CS 43: Computer Networks
Switches and LANs

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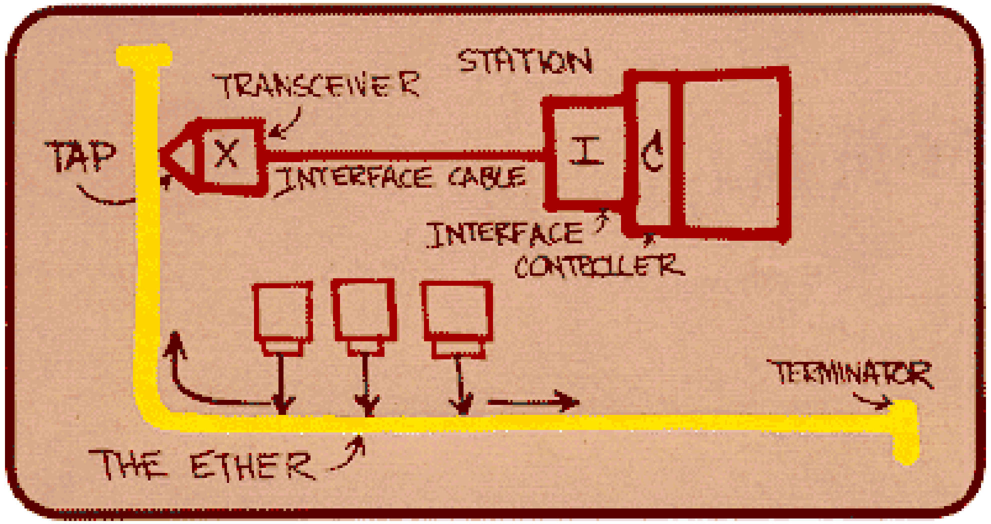
Ethernet



Metcalfe’s Ethernet sketch

“Dominant” wired LAN technology:

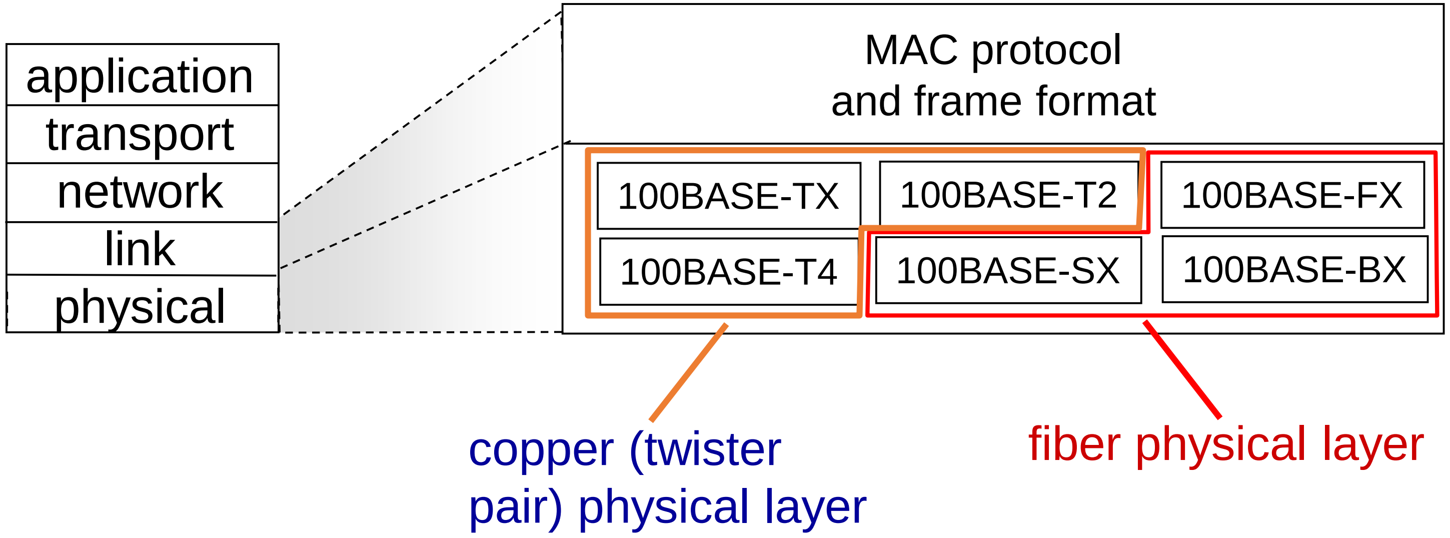
- cheap $20 for NIC
- first widely used LAN technology
- simpler, cheaper than token LANs and ATM
- kept up with speed race: 10 Mbps – 10 Gbps

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*

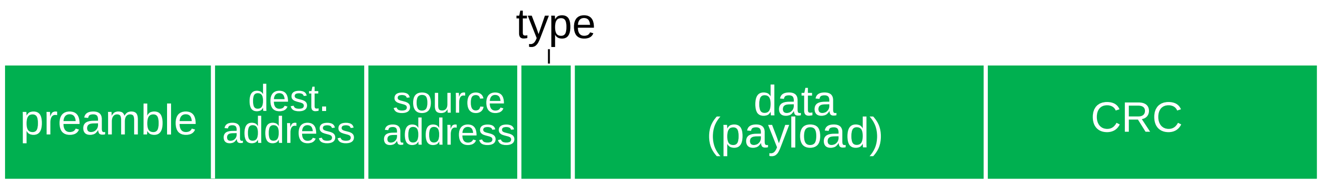
802.3 Ethernet standards: link & physical layers

- *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

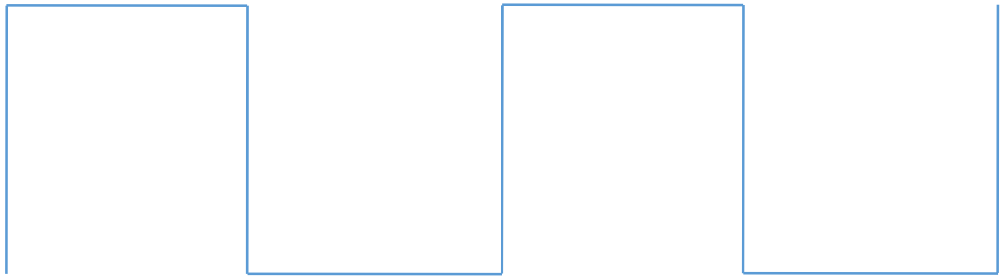


preamble:

- 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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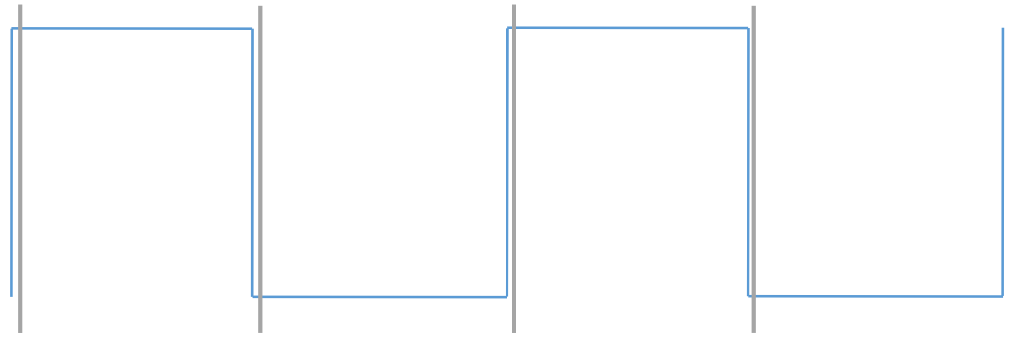

Ideal receiver: Sample signal at regular interval.

For 1 Gbps Ethernet, ~1 nanosecond interval.

Clock Synching

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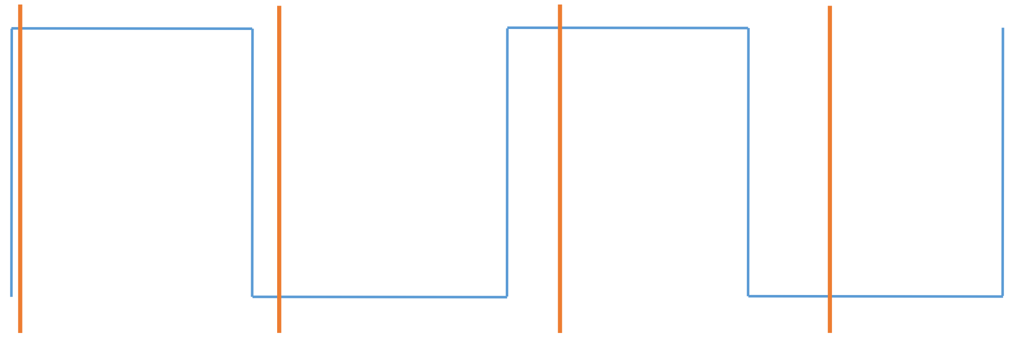
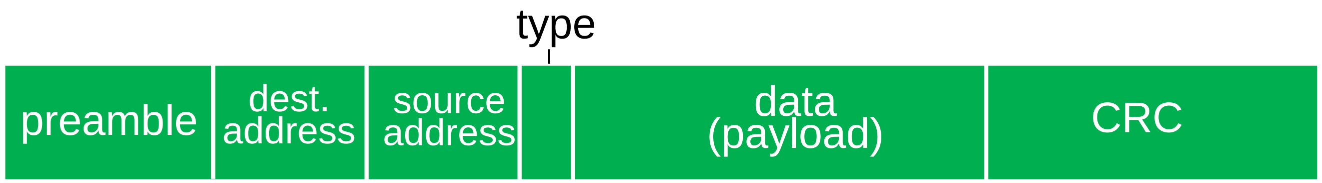


Problem: receiver clock may not agree with sender!

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



MAC Addresses

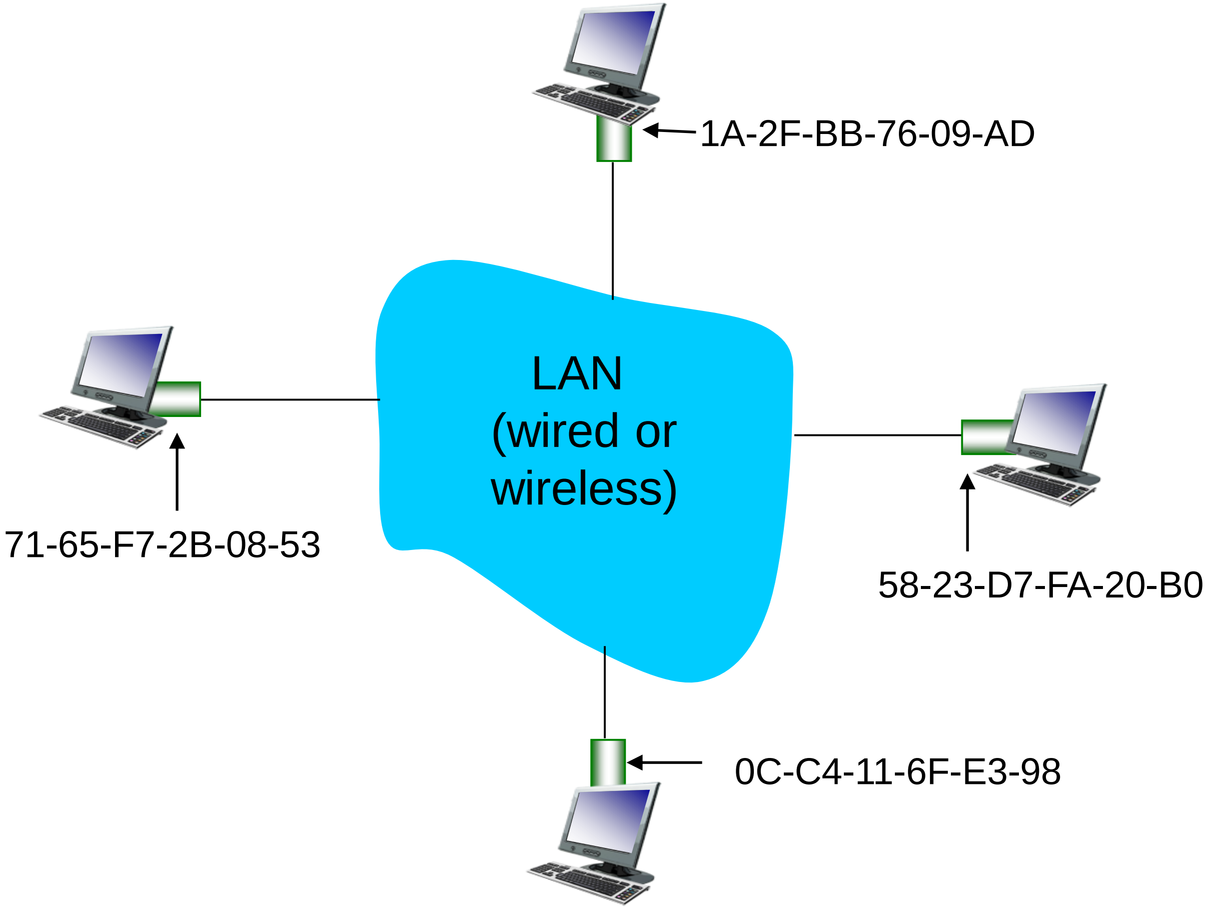
- 32-bit IP address:
  - *network-layer* address for interface
  - used by network layer for end-to-end routing

- 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



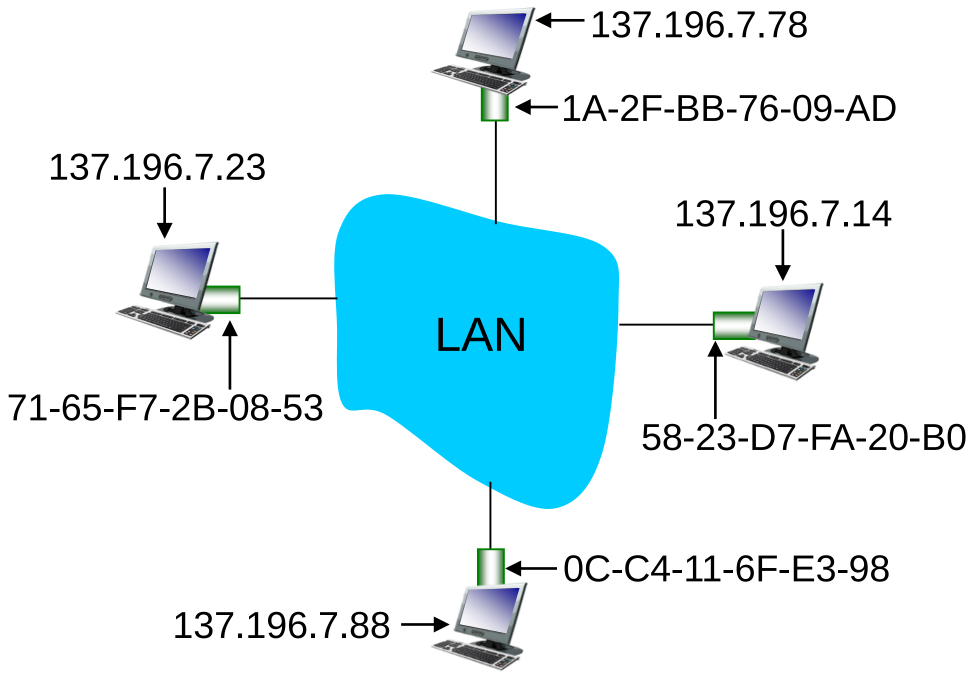
▯ network interface card (NIC) / adapter

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 keeps a 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 an IP packet 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
    - destination 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)

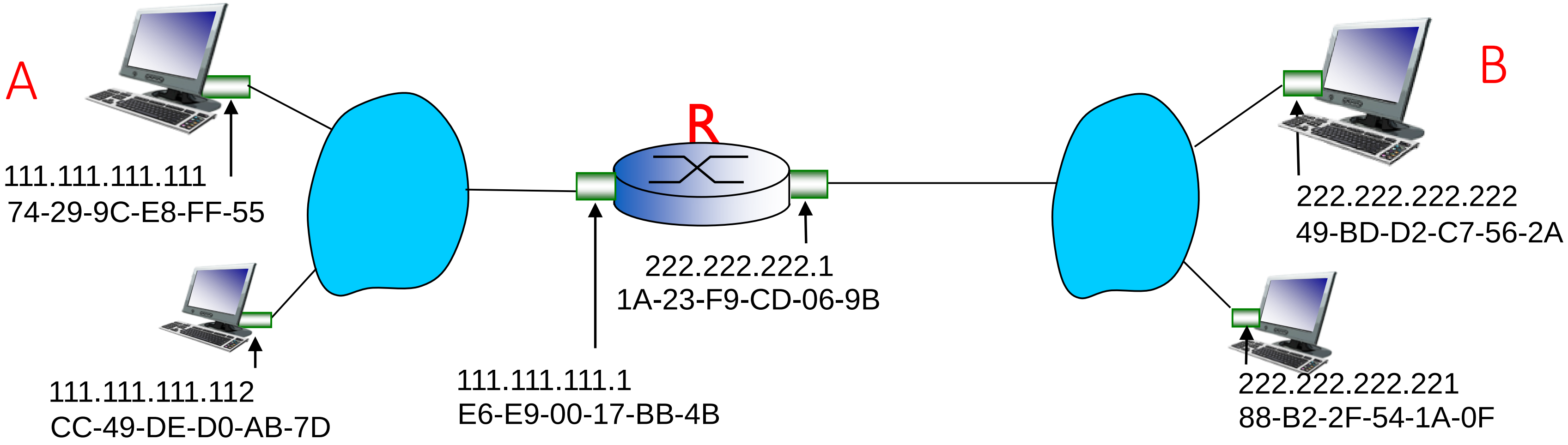
- A caches IP-to-MAC address pair in its ARP table until timeout
    - soft state / "hint": times out unless refreshed, can be reacquired

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

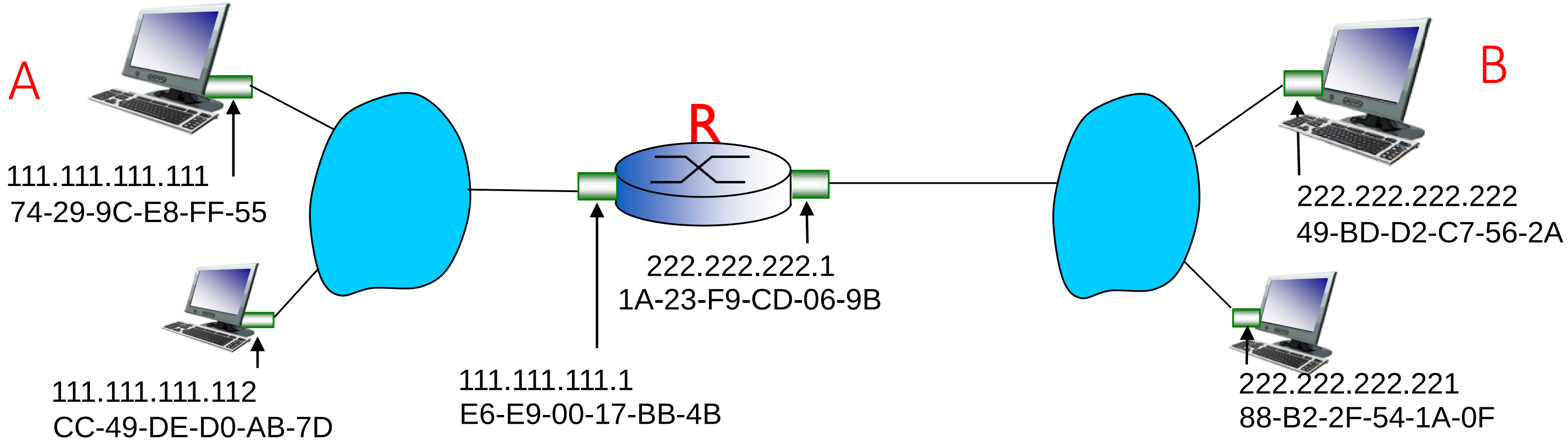


Addressing: routing to another LAN

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?



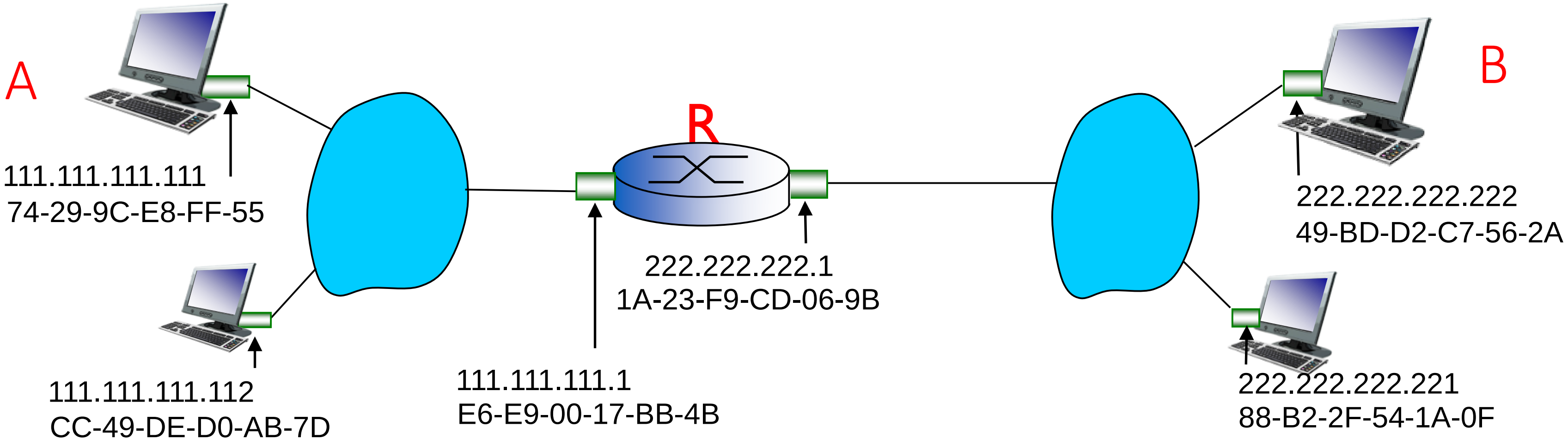
How does A learn the IP address of R?

A. ARP

B. DHCP

C. IP

D. Routing protocol



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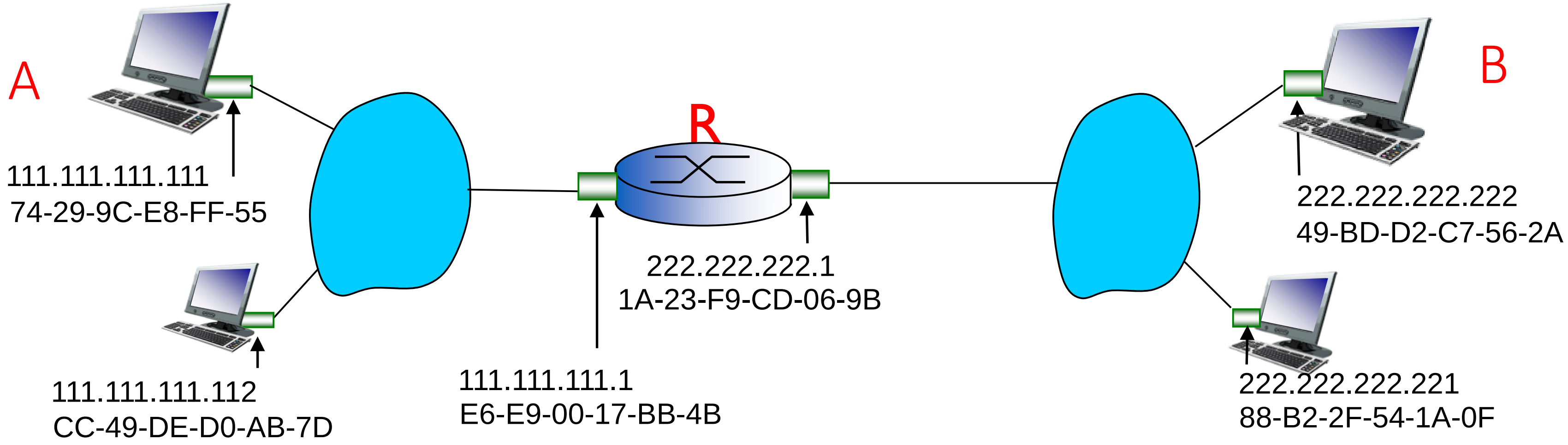
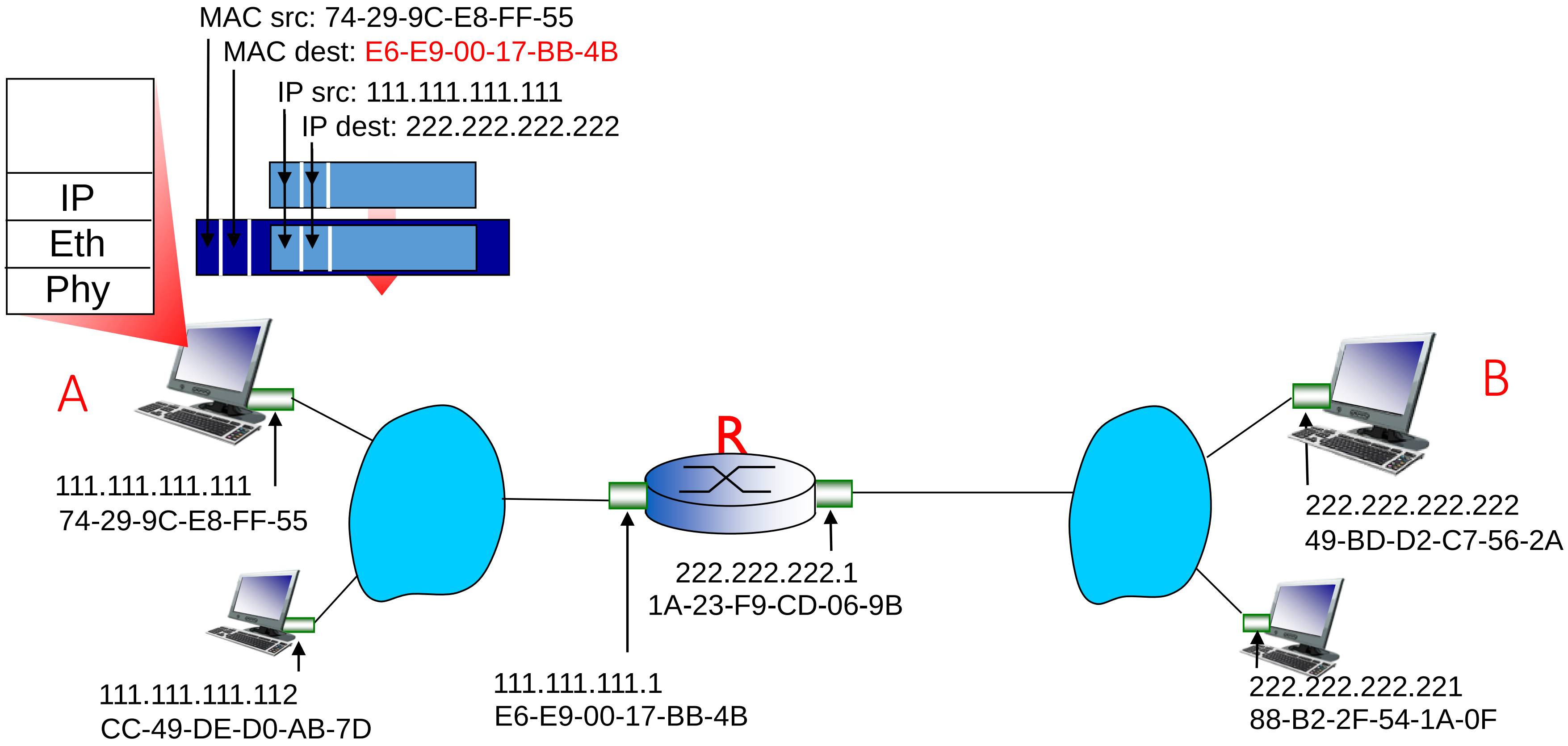


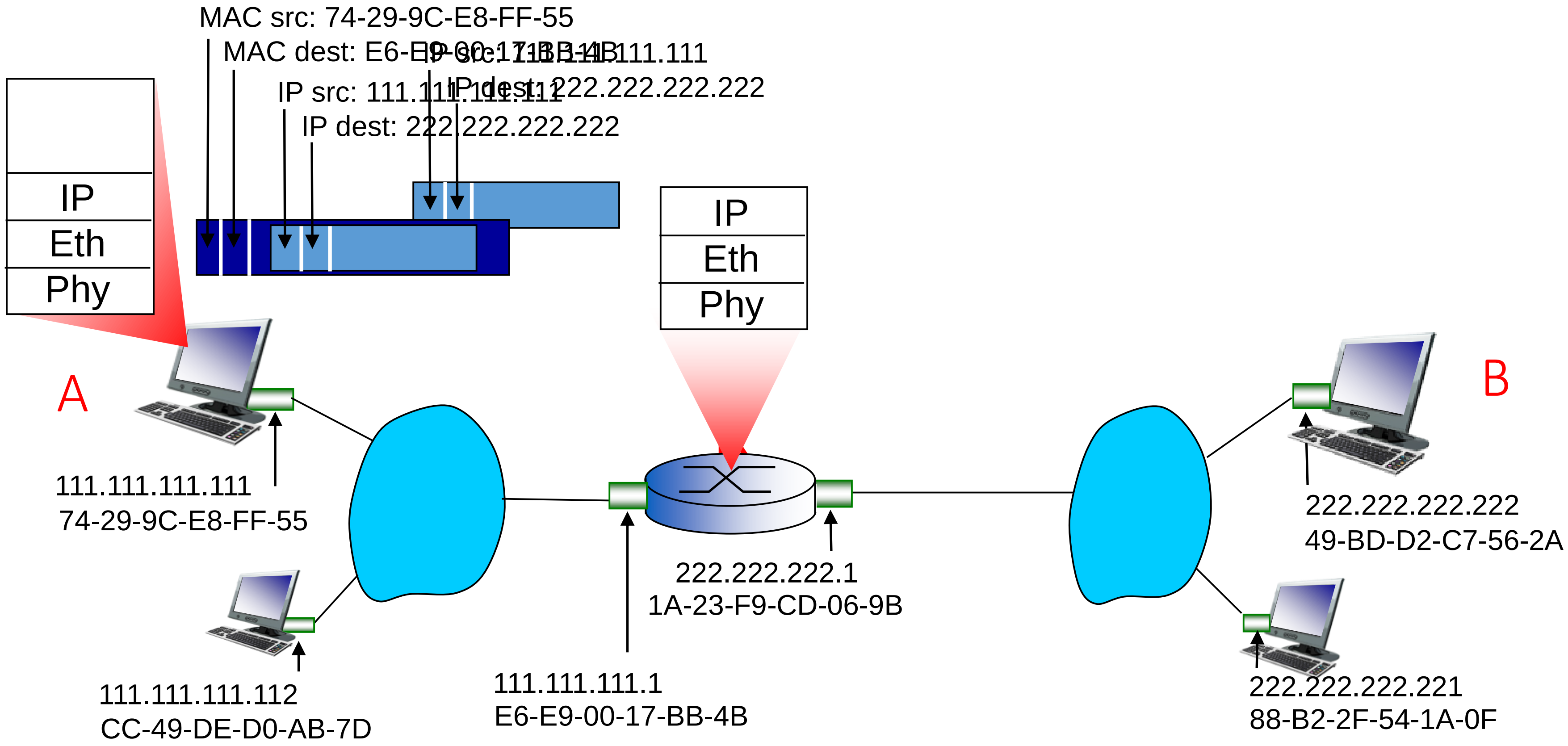
Addressing: routing to another LAN

- 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

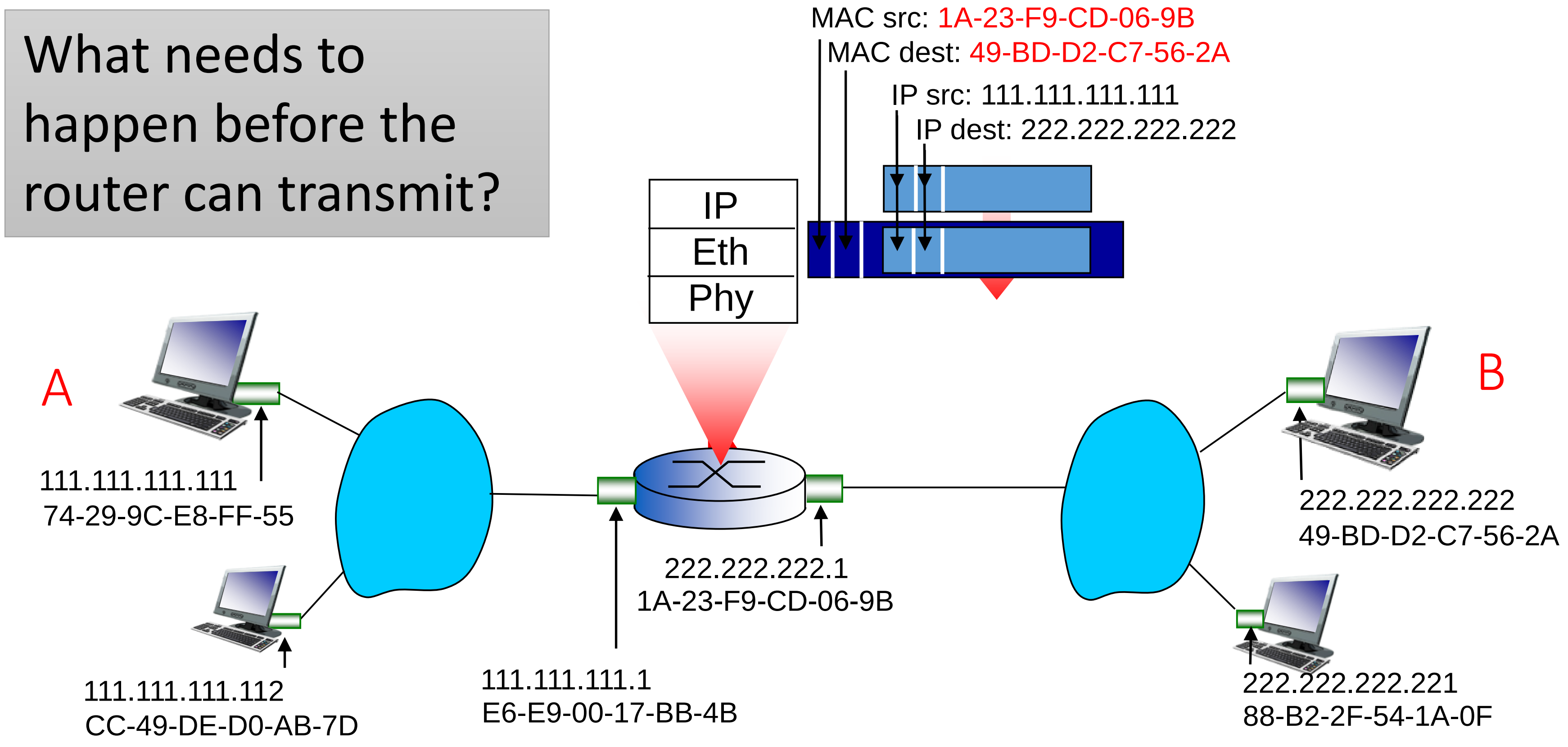
- frame sent from A to R
- frame received at R, datagram removed, passed up to IP



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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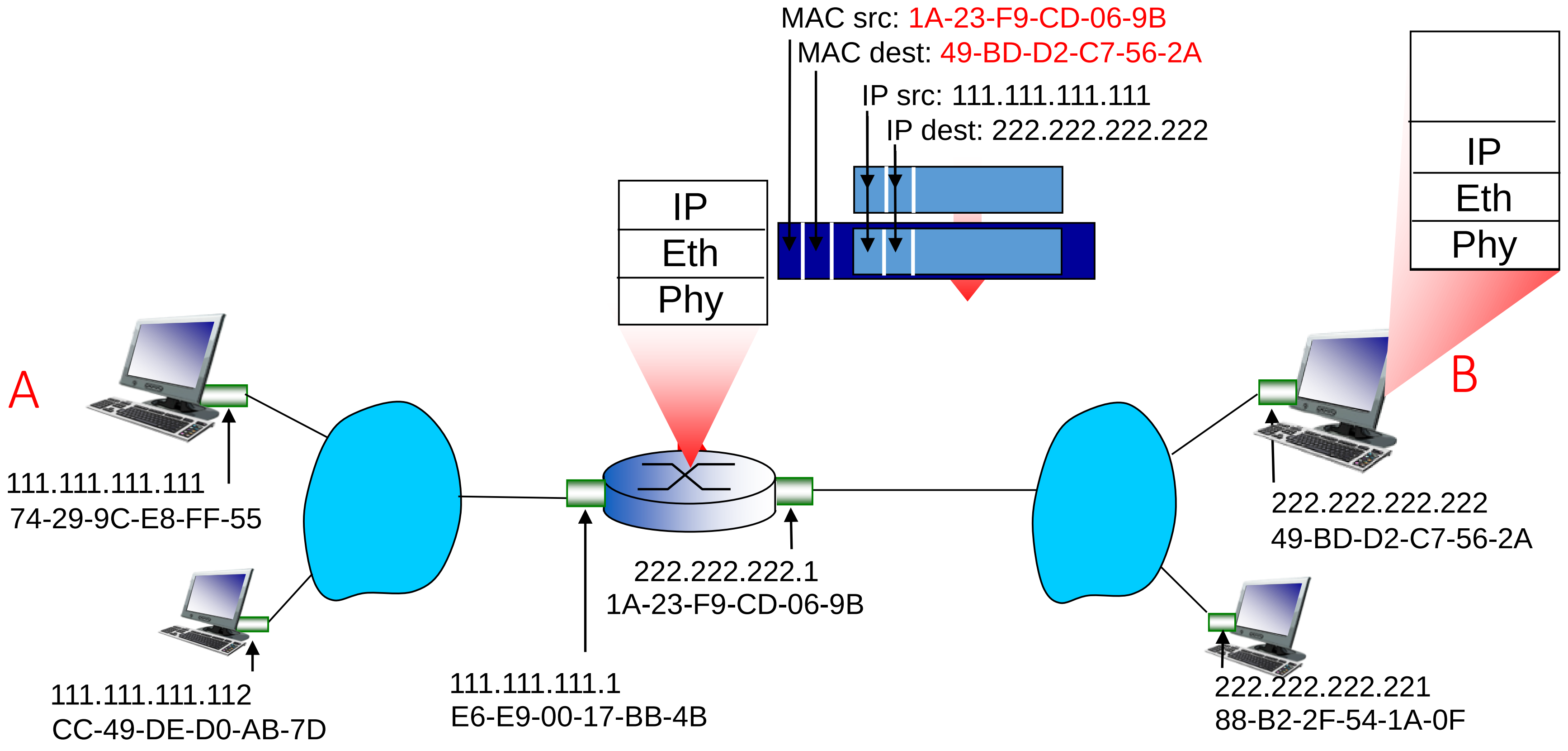

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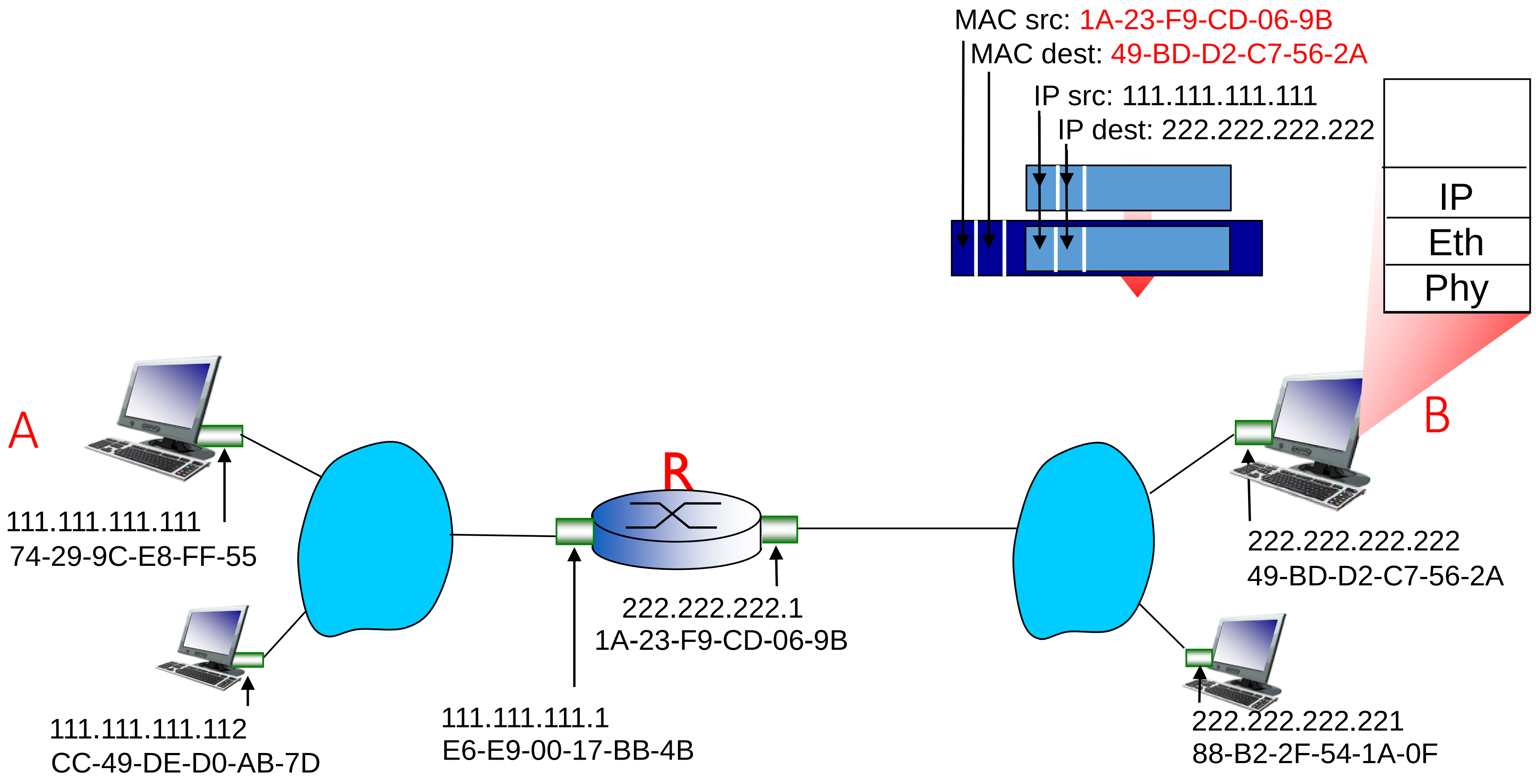
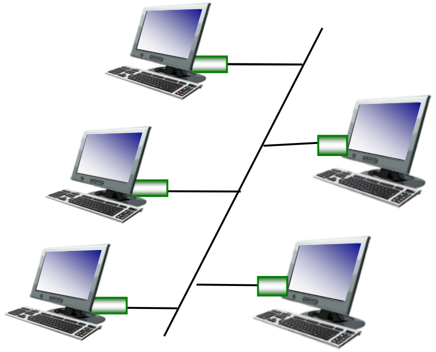
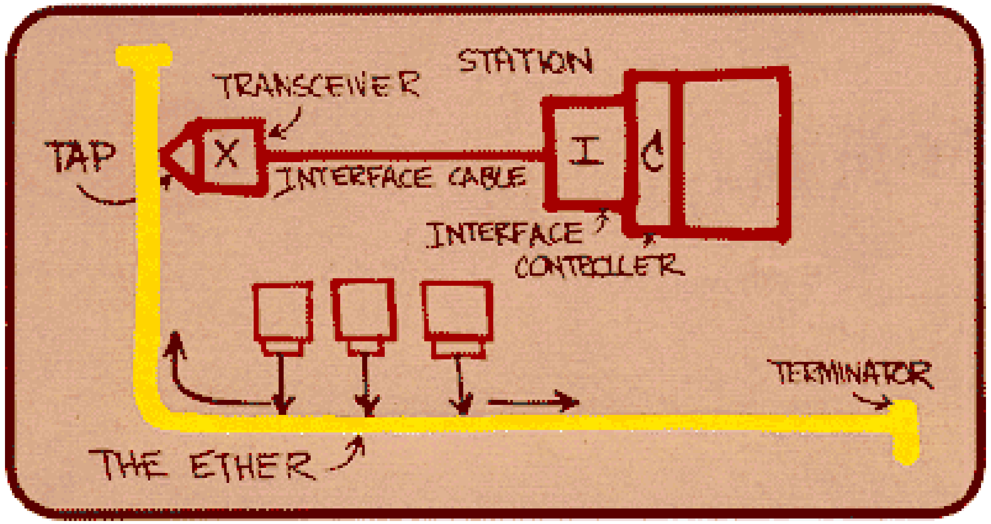


Physical Topology: Bus

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

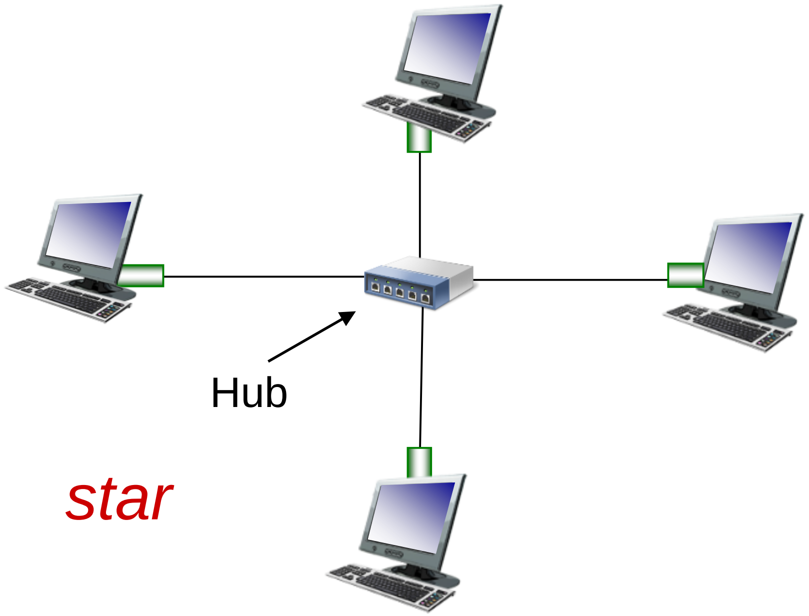


bus: coaxial cable



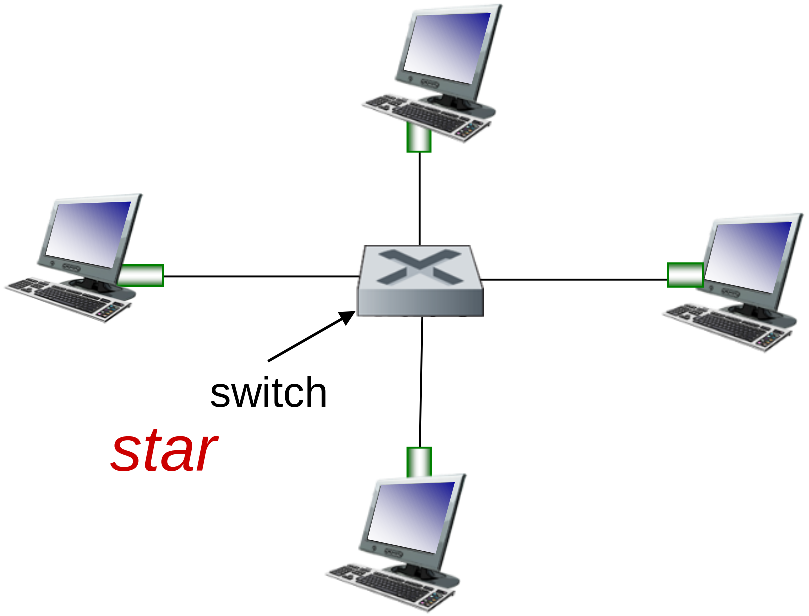
Physical Topology: Star

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

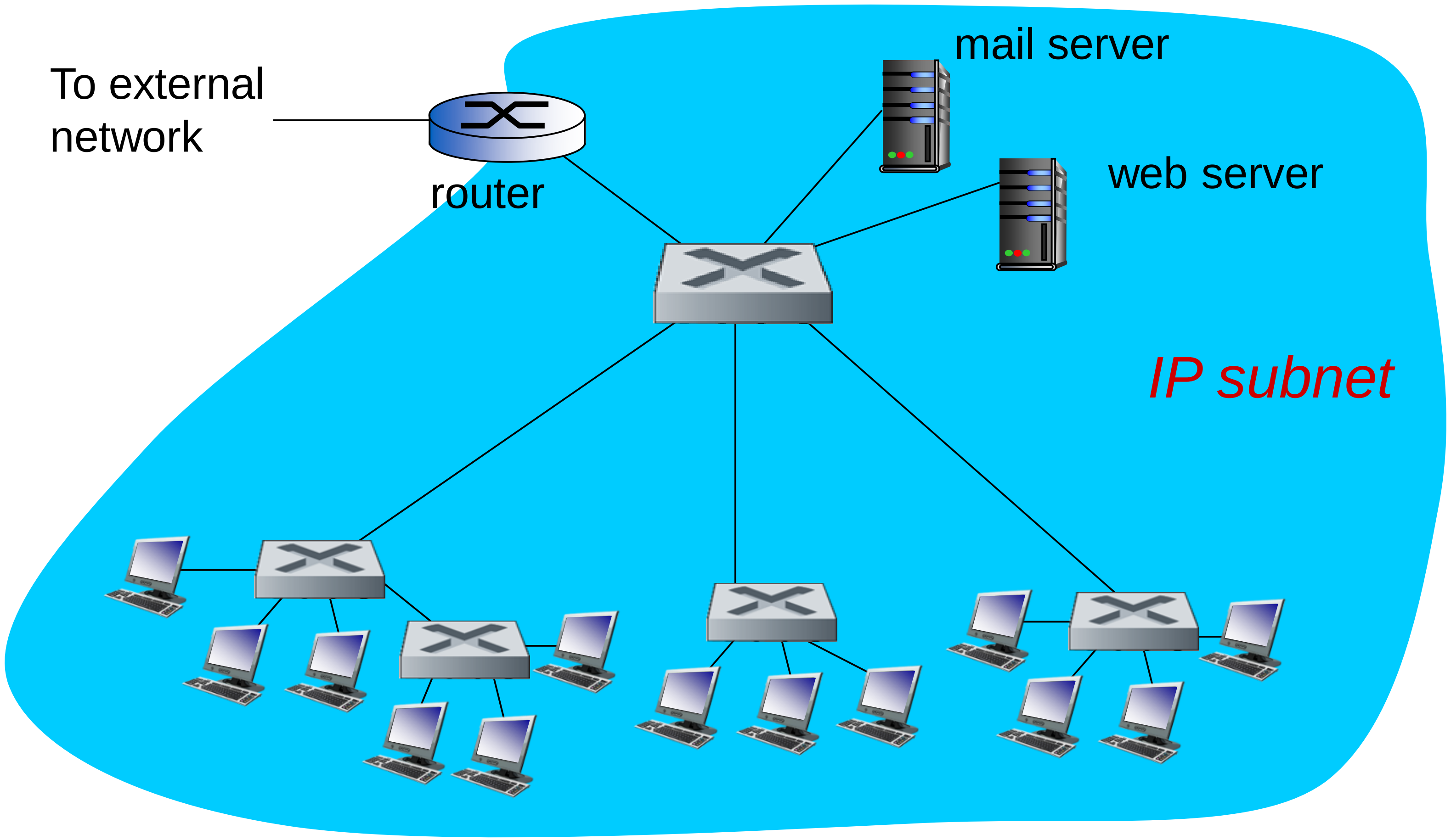


Physical Topology: Star (Switched)

- *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)

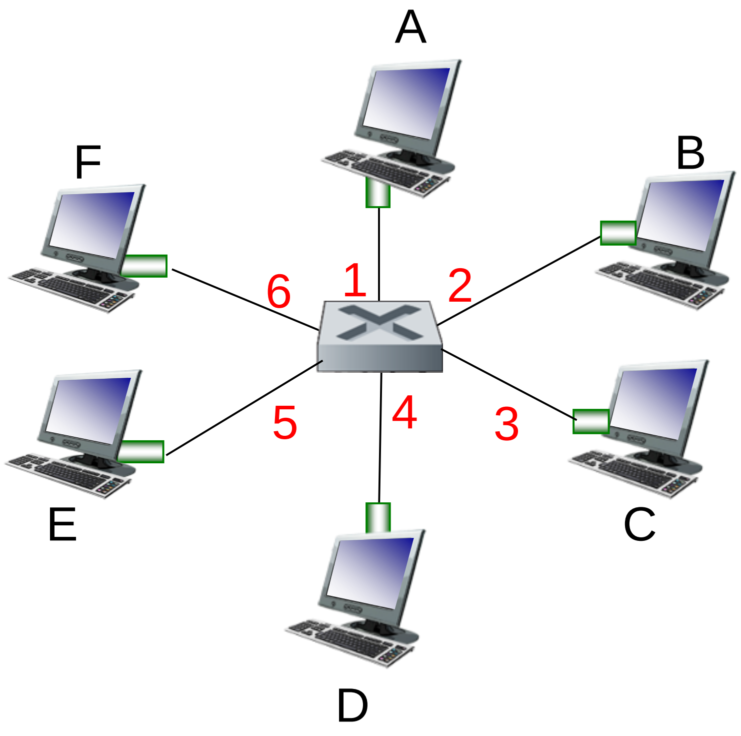


Ethernet switch

- 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

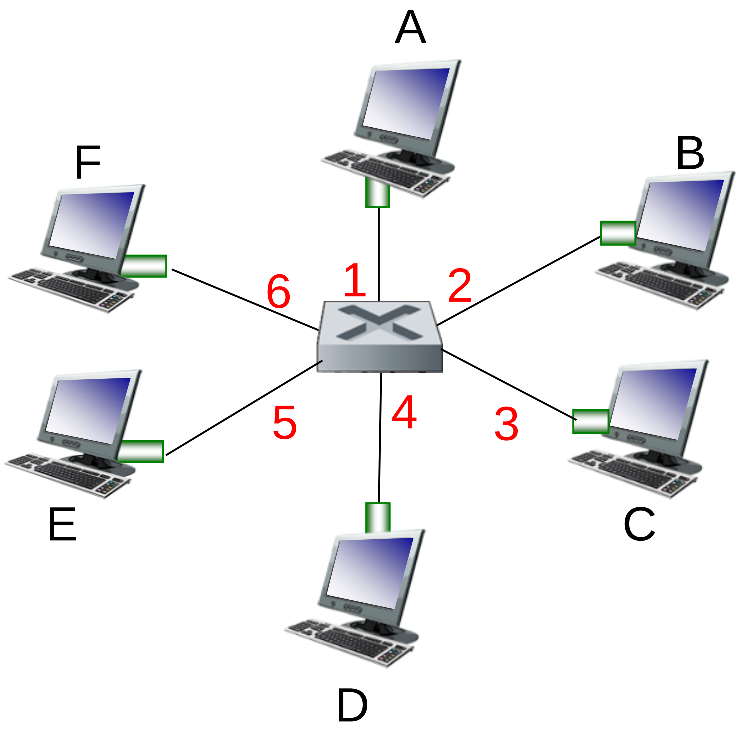


switch with six interfaces (1,2,3,4,5,6)

Switch forwarding table

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

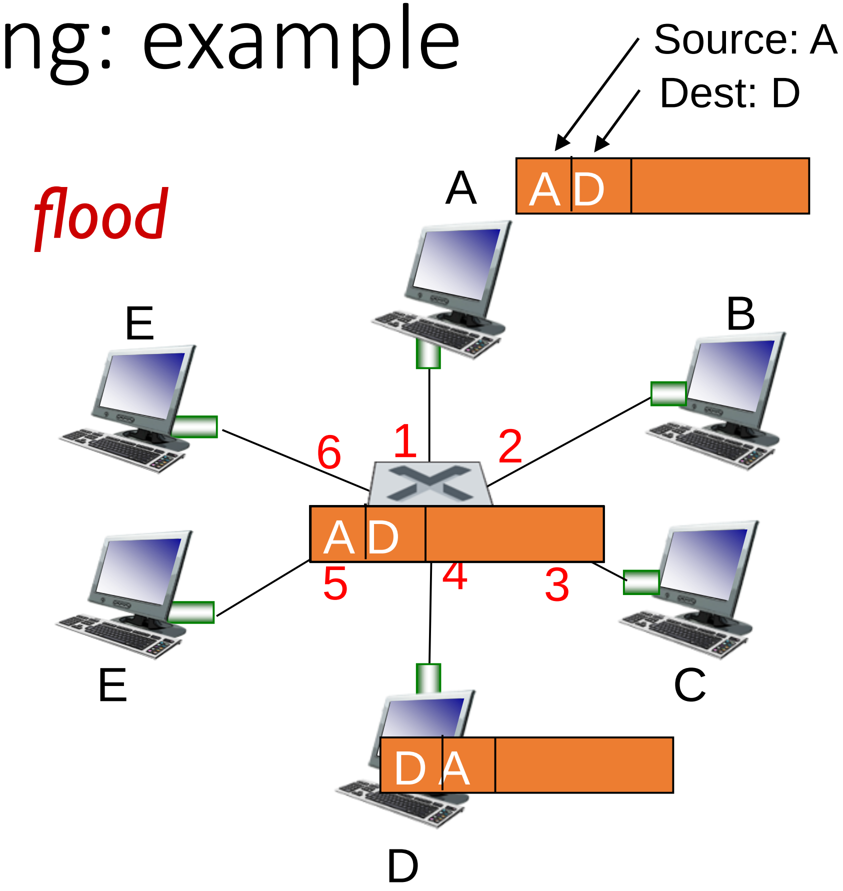
- A: each switch has a forwarding table, each entry:
  - (MAC address of host, interface to reach host, time stamp)
  - looks like a router's forwarding table!



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 D	*1* *4*	*20* *20*

switch table (initially empty)

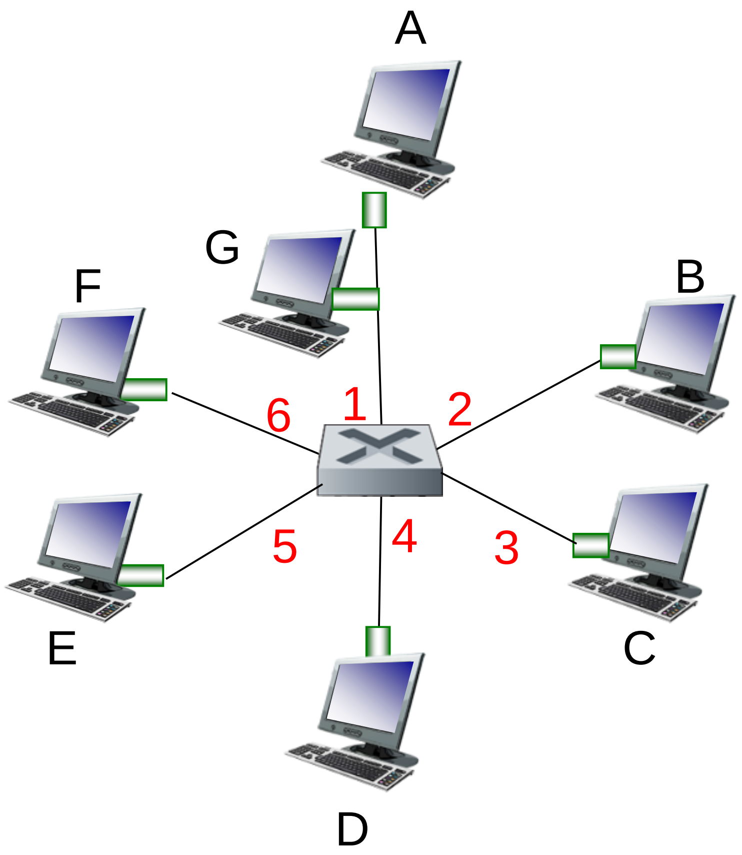
Suppose the switch receives a packet from A to G. (Assume it knows what interface both A and G are on.) It should…

A. Flood the packet

B. Throw the packet away

C. Send the packet out on interface 1

D. Do something else



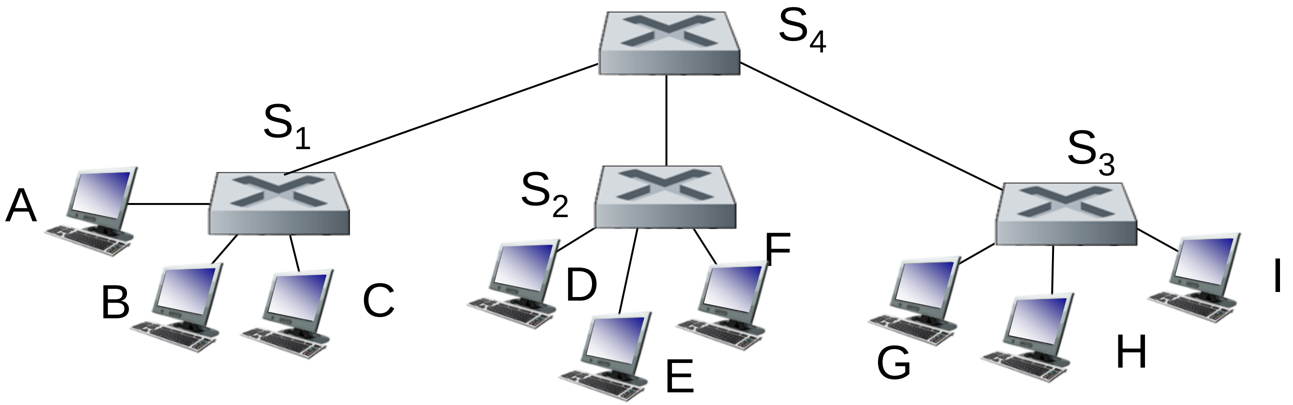
Switch: frame filtering/forwarding

when frame received at switch:

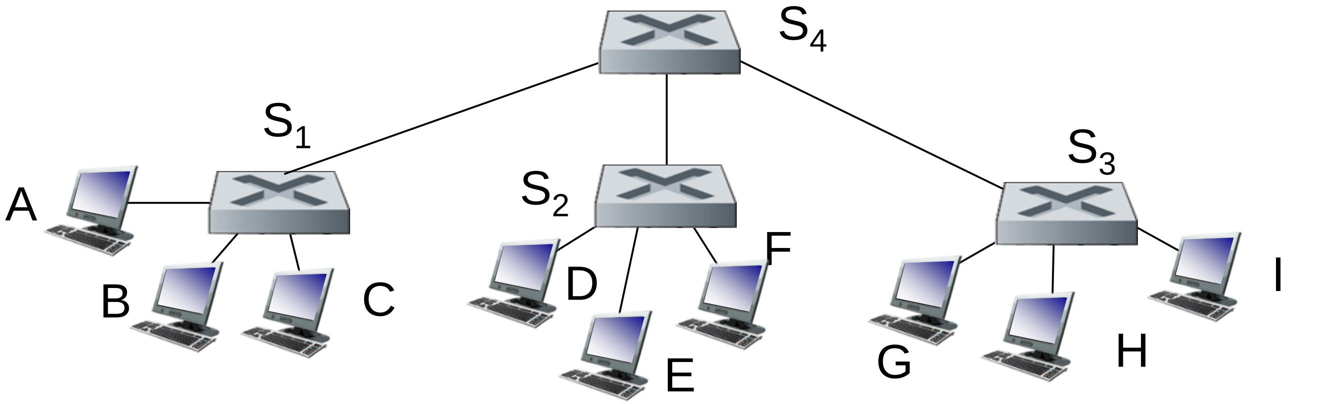
```
1. record incoming link, MAC address of sending host
2. index switch table using MAC destination address
3. if entry found for destination {
      if destination on segment from which frame arrived
          drop frame
      else
          forward frame on interface indicated by entry
      }
  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

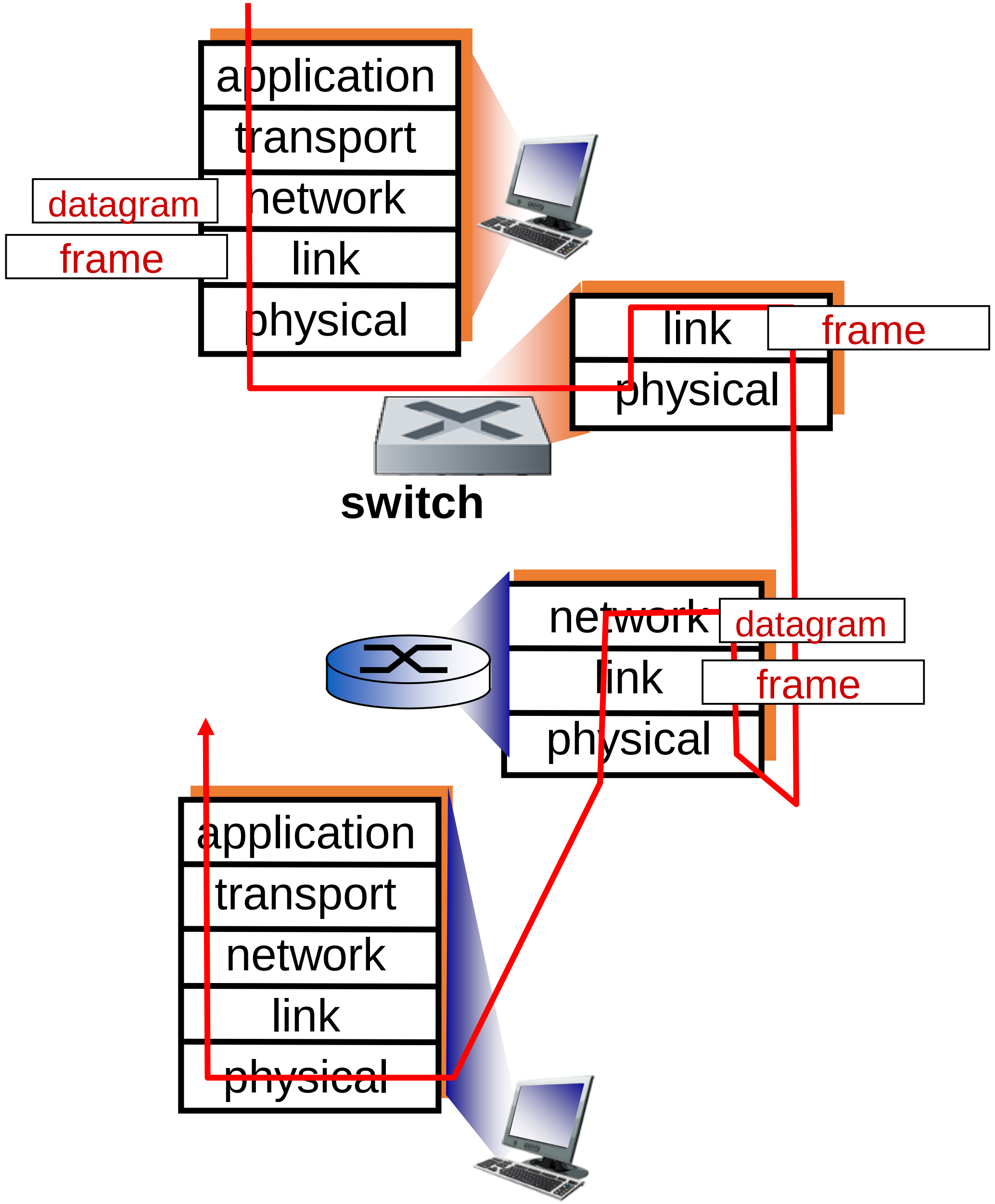
Switches vs. routers

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.

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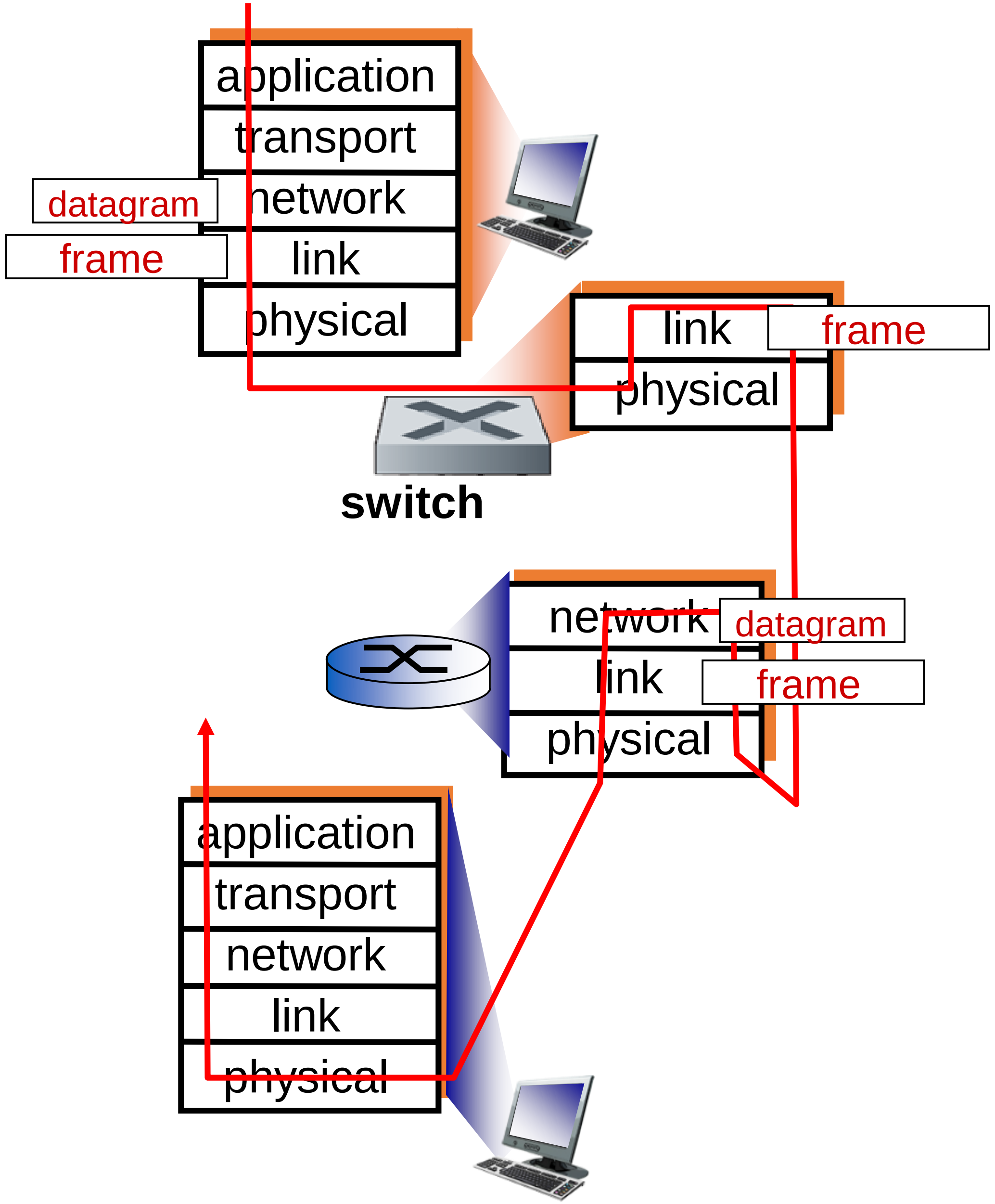

Switches vs. routers

You do NOT address frames directly to a switch (unless you're configuring it).

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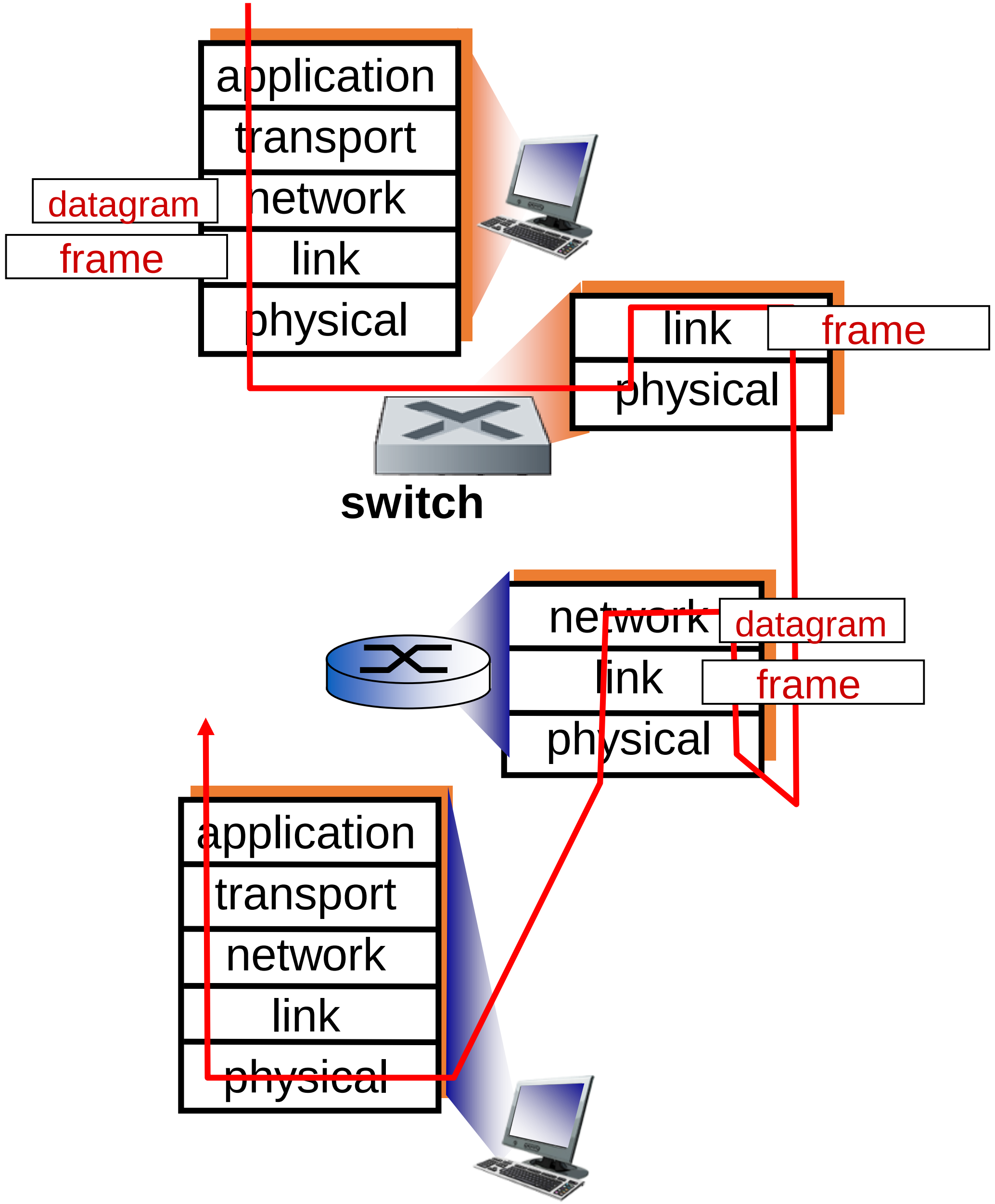

Summary

- 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