

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
- VLANs

5.5 link virtualization:
MPLS

5.6 data center
networking

5.7 a day in the life of a
web request

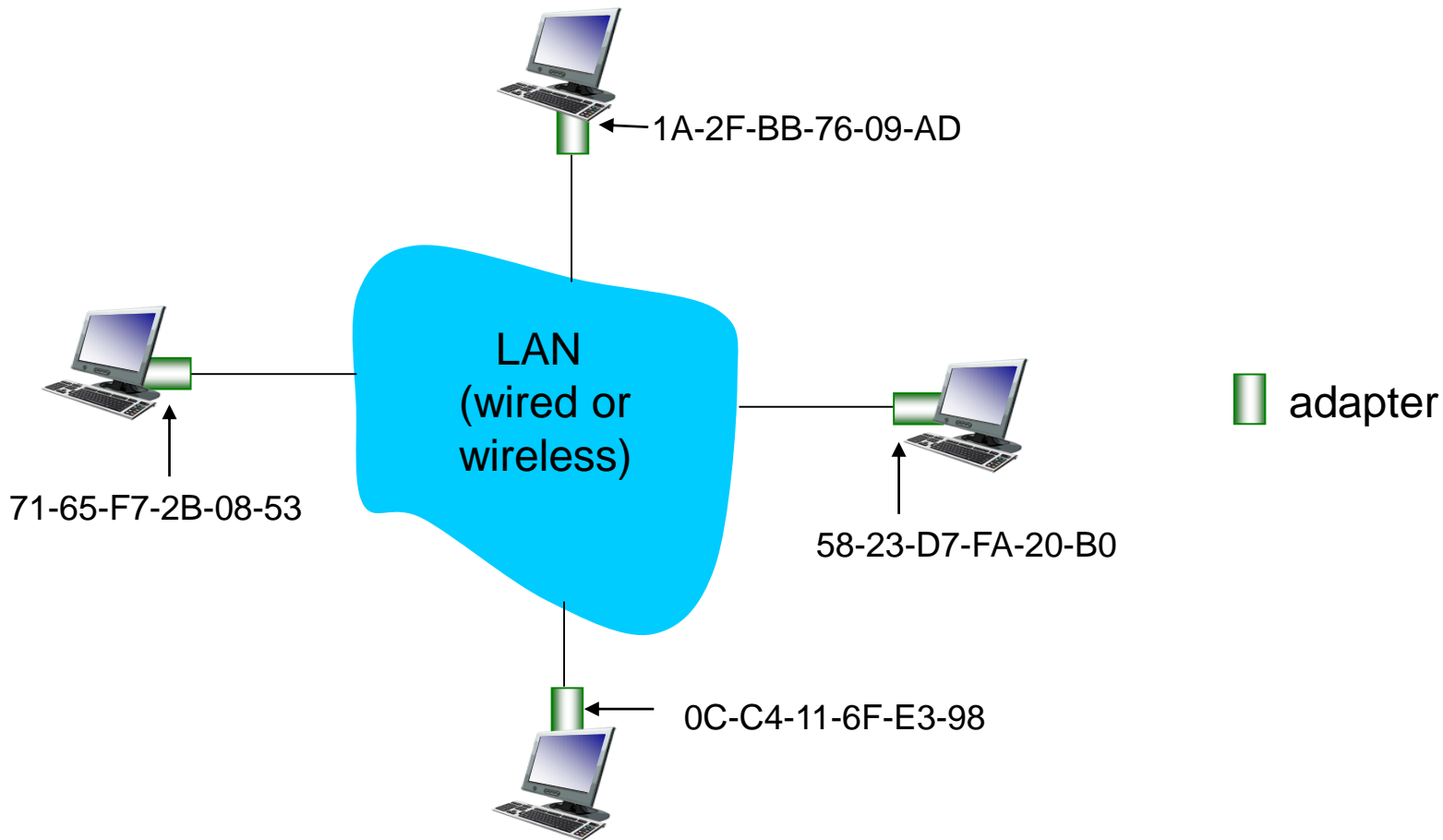
MAC addresses and ARP

- ❖ 32-bit (4-byte) IP address:
 - *network-layer* address for interface
 - used for layer 3 (network layer) forwarding
- ❖ 48-bit (6-byte) MAC/LAN/physical/Ethernet address:
 - function: *used ‘locally’ to get frame from one interface to another physically-connected interface (same network, in IP-addressing sense)*
 - burned in NIC ROM, also sometimes software settable
 - e.g.: 1A-2F-BB-76-09-AD

hexadecimal (base 16) notation
(each character represents 4 bits)
(each pair represents one byte)

LAN addresses and ARP

each adapter on LAN has unique **LAN** address



LAN addresses (more)

- ❖ 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

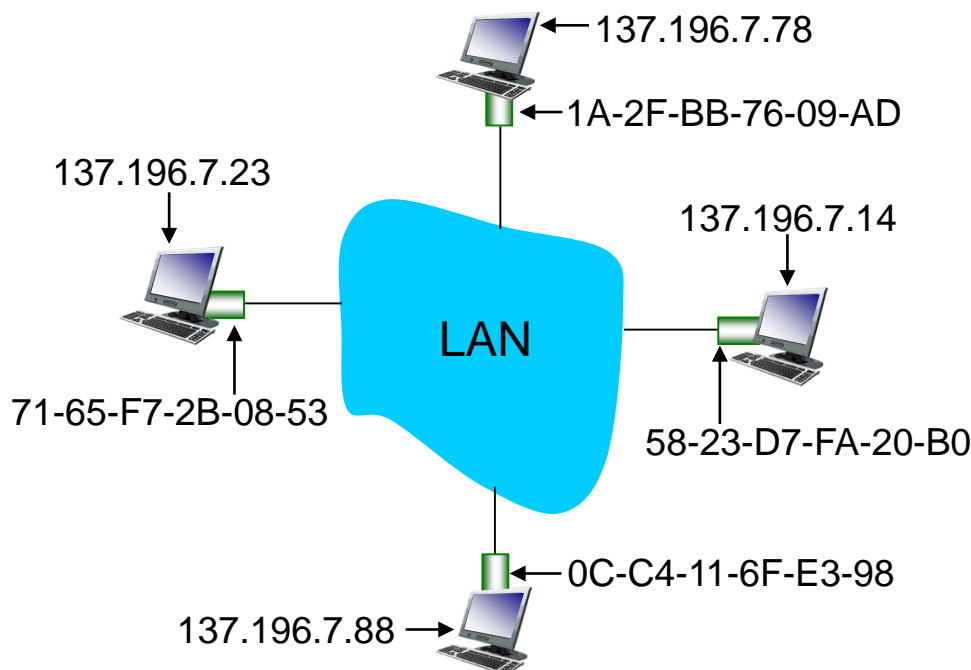
Question: how to determine interface's MAC address, knowing its IP address?

Question: why do we care about this?

Answer: because at the link layer, nodes cannot talk to other nodes based on IP addresses.

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)

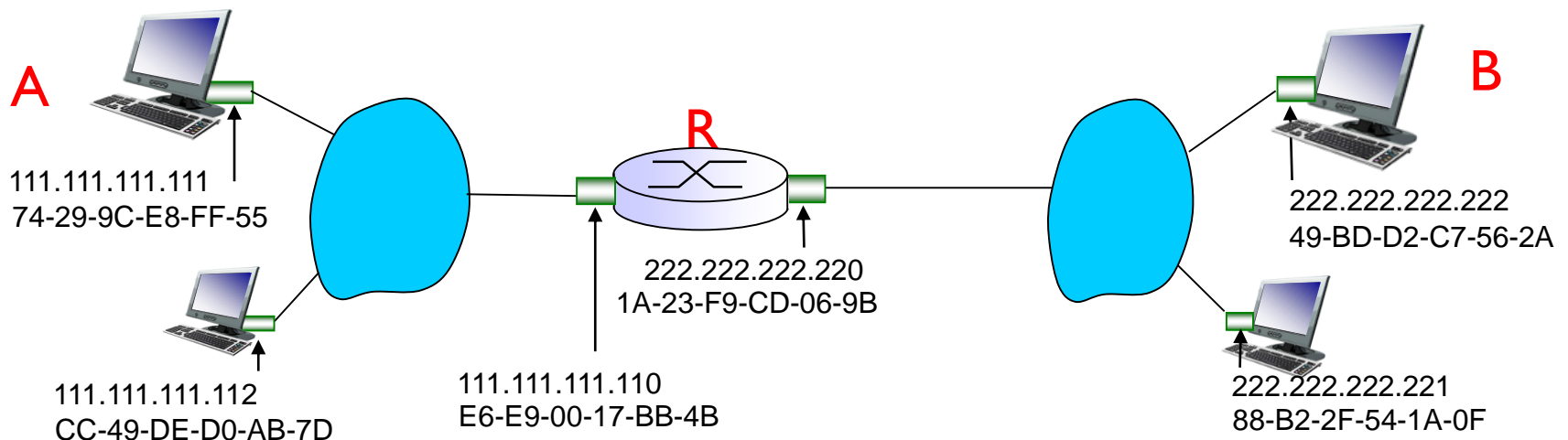
ARP protocol: same LAN

- ❖ A wants to send datagram to B
 - But B's MAC address not in A's ARP table.
- ❖ A **broadcasts** ARP query packet containing B's IP address to all MAC addresses:
dest MAC address = FF-FF-FF-FF-FF-FF
 - all nodes 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)
 - It's 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*

Addressing: routing to another LAN

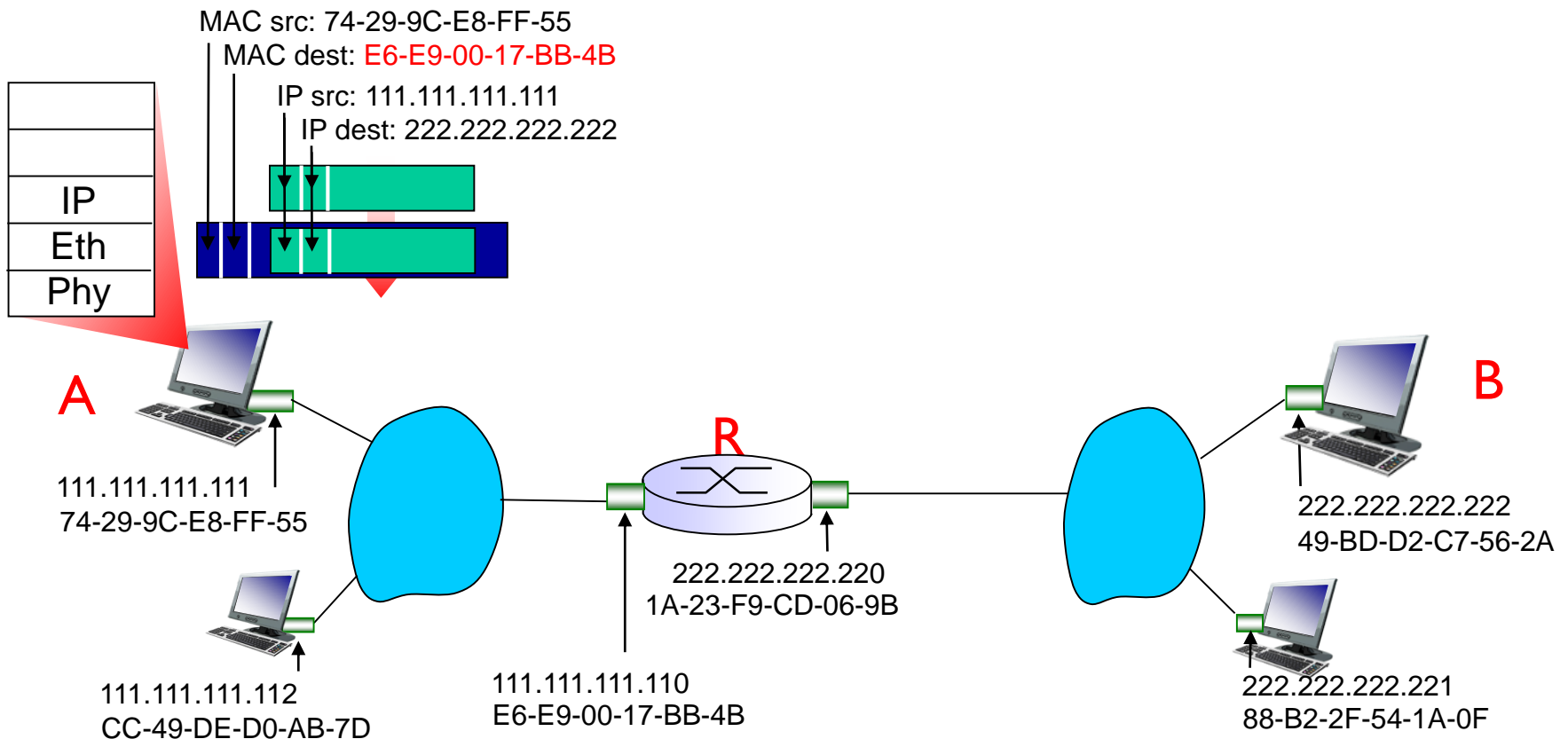
walkthrough: **send datagram from A to B via R**

- 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?)
 - Default gateway, identified in DHCP or statically assigned
- assume A knows R's MAC address (how?)
 - A does ARP resolution of R's IP address to R's MAC



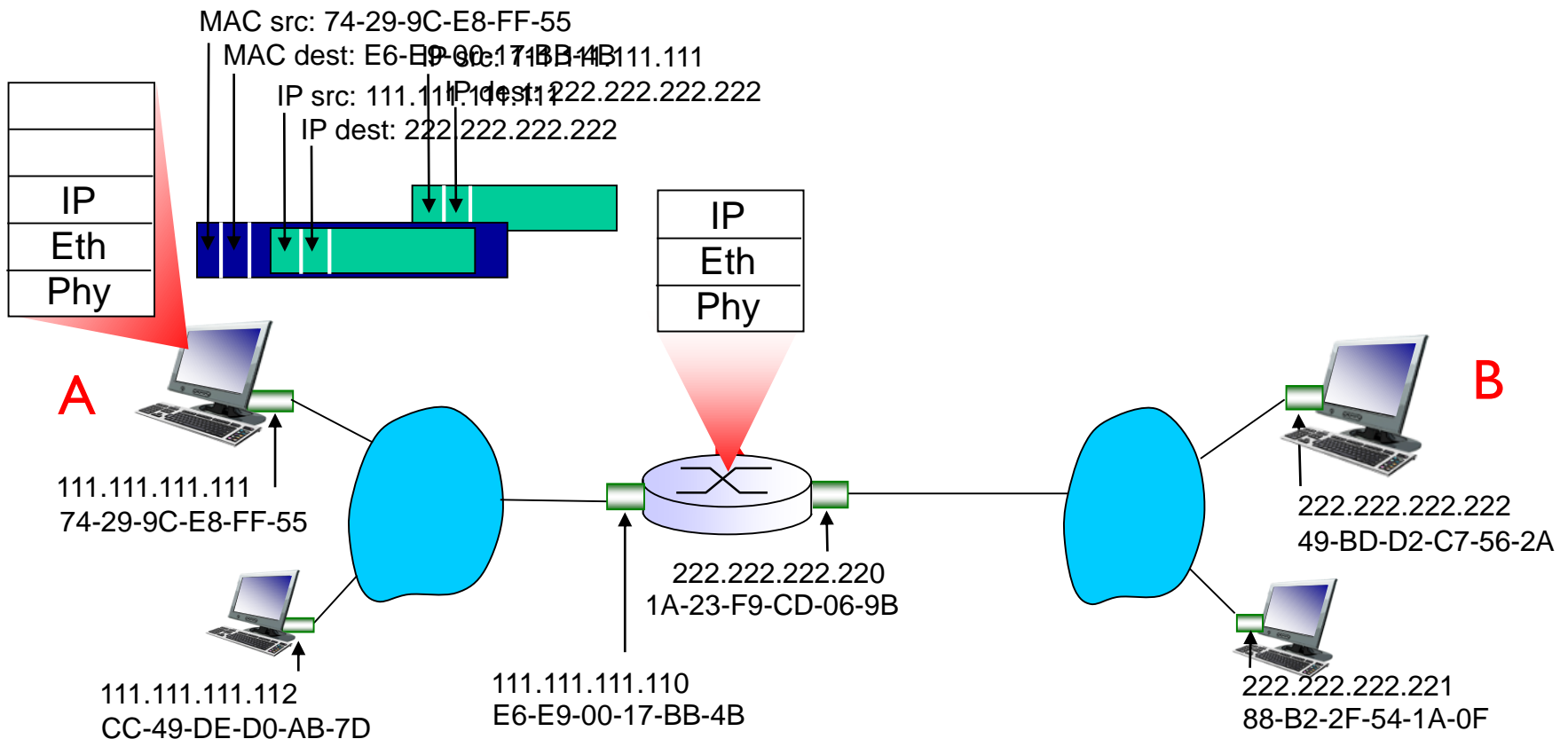
Addressing: routing to another LAN

- ❖ 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



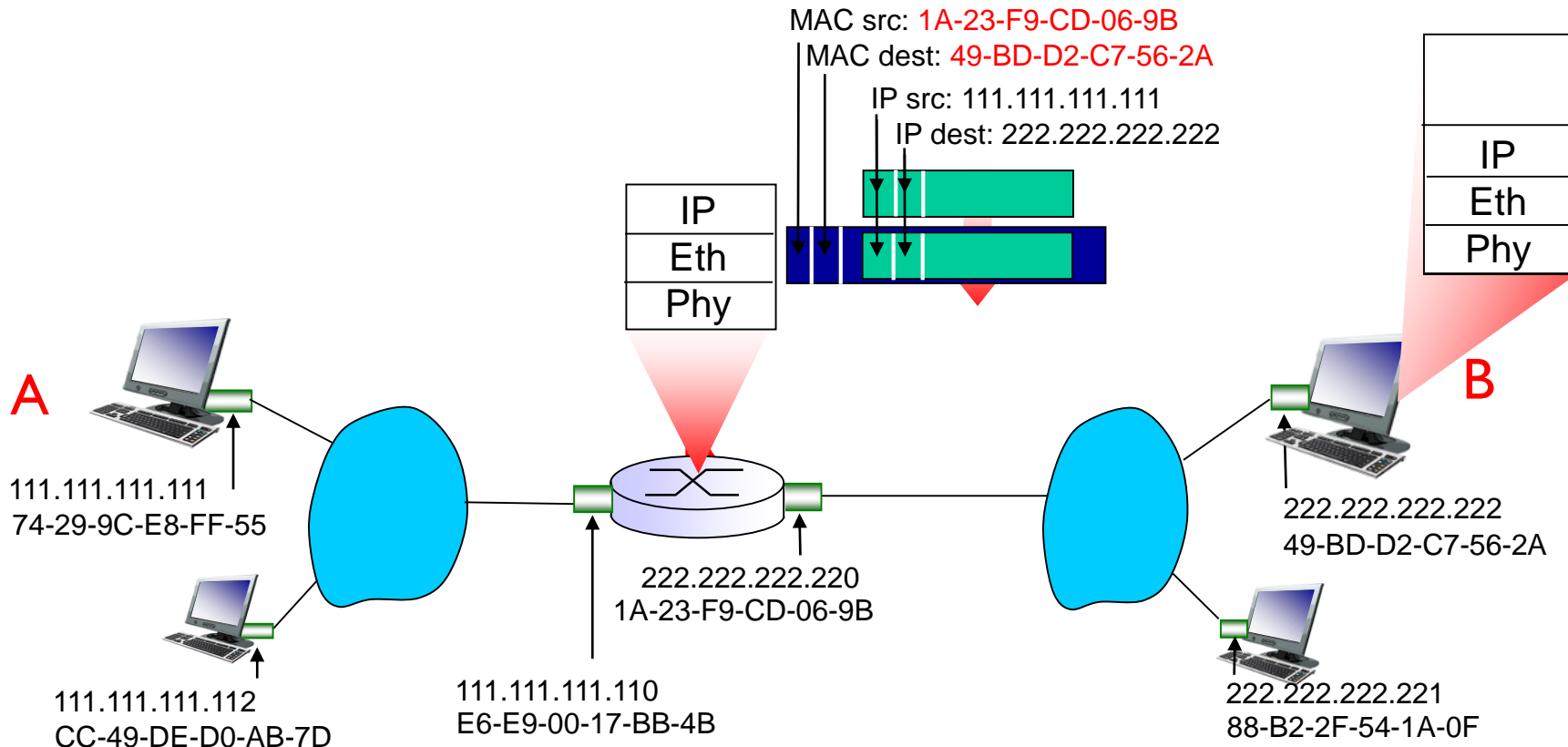
Addressing: routing to another LAN

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



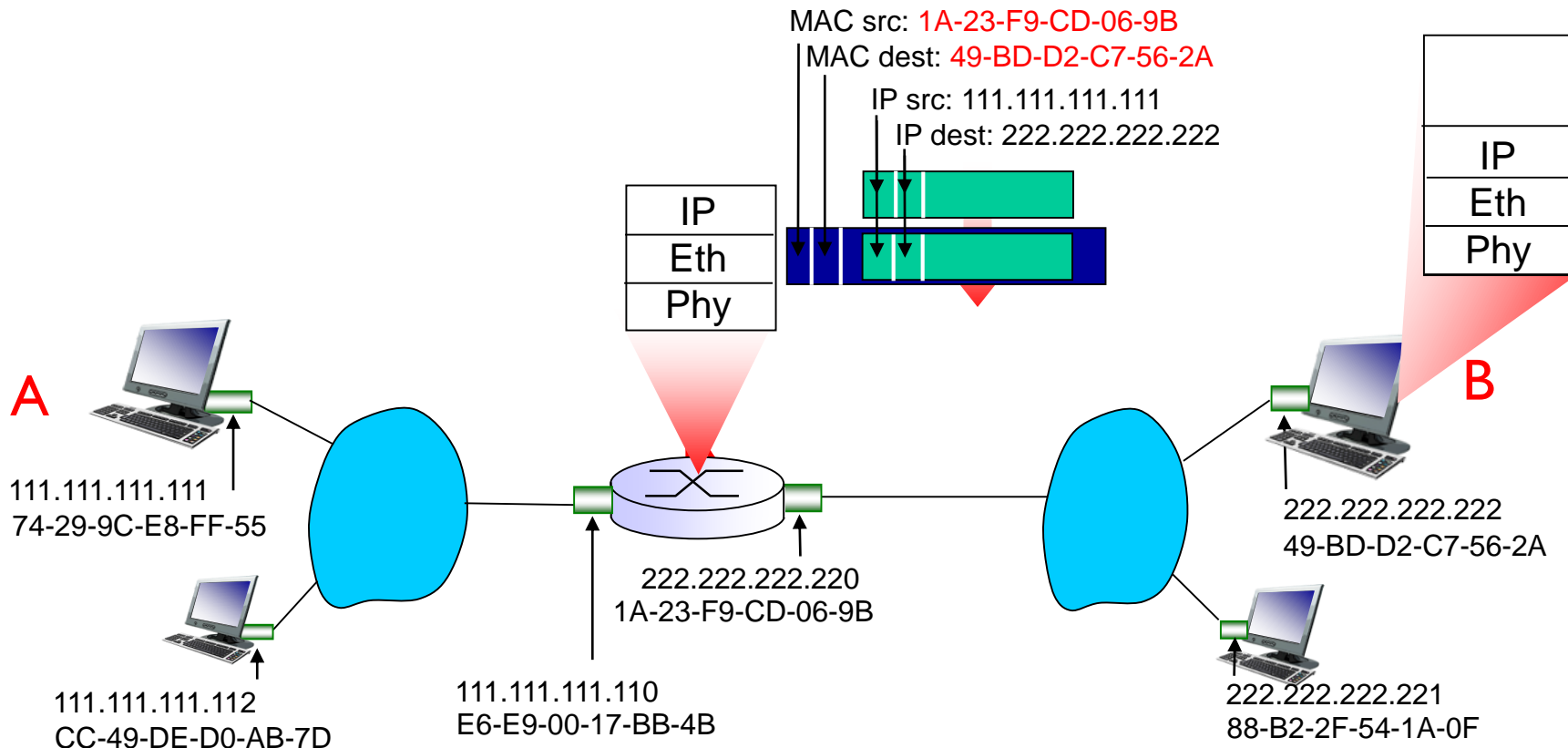
Addressing: routing to another LAN

- ❖ 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



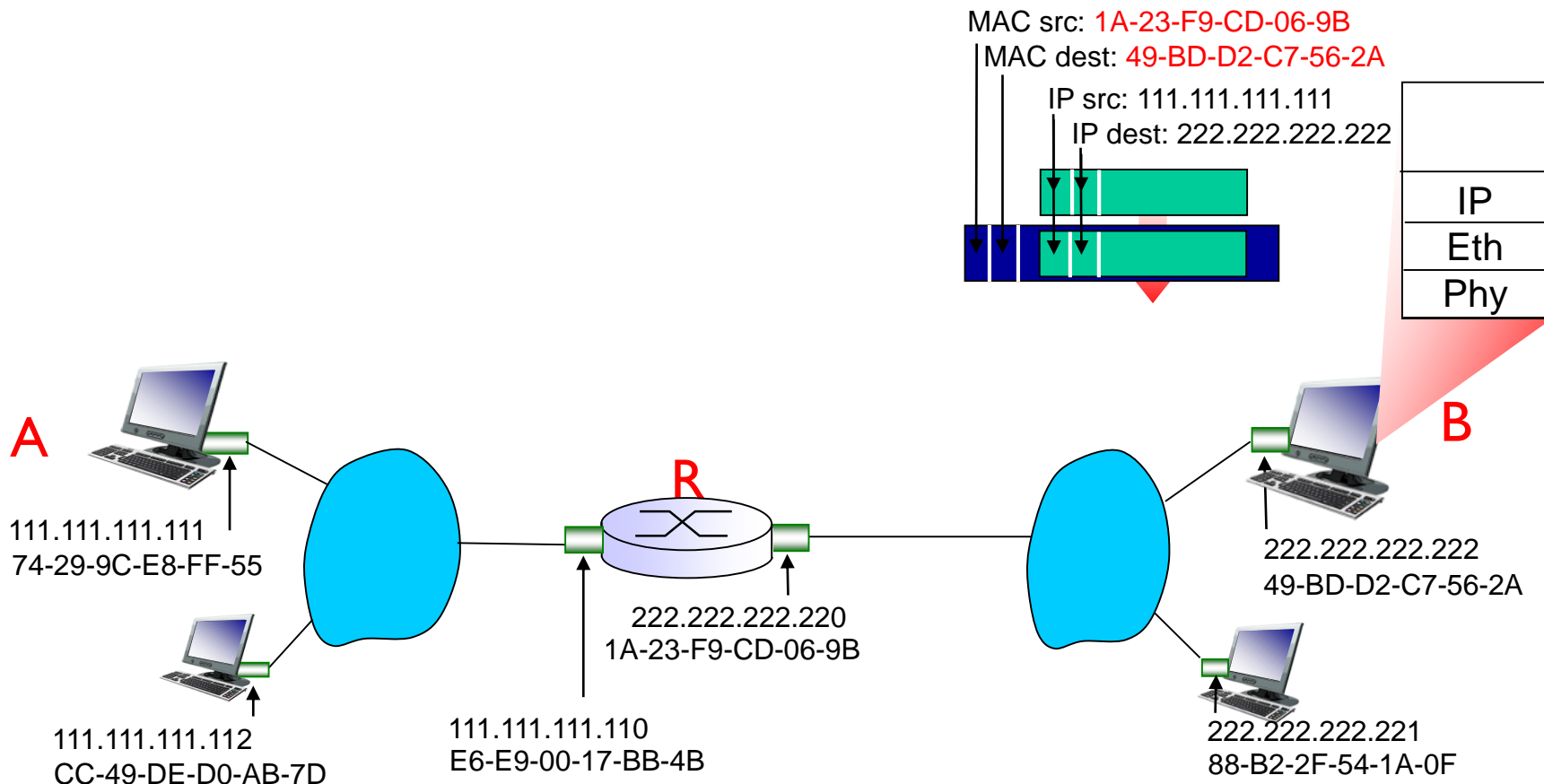
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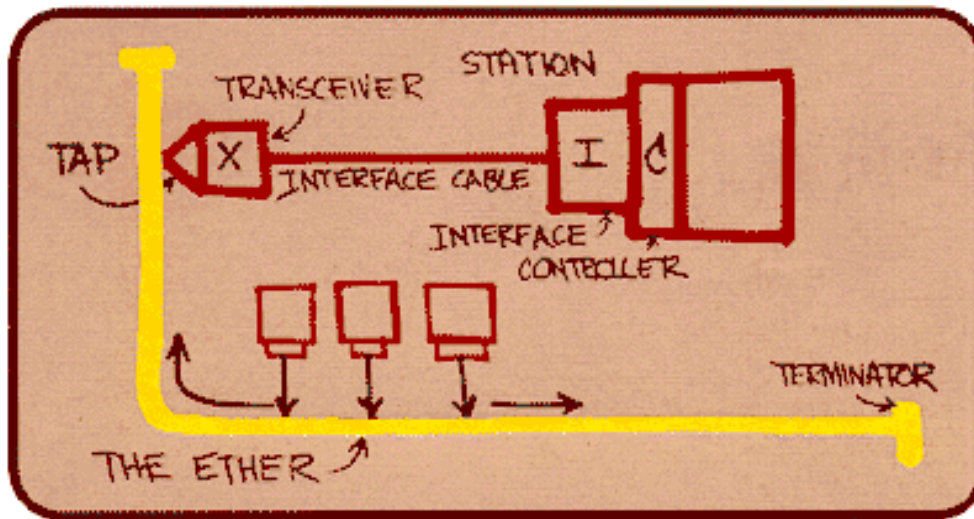
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Ethernet

"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



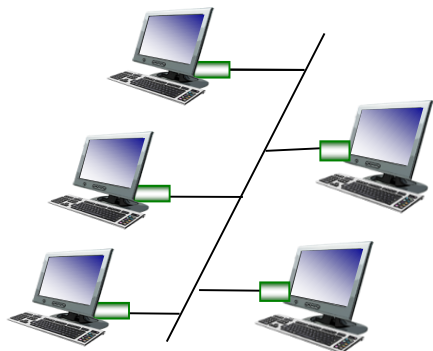
Metcalfe's Ethernet sketch

Ethernet: unreliable, connectionless

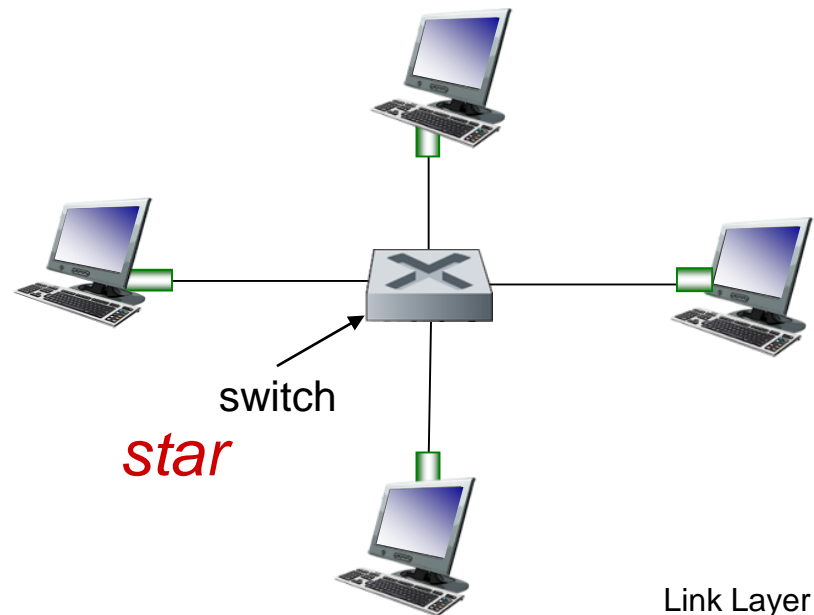
- ❖ *connectionless*: no handshaking between sending and receiving NICs
- ❖ *unreliable*: receiving NIC doesn't send acks or nacks to sending NIC
 - data in dropped frames recovered only if initial sender uses higher layer reliable data transfer (e.g., TCP), otherwise dropped data lost
- ❖ Ethernet's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

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

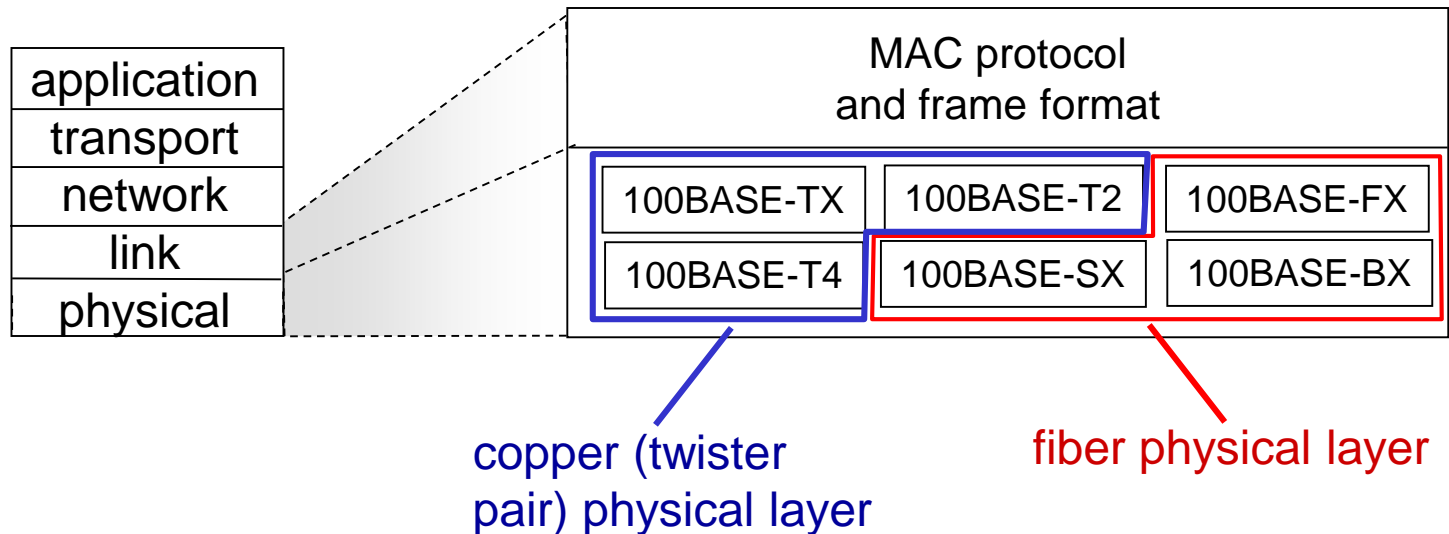
Ethernet frame structure (more)

- ❖ **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



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, 1 Gbps, 10G bps
 - different physical layer media: fiber, cable



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