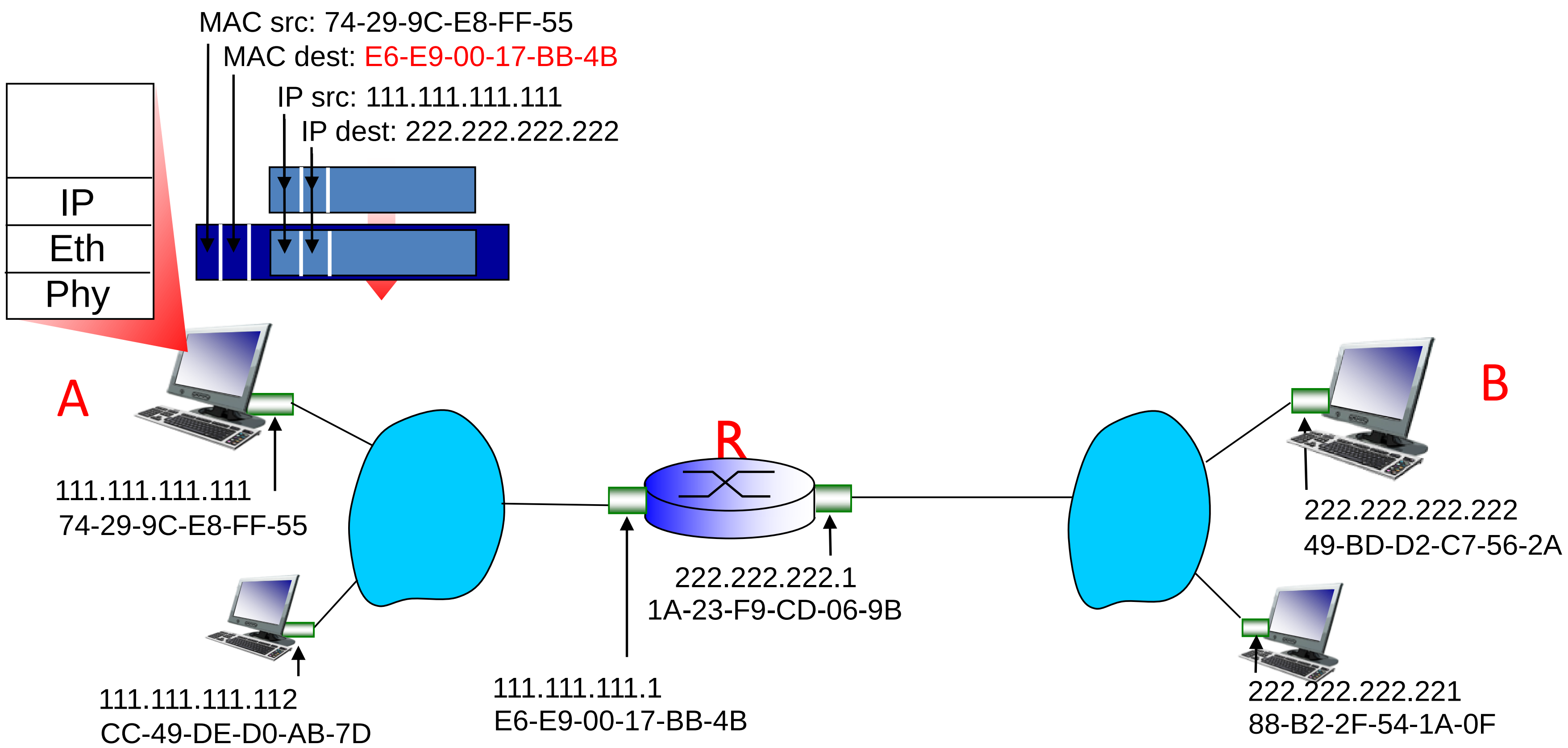


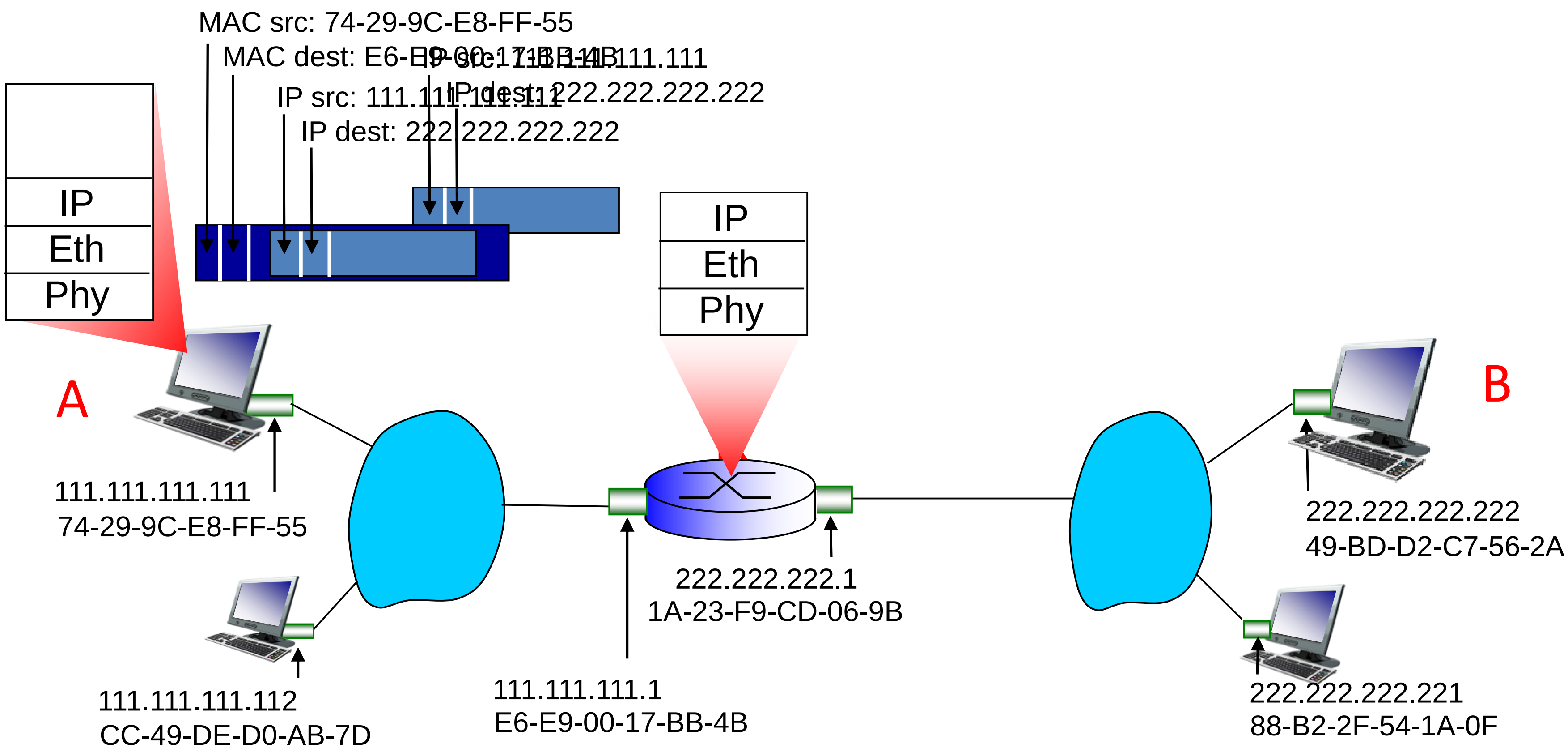
Addressing: routing to another LAN

- 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

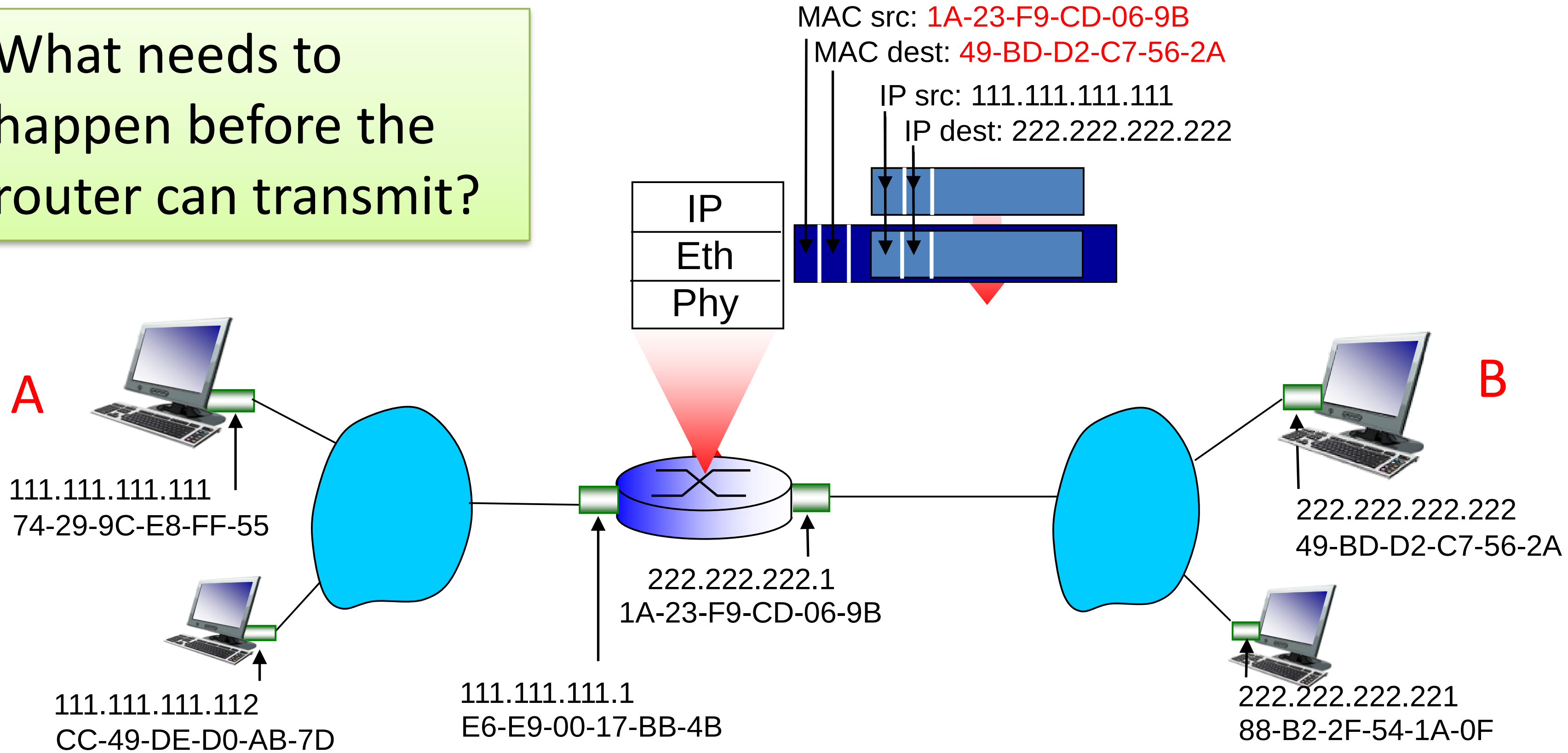
- frame sent from A to R
- frame received at R, datagram removed, passed up to IP



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

What needs to happen before the router can transmit?



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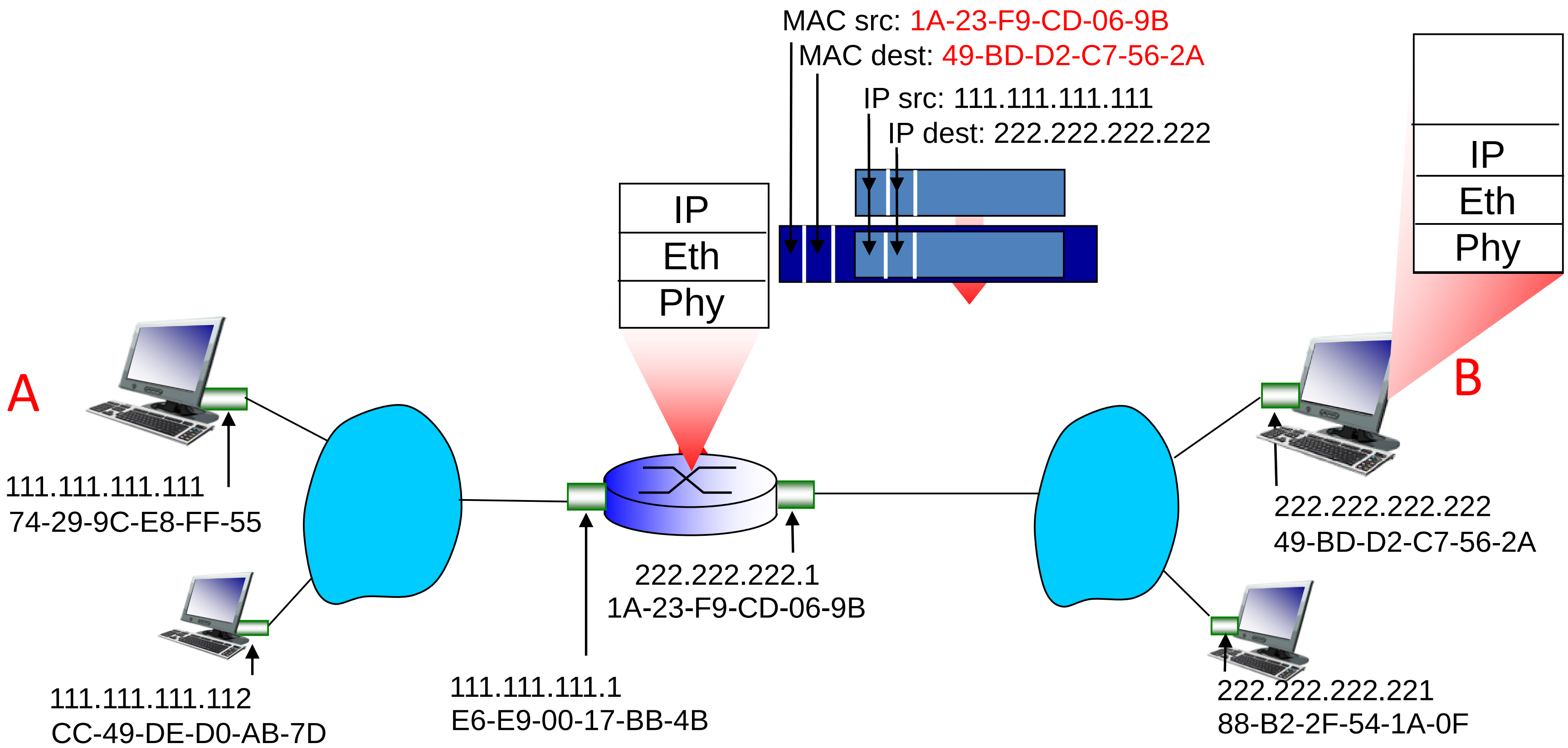

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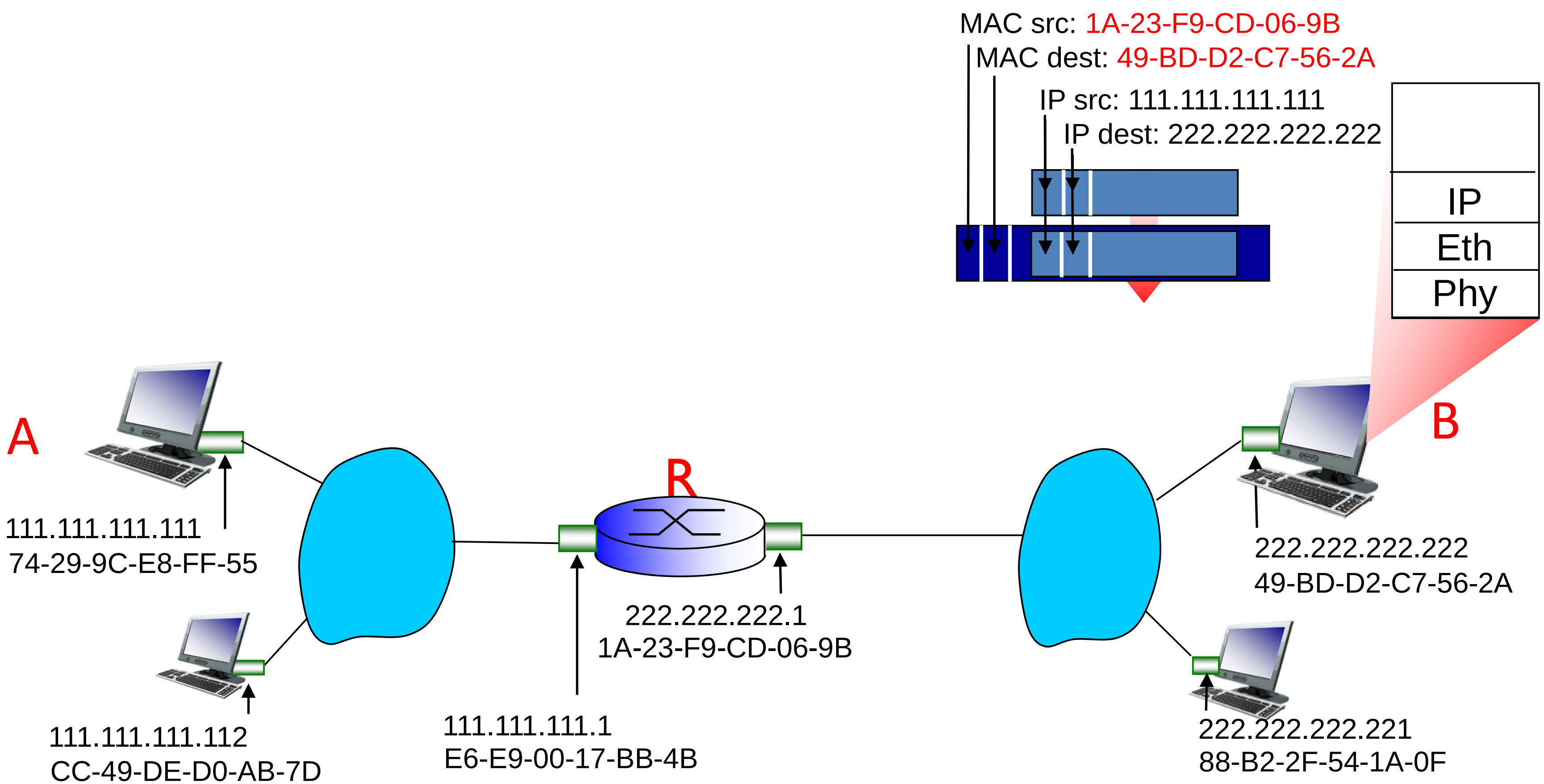
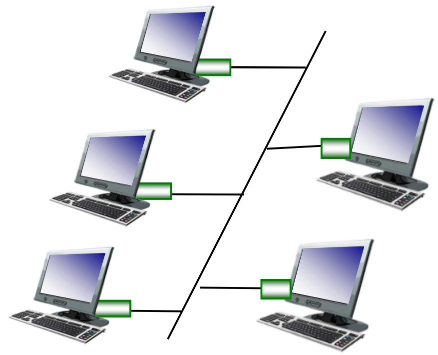
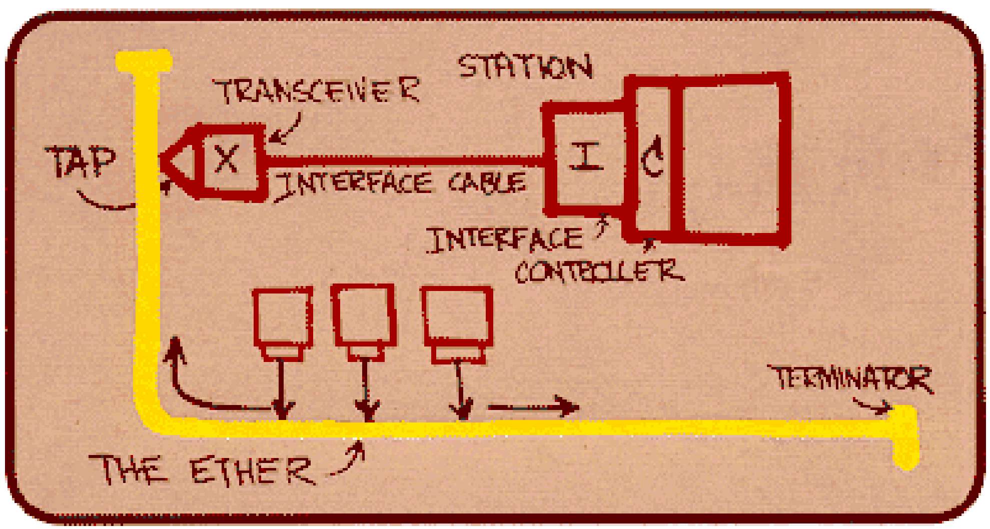


Physical Topology: Bus

- *Bus:* popular through mid 90s
  - all nodes in same collision domain (transmissions collide with each other)

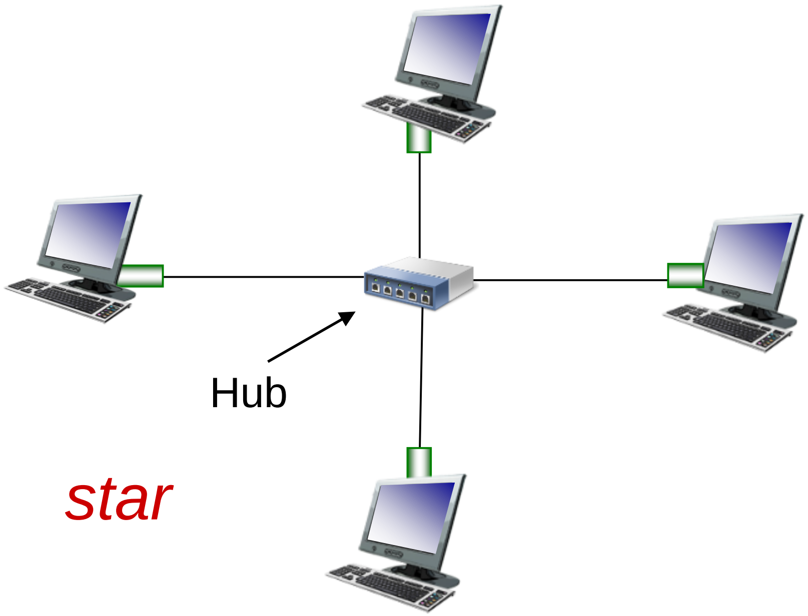


bus: coaxial cable



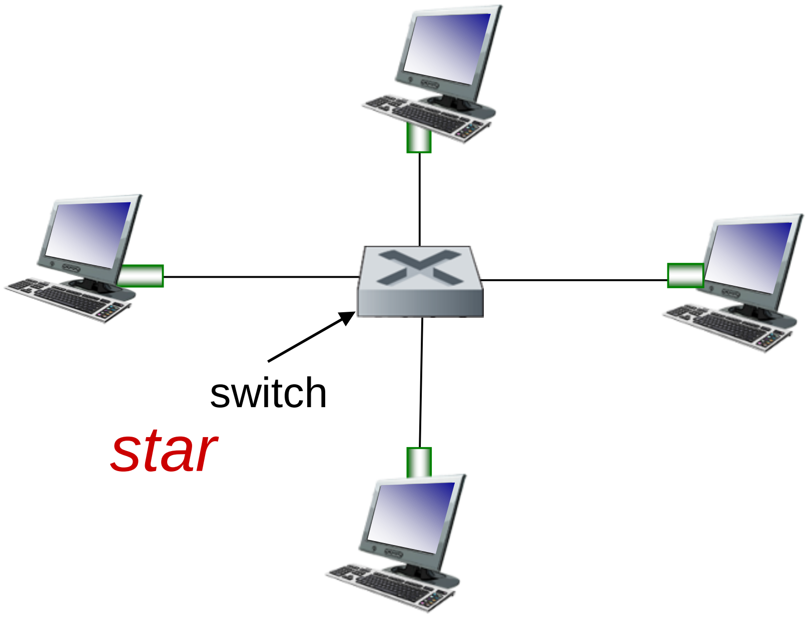
Physical Topology: Star

- *Hub* in the center:
  - broadcasts all messages to all hosts
  - retransmits on collisions
  - often considered a physical layer device (like a bus wire)

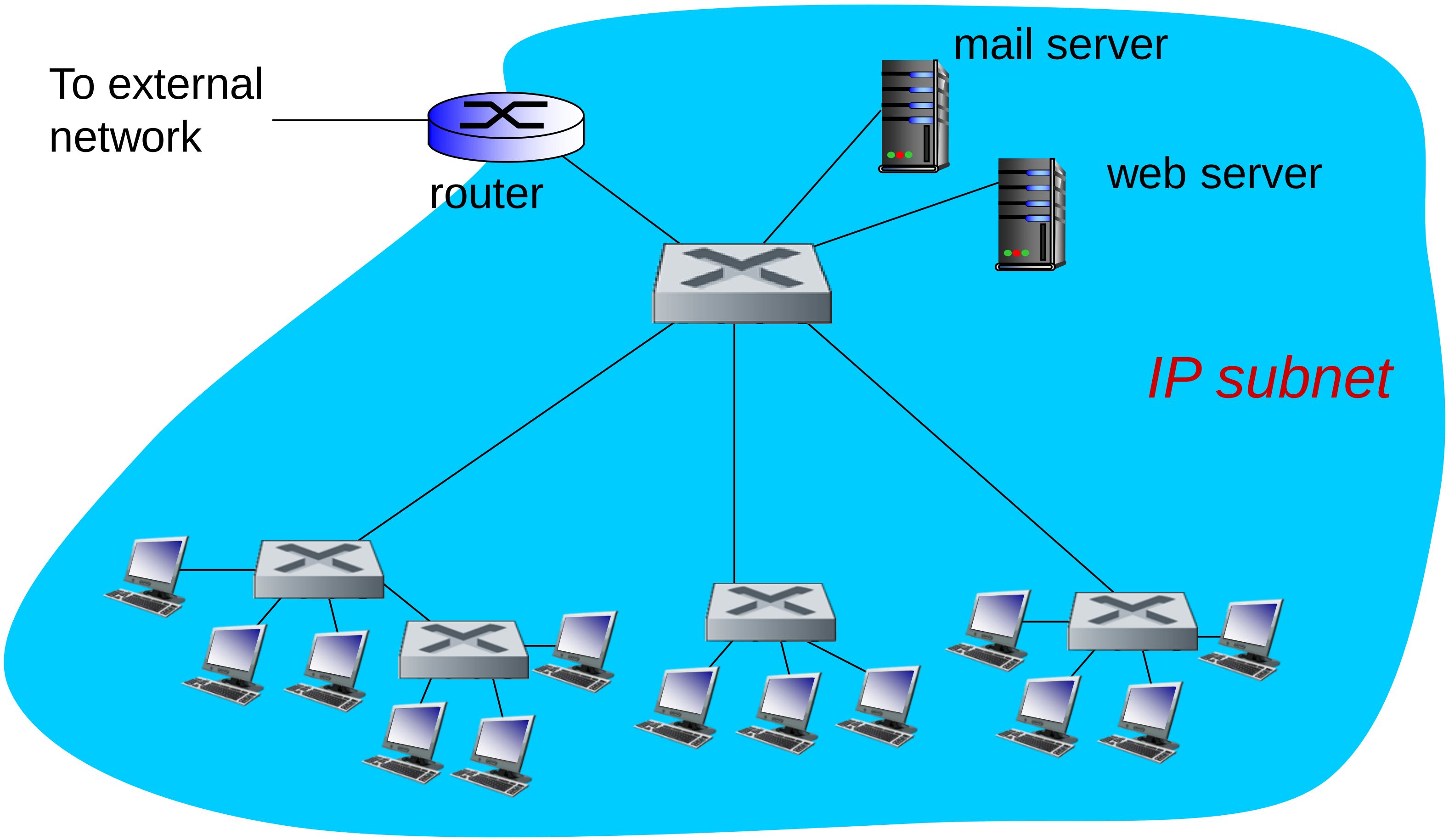


Physical Topology: Star (Switched)

- *Switch:* prevails today
  - each "spoke" runs a (separate) Ethernet protocol (nodes do not collide with each other)
  - Full duplex: No collisions on spoke



Institutional Network (Tree)

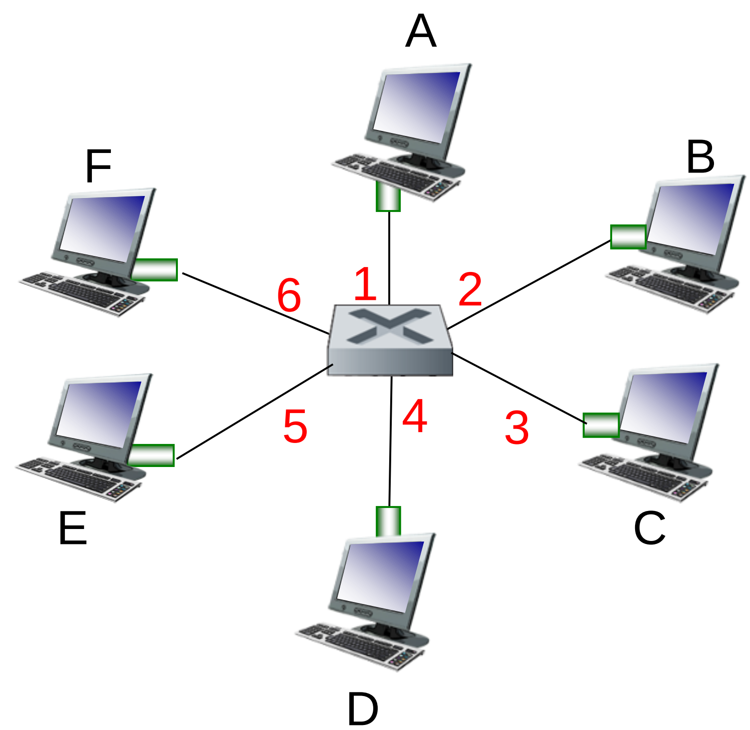


Ethernet switch

- link-layer device: takes an *active* role
  - store, forward Ethernet frames
  - examines incoming frame's MAC address, selectively forwards 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-D and B-to-E can transmit simultaneously, without collisions

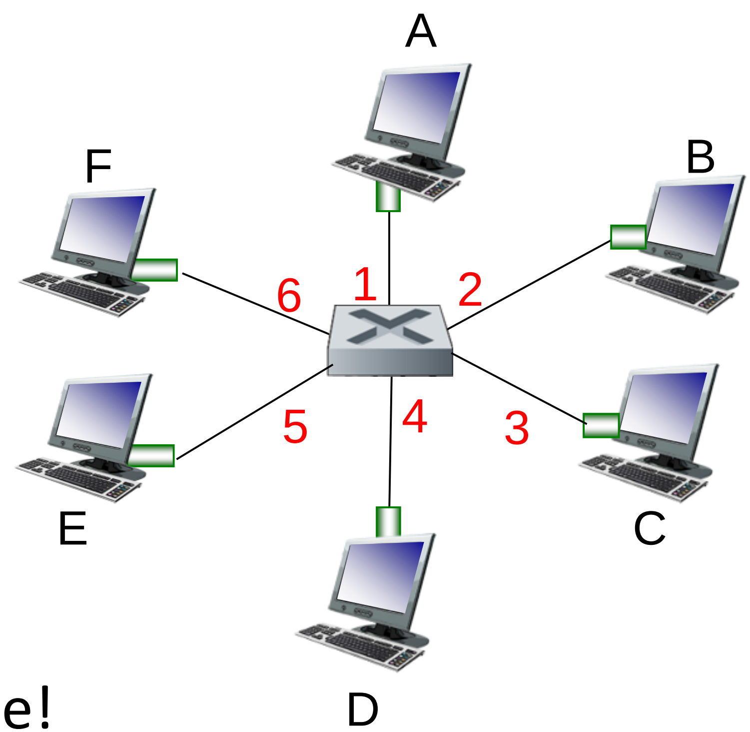


switch with six interfaces (1,2,3,4,5,6)

Switch forwarding table

Q: how does switch know D reachable via interface 4, E reachable via interface 5?

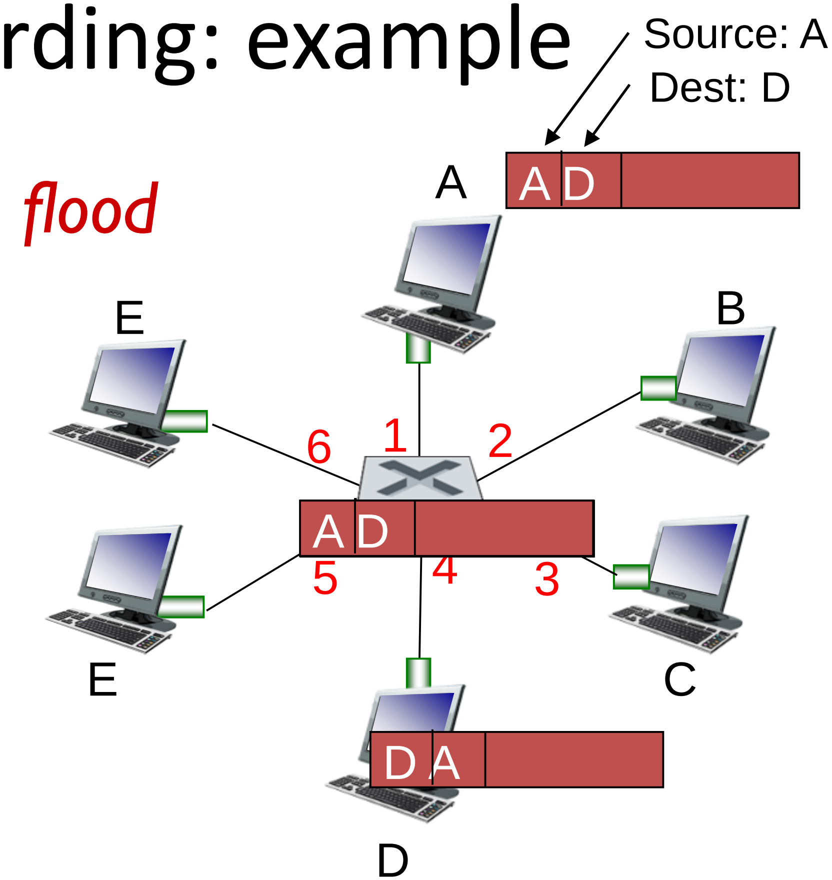
- A: each switch has a forwarding table, each entry:
  - (MAC address of host, interface to reach host, time stamp)
  - looks like a router's forwarding table!



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

Self-learning, forwarding: example

- frame destination, D, location unknown:
- destination A location known: selectively send on just one link



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

switch table (initially empty)

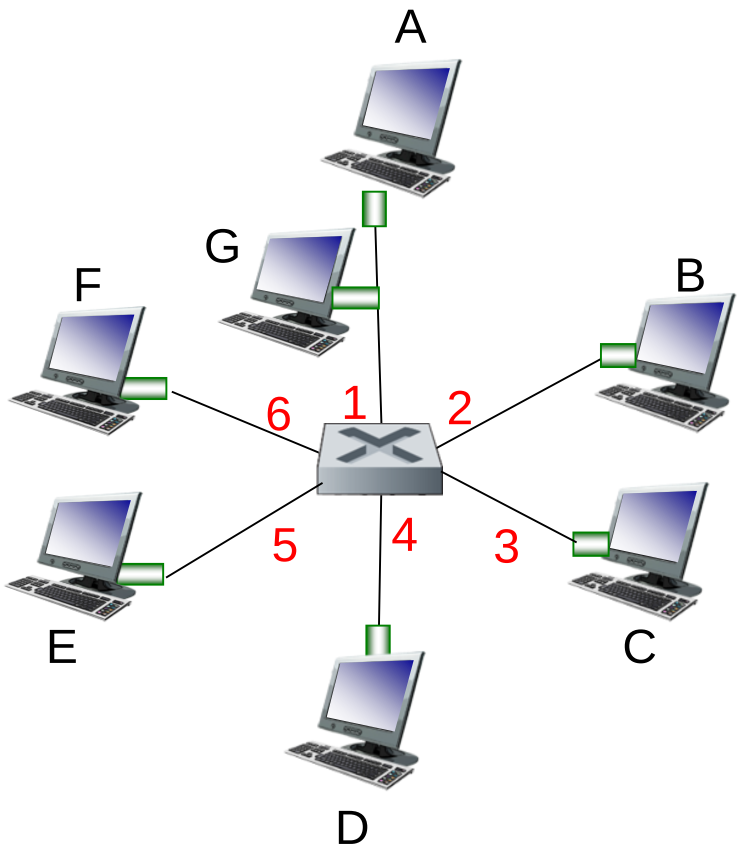
Suppose the switch receives a packet from A to G. (Assume it knows what interface both A and G are on.) It should…

A. Flood the packet

B. Throw the packet away

C. Send the packet out on interface 1

D. Do something else



Switch: frame filtering/forwarding

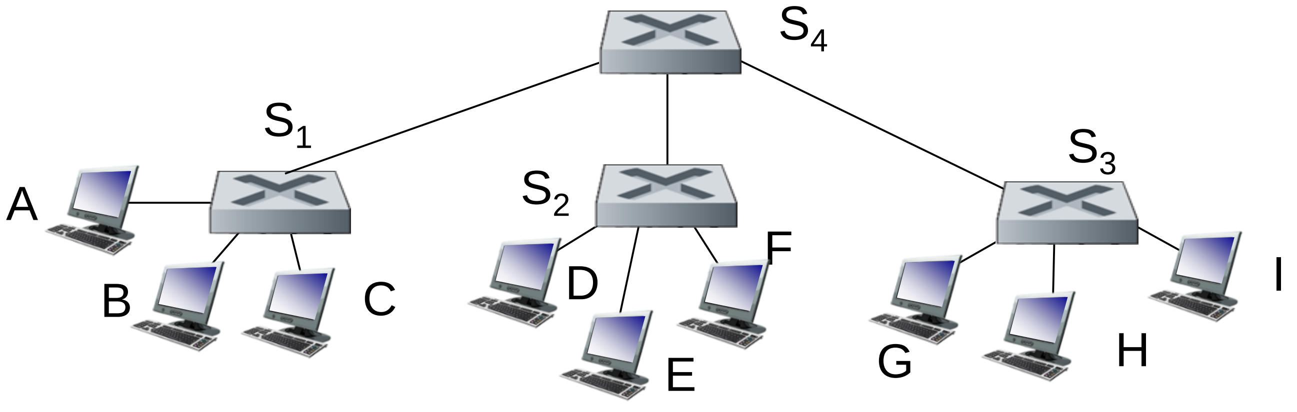
when frame received at switch:

1. record incoming link, MAC address of sending host
2. index switch table using MAC destination address
3. if entry found for destination {

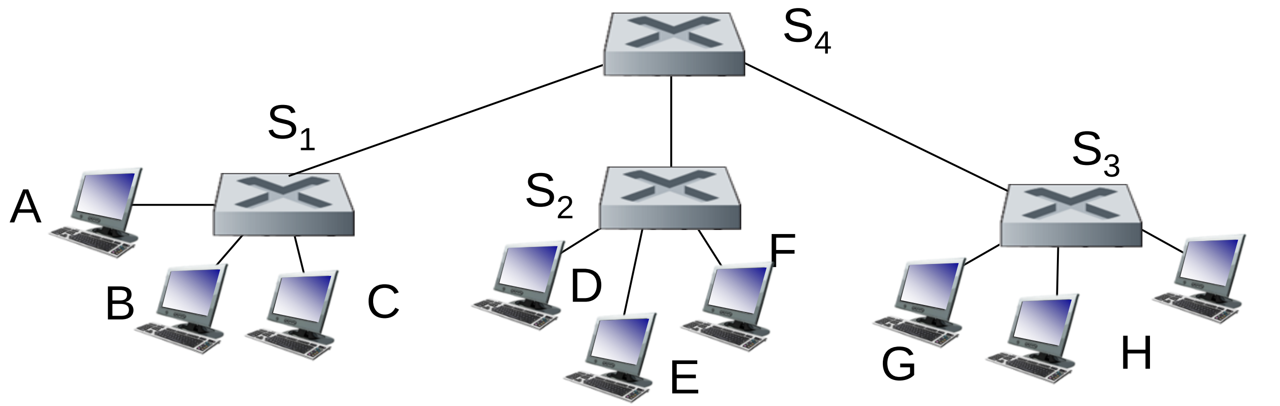
```
    if destination on segment from which frame arrived
        drop frame
    else
        forward frame on interface indicated by entry
    }
  else flood  /* forward on all interfaces except arriving
                 interface */
```

Interconnecting switches

- Switches often connected to form trees.



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



A. A network administrator will need to configure this.

B. S_1 will automatically learn the entire path.

C. S_1 will learn to send packets to G on the interface that leads to S_4.

Eve wants to snoop and read all of the frames being sent to anyone on the LAN. She will NOT be able to do this on a

A. Bus

B. Hub

C. Switch

D. She can do this on all of these

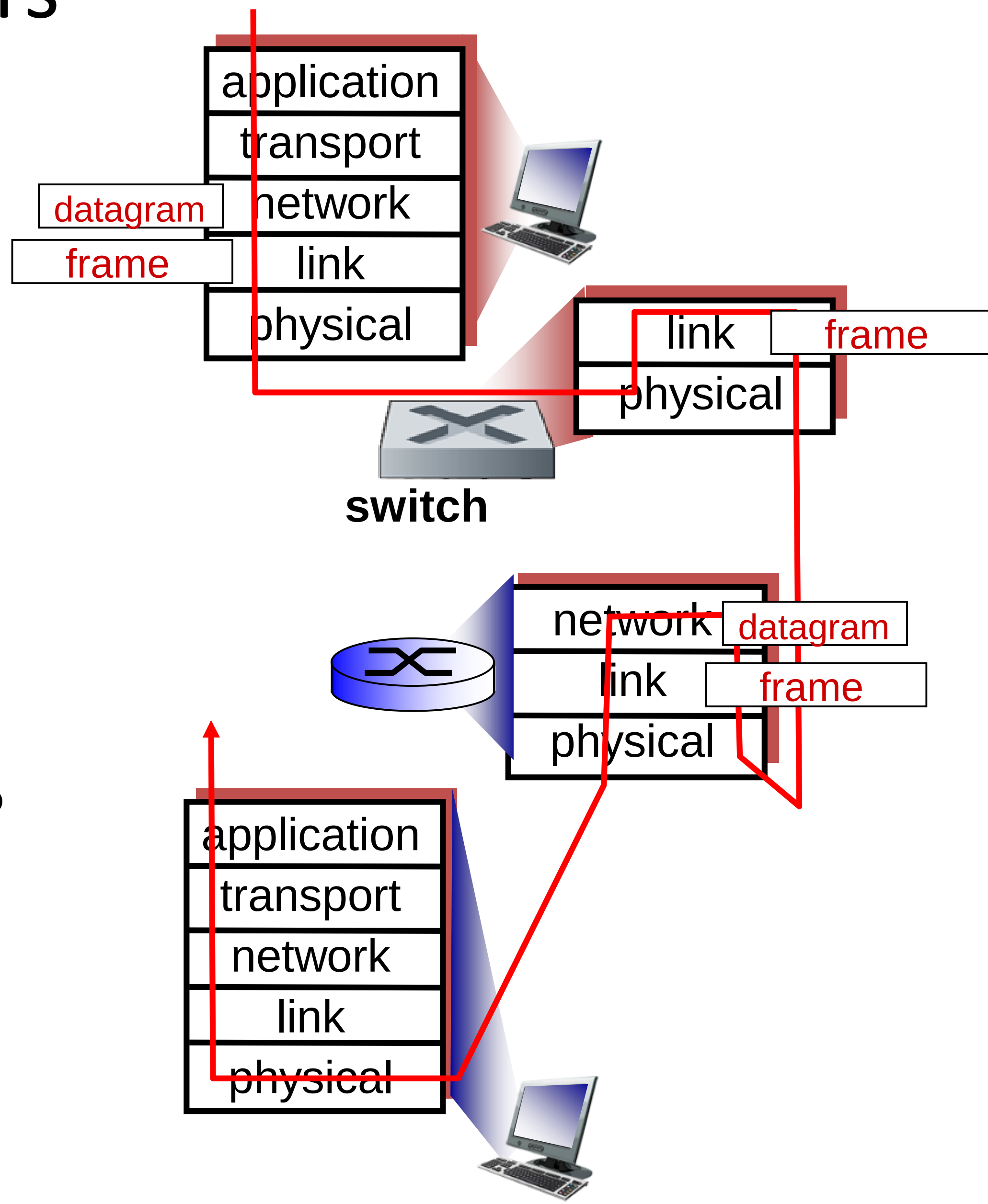
Switches vs. routers

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

Switches do NOT run a complex coordination protocol like routing.

both have forwarding tables:

- *routers:* compute tables using routing algorithms, IP addresses
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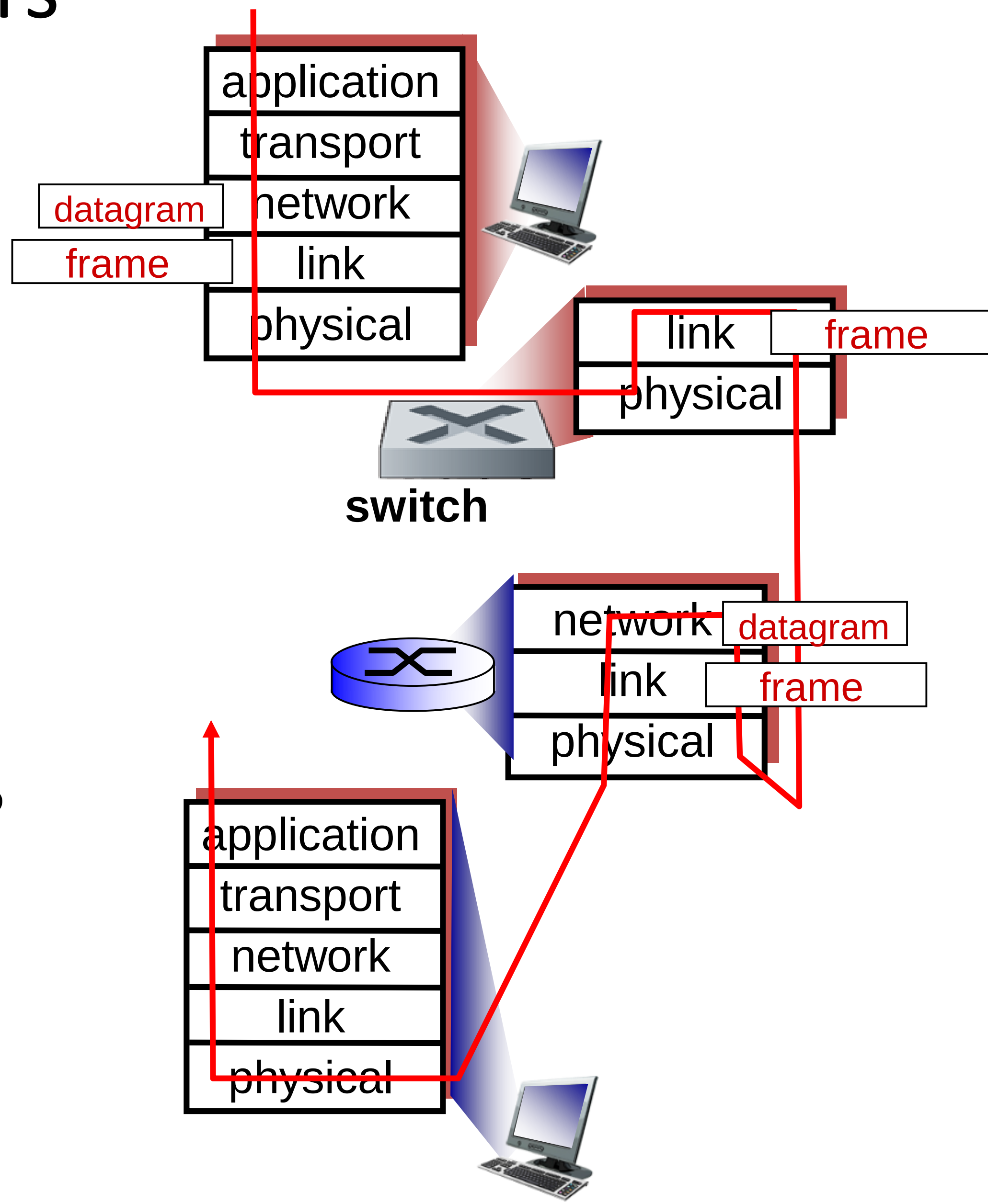

Summary

- LAN address: flat (vs. hierarchical IP)
- Many potential topologies:
  – Bus: shared wire, star (hub)
  – Switched: star, tree
- Switches learn who is connected, selectively forward toward destination