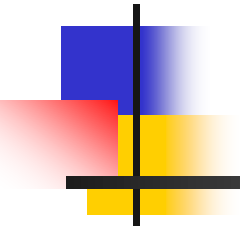
Switched Local Area Networks



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Lecture 18

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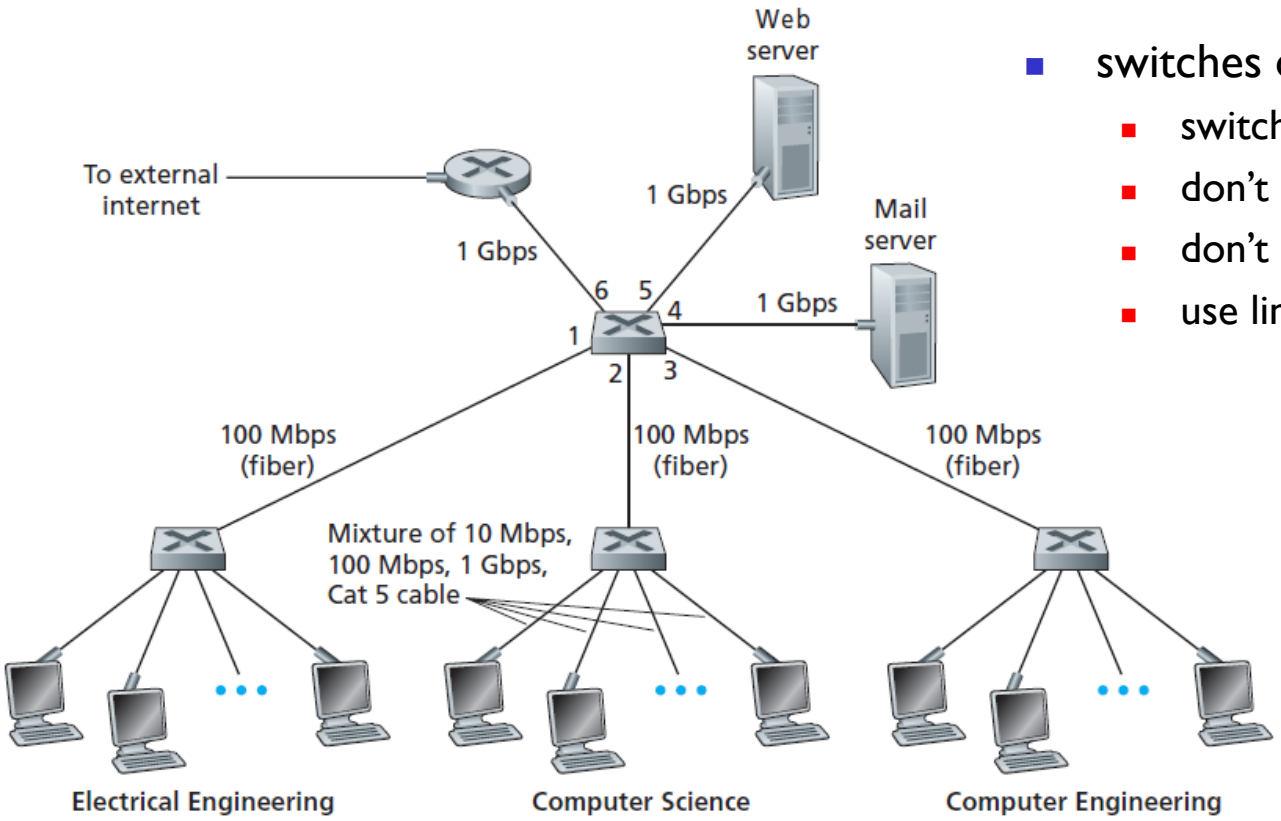
Introduction

- a switched local network connecting three departments, two servers and a router with four switches

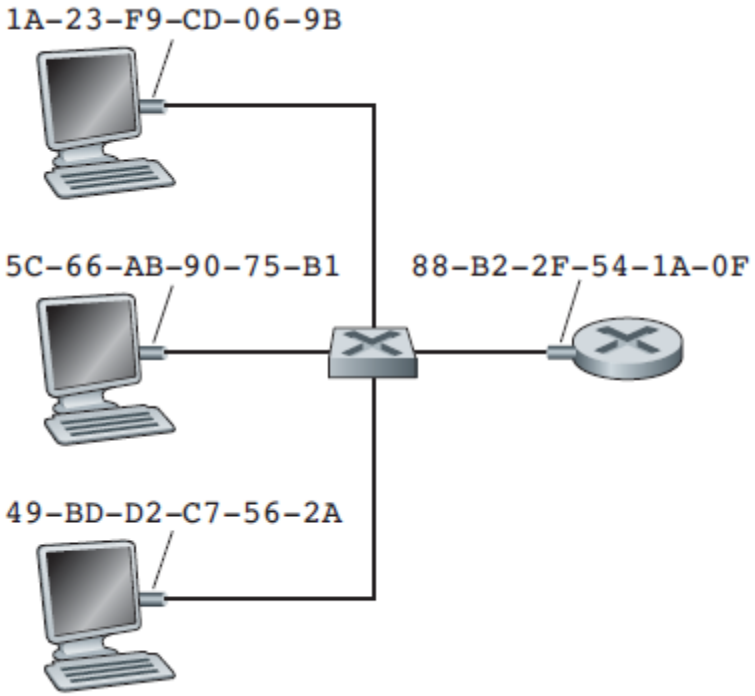


- switches operate at the link layer
  - switch link layer frames
  - don't recognize network layer address
  - don't use routing algorithms
  - use link layer address to forward frame

MAC Addresses

- hosts and routers have ***link-layer address***
- adapters or network interfaces of hosts and routers have ***link-layer addresses***
  - a host or router with multiple network interfaces will have ***multiple*** link-layer addresses
  - just as having multiple IP addresses
- a link-layer address is called ***LAN address***, ***physical address***, or ***MAC address***
- For most LANs, the MAC address is 6 bytes long, giving 2^{48} possible MAC address
  - 6-byte addresses are typically expressed in ***hexadecimal*** notation
  - each byte of the address expressed as a pair of hexadecimal numbers

MAC Addresses



MAC Addresses

- ***no*** two adapters have the same address
- IEEE manages the MAC address space
  - when a company wants to manufacture adapters, it purchase a chunk of the address space consisting of 2^{24} addresses for a nominal fee
  - IEEE allocates the chunk of 2^{48} addresses by fixing the first 24 bits of a MAC address and letting the company create unique combinations of the last 24 bits for each adapter
- an adapter's MAC address has a ***flat structure***, does not change no matter where the adapter goes
  - an adapter's MAC address is analogous to a person's social security number
  - an IP address is analogous to a person's postal address

MAC Addresses

- when an adapter wants to send a frame to some destination adapter, the sending adapter inserts the destination adapter's ***MAC address*** into the frame and then sends the frame into the LAN

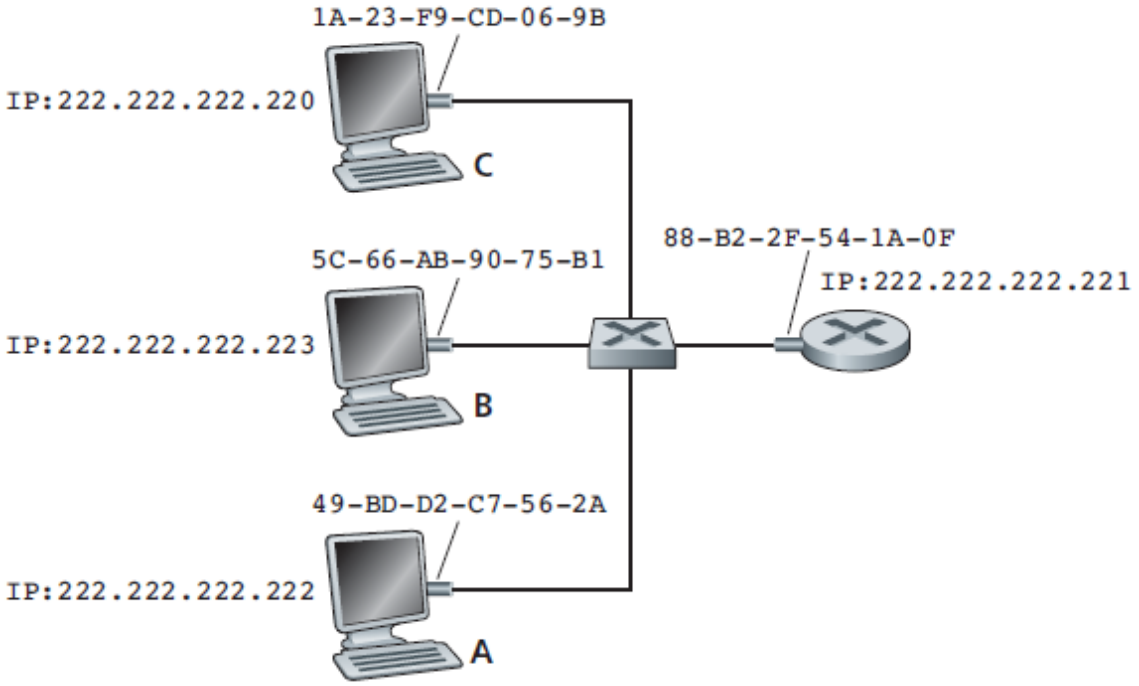
- a switch occasionally broadcasts an incoming frame onto all of tis interfaces
  - an adapter may receiver a frame that ***isn't*** addressed to it
  - when an adapter receivers a frame, it will check to see whether the destination MAC address in the frame ***matches*** its own MAC address
    - if match, accept frame
    - if no match, discard the frame

MAC Addresses

- How about a sending adapter wants *all the other adapters* on the LAN to receiver and process the frame it is about to send??
  - the sending adapter inserts a special ***MAC broadcast address*** into the destination address filed of the frame.
  - for LANs that use 6-byte address, the broadcast address is a string of ***48 consecutive 1s***, **FF-FF-FF-FF-FF-FF**

Address Resolution Protocol (ARP)

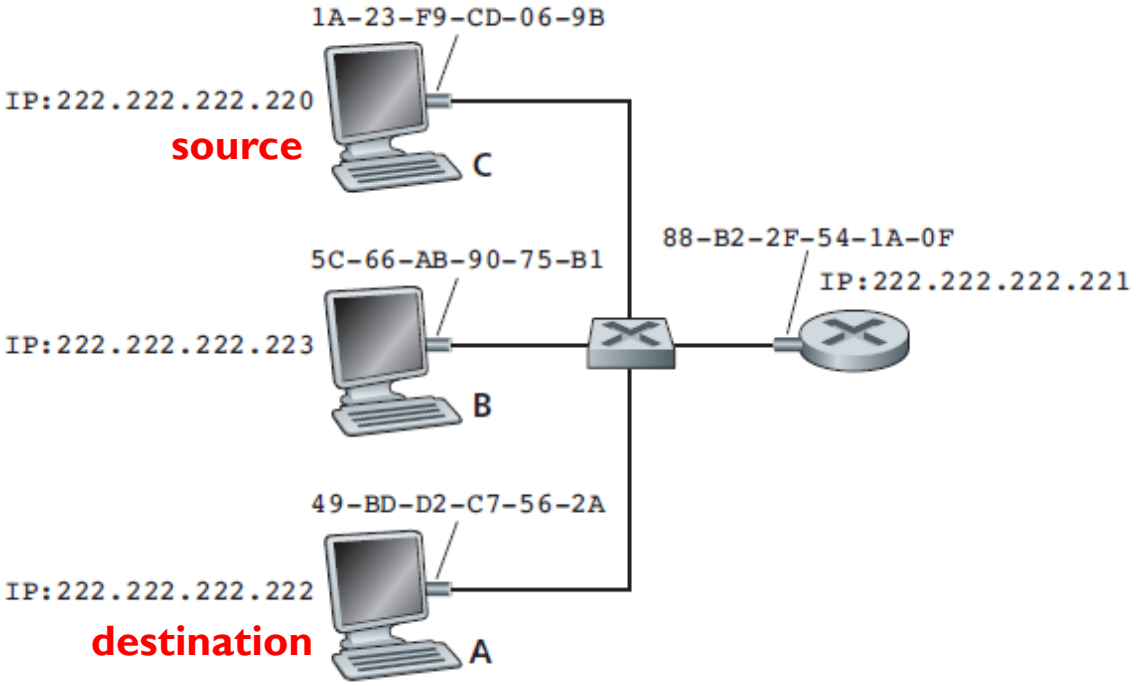
- translation between *link-layer address* and *network-layer address*
- Address Resolution Protocol (ARP)
- Example:



- each host and router has a single IP address and single MAC address
  - IP: dotted-decimal notation
  - MAC: hexadecimal notation
- the switch broadcasts all frames
  - whenever a switch receivers a frame on one interface, it forwards the frame on all of its other interfaces

Address Resolution Protocol (ARP)

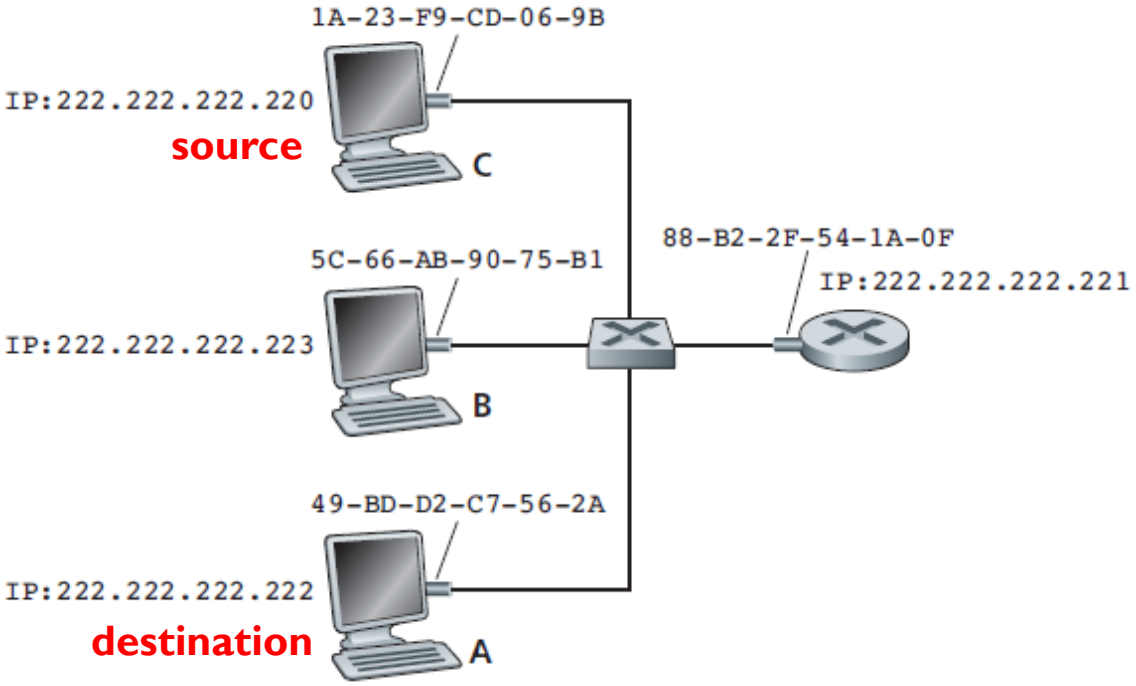
- translation between *link-layer address* and *network-layer address*
- Address Resolution Protocol (ARP)
- Example:



- the host with IP address 222.222.222.220 wants to send an IP datagram to host 222.222.222.222
  - IP datagram and MAC address of destination
  - the sending adapter will construct a link-layer frame containing the destination's MAC address and send the frame into the LAN

Address Resolution Protocol (ARP)

- translation between *link-layer address* and *network-layer address*
- Address Resolution Protocol (ARP)
- Example:



- *how does the sending host determine the MAC address of the destination host with IP address 222.222.222.222??*
- ***ARP***: take any IP address on the same LAN as input, and return the corresponding MAC address
  - in the example, ARP returns the MAC address 49-BD-D2-C7-56-2A

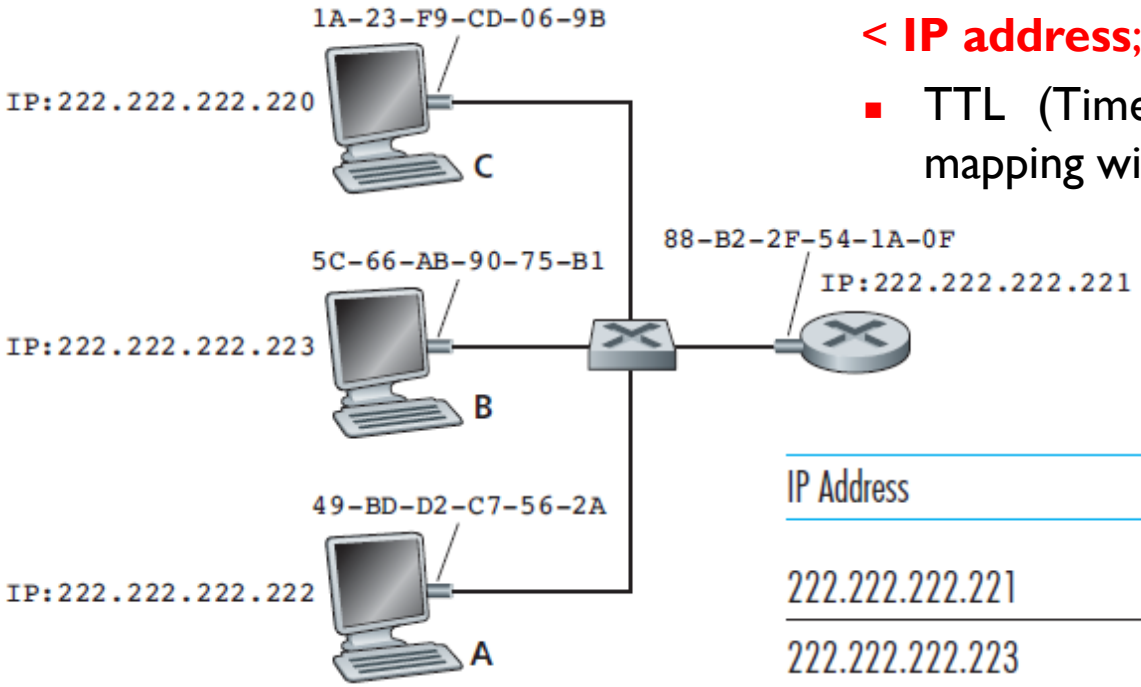
Question: how to determine MAC address of B knowing B's IP address?

Address Resolution Protocol (ARP)

- each host and router on LAN has ARP table
- *ARP 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 mins)



IP Address	MAC Address	TTL
222.222.222.221	88-B2-2F-54-1A-0F	13:45:00
222.222.222.223	5C-66-AB-90-75-B1	13:52:00

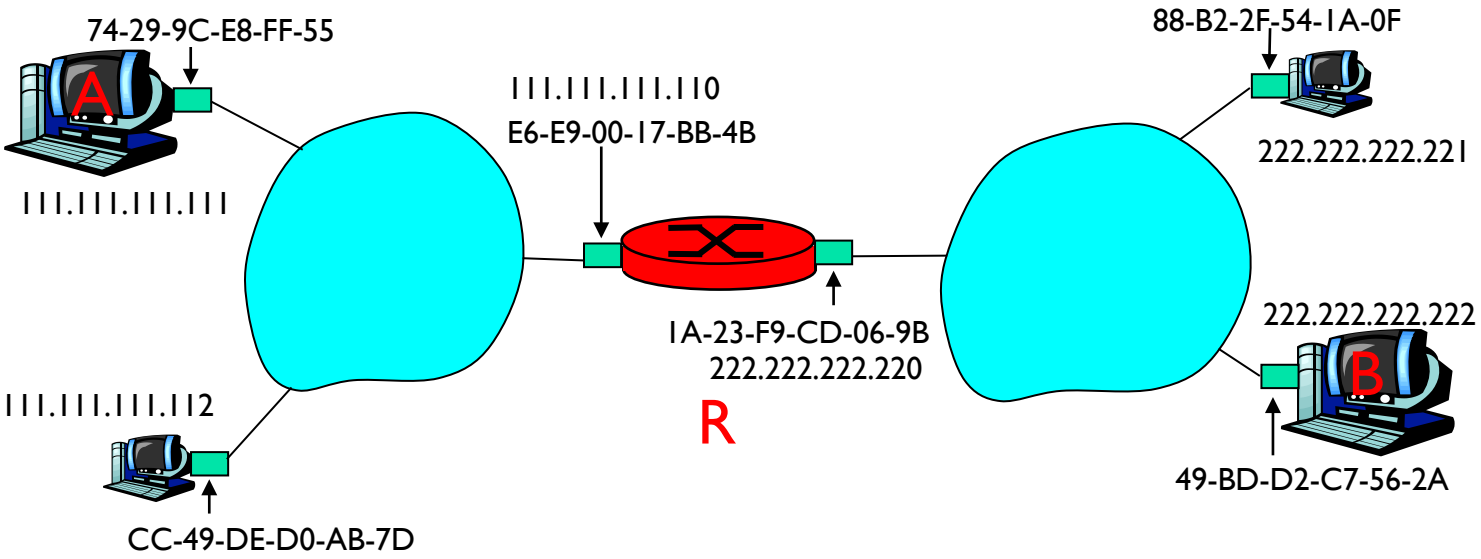
A possible ARP table in 222.222.222.220

Address Resolution Protocol (ARP)

- A wants to send datagram to B, and B's MAC address **not** in A's ARP table
  - A uses ARP to resolve the MAC of B
- A **broadcasts** ARP query packet, containing B's IP address
  - dest MAC address = FF-FF-FF-FF-FF-FF
  - all machines on LAN receive ARP query
- B receives ARP packet, replies to A with its (B's) MAC address
  - frame sent to A's MAC address (**unicast**)
- A caches (saves) IP-to-MAC address pair in its ARP table until information becomes old (times out)
  - soft state: information that times out (goes away) unless refreshed
- ARP is "plug-and-play":
  - nodes create their ARP tables ***without*** *intervention from net administrator*

Sending a Datagram off the Subnet

- when a host wants to send a datagram to another host on the same subnet: ARP
- complicated situation: when a host on a subnet wants to send a network-layer datagram to a host off the subnet?

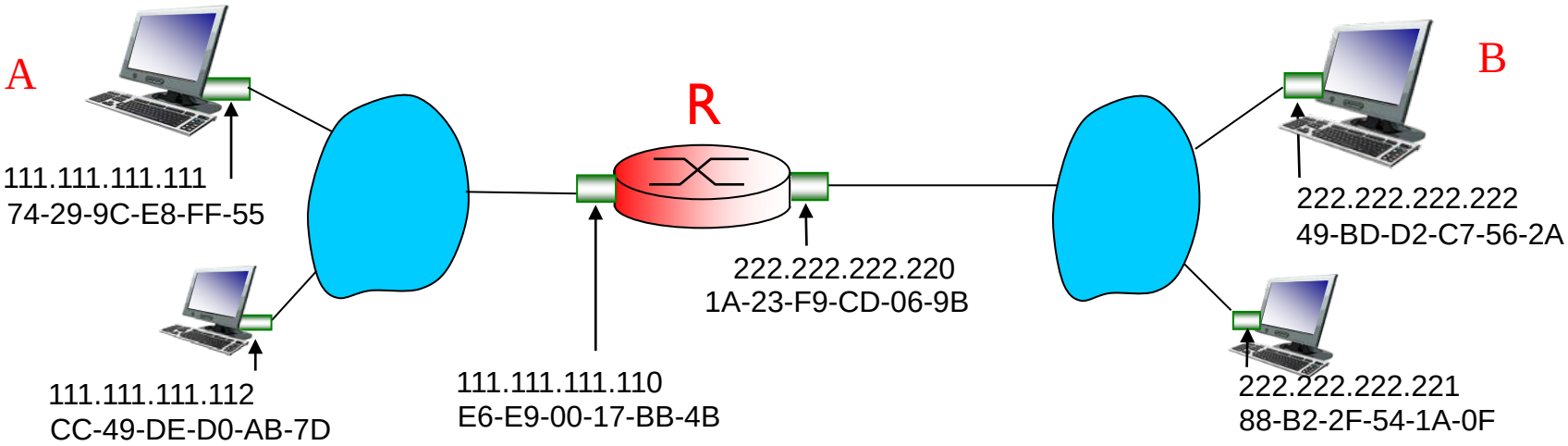


- a host has exactly one IP address and one adapter
- a router has an IP address for each of its interface
  - for each router interface, there is also an ARP module and an adapter

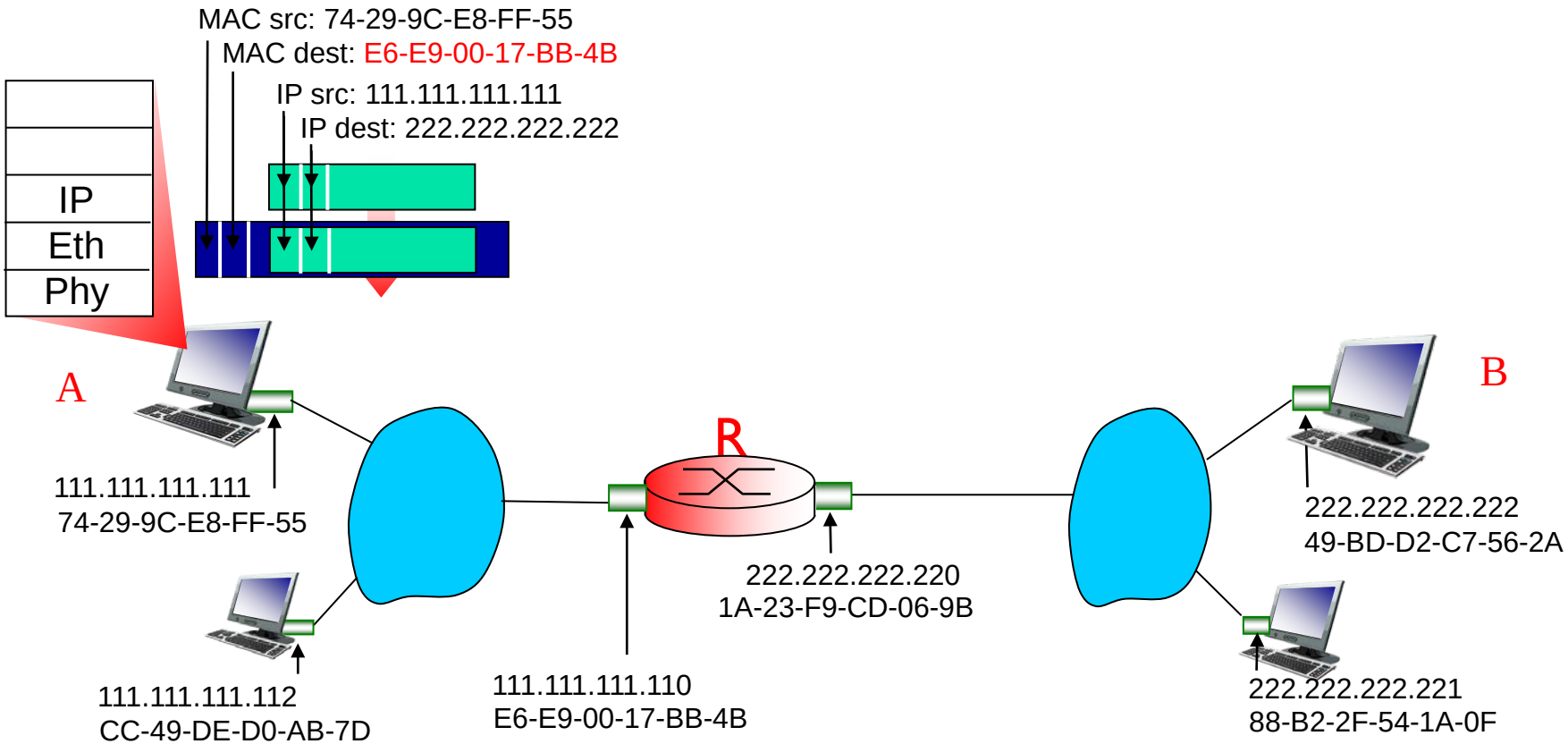
Addressing: Routing to another LAN (cont.)

walkthrough: send datagram from A to B via R

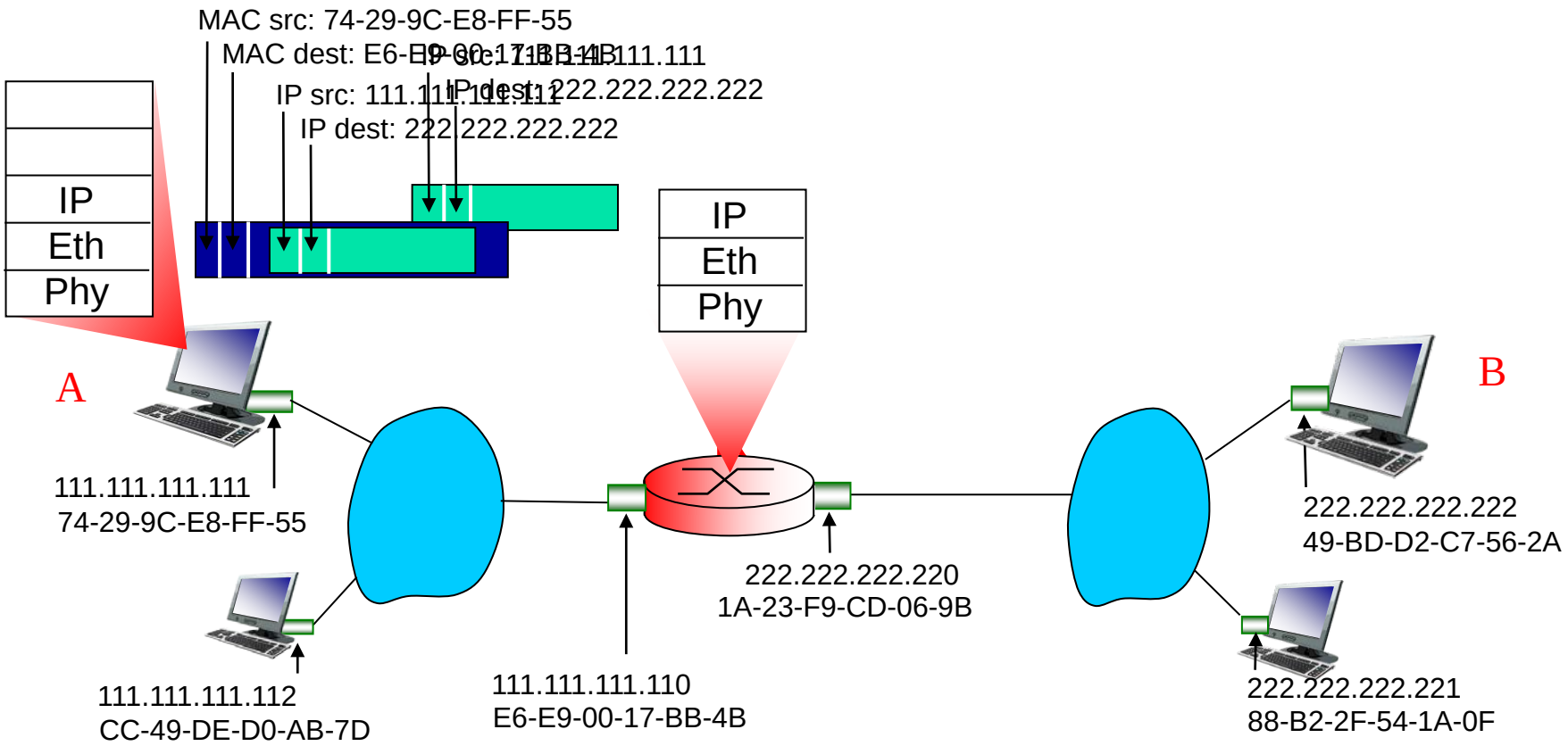
- focus on addressing – at IP (datagram) and MAC layer (frame)
- assume A knows B's IP address
- assume A knows IP address of first hop router, R
- assume A knows R's MAC address



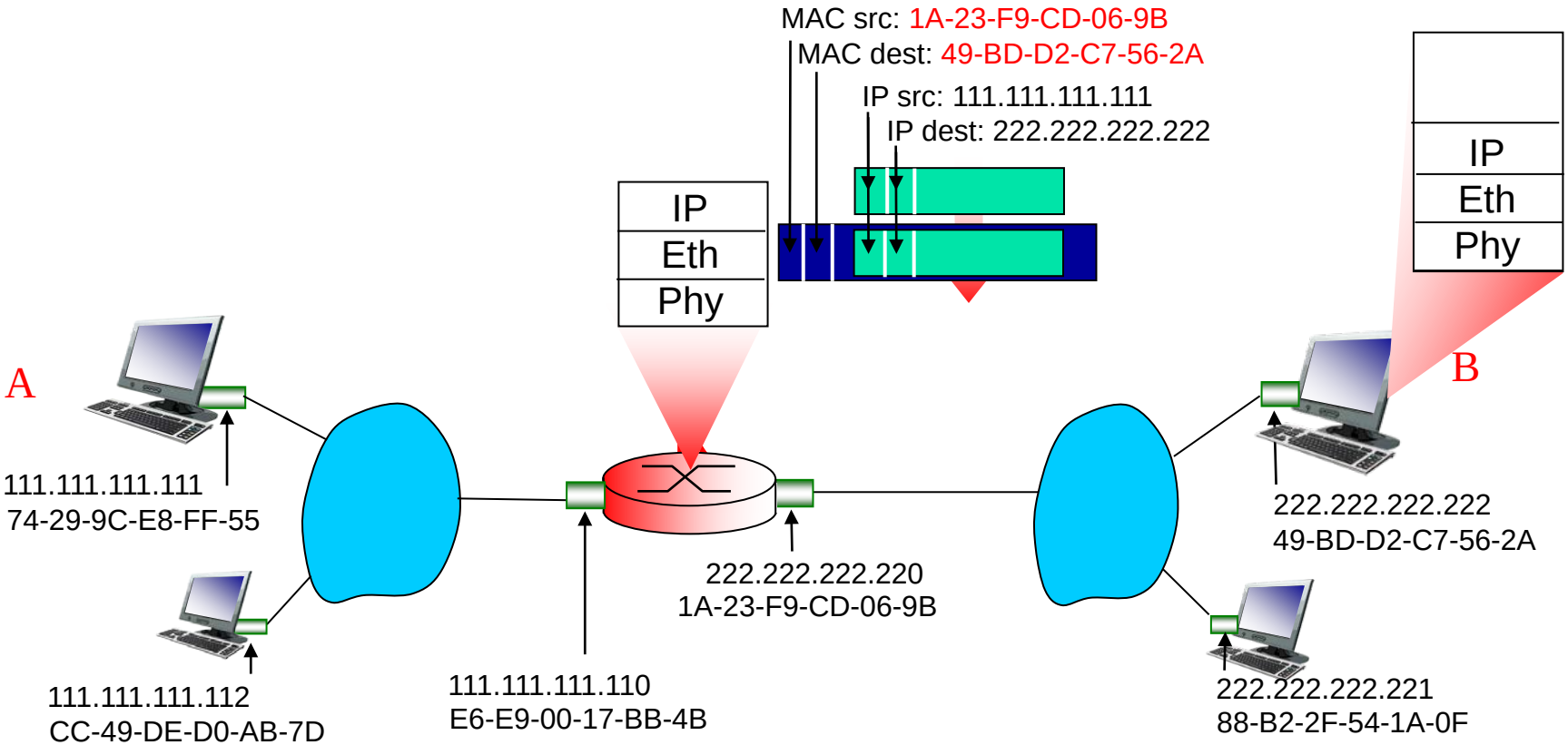
- A creates IP datagram with IP source A, destination B
- A creates link-layer frame with **R's MAC address** as dest, frame contains A-to-B IP datagram



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



- 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



- R forwards datagram with IP source A, destination B
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