Transmission over links and local area networks

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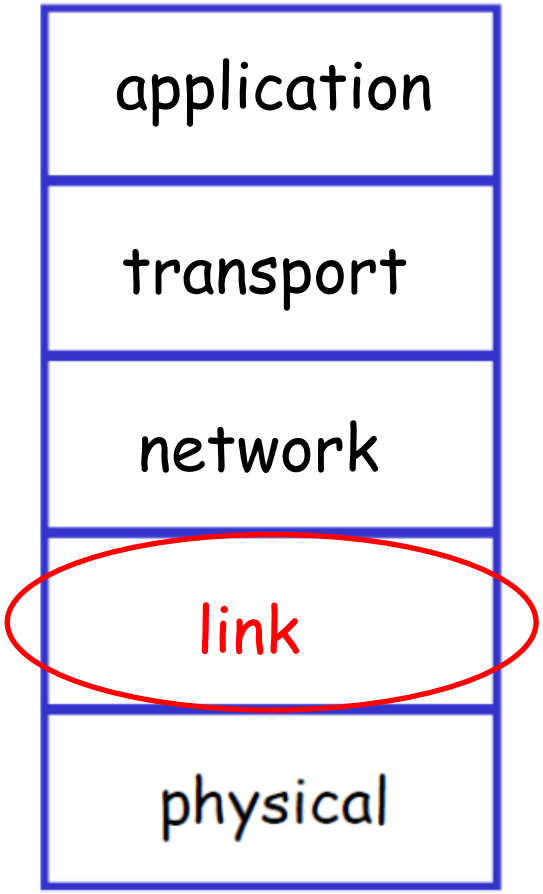


Transmission over links and local area networks

Outline

- Context/overview
- Introduction and services
- Link types and overview of multiple access protocols
- Link-layer addressing
- Ethernet
- Link-layer switches
- PPP
- A day in the life of a web request

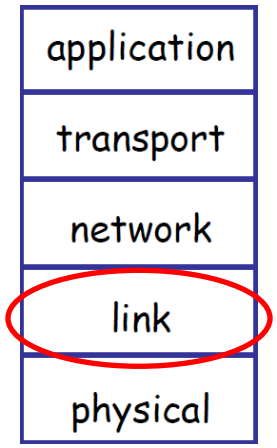
Transmission over links and local area networks

Context/Overview

- Transmission over links and LANs, and the link layer
- The link layer and its relevance to the network edge and the network core
- Transmission over links: end-to-end transmission using multiple heterogeneous links and associated networks
- Link types: broadcast and point-to-point links

  Network types: broadcast networks (Wifi) and switched networks (Today's Ethernet)

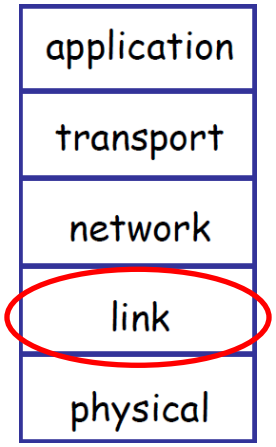
Internet protocol stack
Data Link Layer

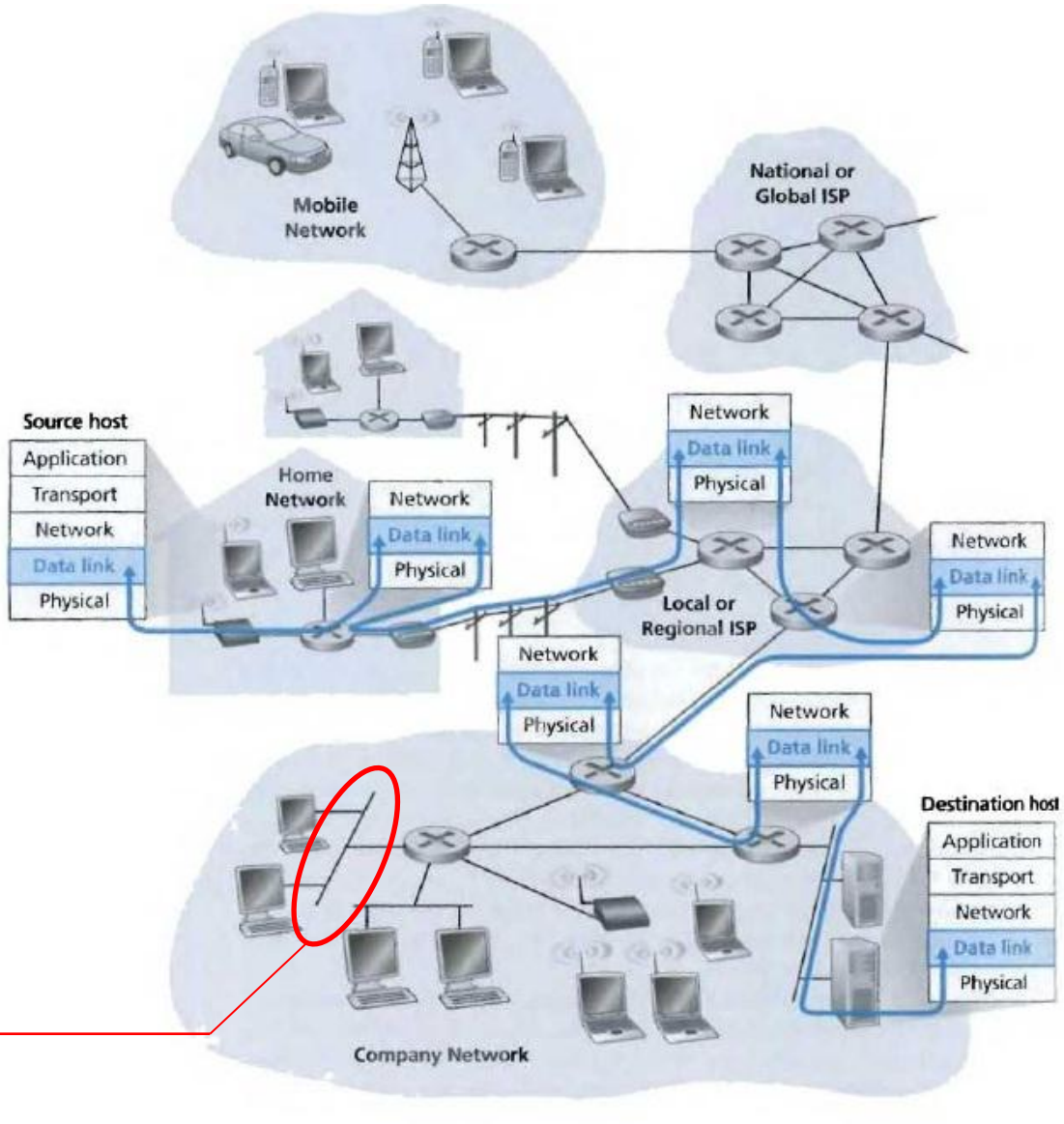


- A host-to-host communication path consists many *links.* The Data Link layer deals with how packets are transmitted over each of the links, which connects two nodes.
  - The links include access networks (or LANs) such as Ethernet.
- At each node, the network layer passes the packet/datagram to the link layer which delivers the packet to the next node. At this next node, the link layer passes this packet/datagram to the network layer.
- Link layer transmission entities are called ***frames.***
- Link layer protocols: Ethernet, Wifi, PPP (point-to-point protocol), etc.
- As packets typically need to traverse several links along their paths, the packets may be handled by different link-layer protocols at different links along the route!
  - E.g., a packet may be handled by Ethernet on one link and by PPP on the next link.
  - The network layer will receive a different service from each of the different link-layer protocols.
- Can provide connectionless or connection oriented services
  - E.g. Ethernet : connectionless service (unacknowledged)

Internet protocol stack

Data Link Layer…





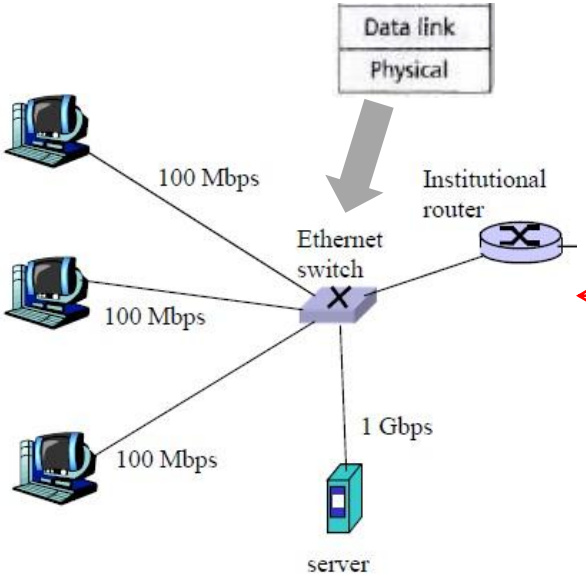
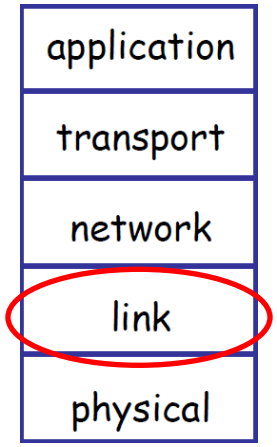


Figure 5.1 ♦ The link layer

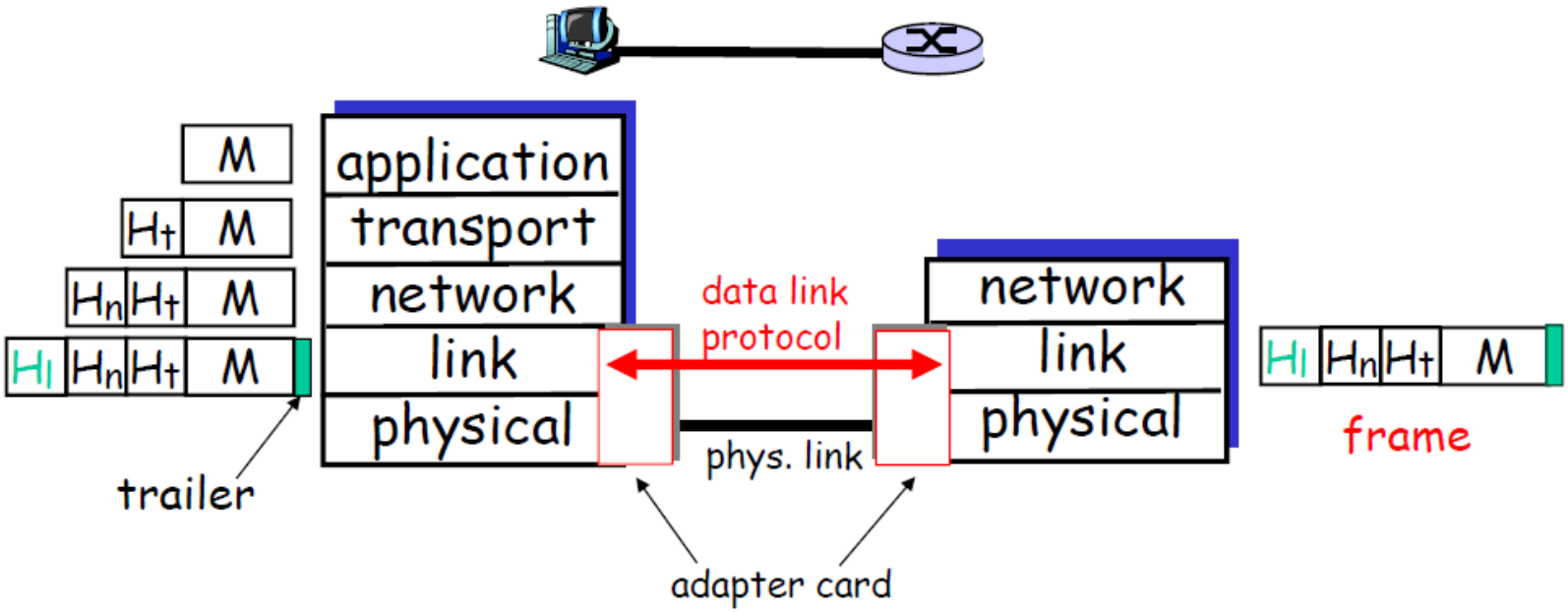
Internet protocol stack
Data Link Layer…



- Key Issues:
  - Framing. Why Framing?
  - Error control or reliable transmission, Flow control (Transport layer already has these services. Why do we need these again in the link-layer?).
  - Medium access control for local area networks
  - Activation, maintenance, & deactivation of data link connections
  - Half duplex and full duplex
    - Full duplex: nodes at both ends of a link may transmit at the same time (i.e., a node can both transmit and receive at the same time)
    - Half duplex: a node cannot both transmit and receive at the same time.
  - Addressing: Link-layer addressing. Why link-layer addresses when we already have network-layer addresses (IP addresses)?

What is a 'link'?

- A 'link' connects 2 adjacent layer-3 nodes (IP nodes in the Internet: hosts and routers) along a path (from the point of view of the layered architecture)



- Link can be:
  - Wire
  - Wireless
  - Local Area Network (LAN) (layer-2): e.g., Ethernet network, WiFi network
  - Wide Area Network (WAN) (Virtual link)

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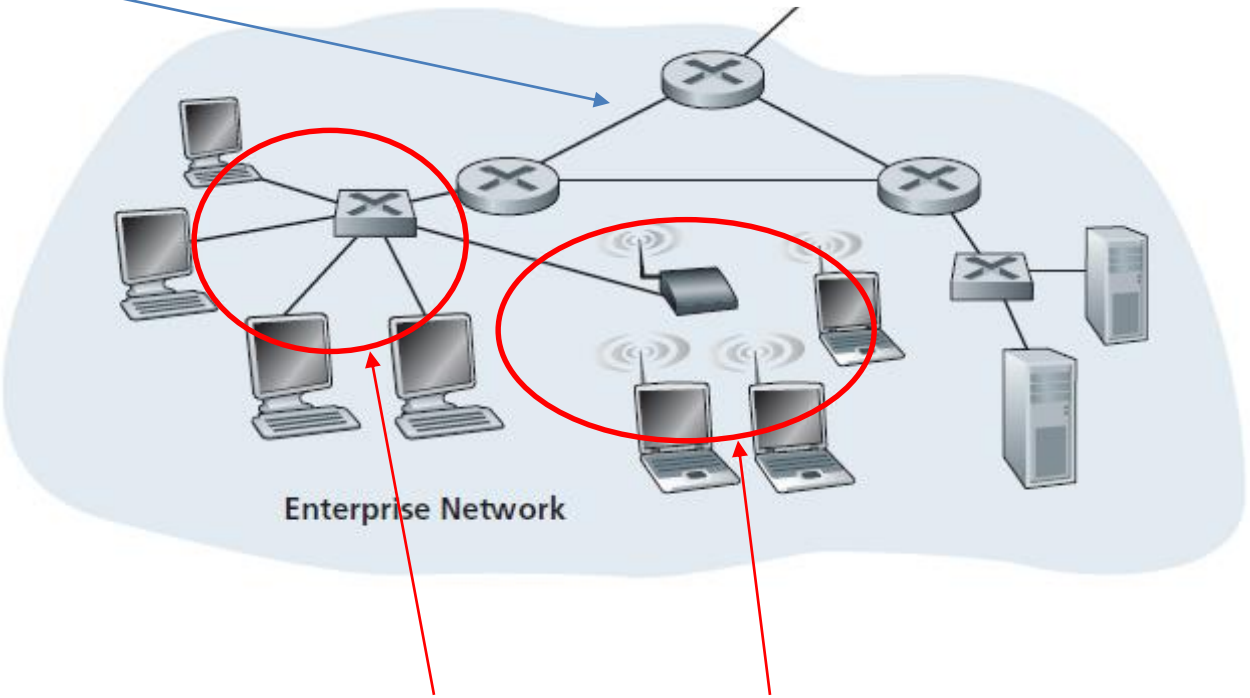

  - Local Area Network (LAN) (layer-2): e.g., Ethernet network, WiFi network
  - Wide Area Network (WAN) (Virtual link):

- Link can be:
  - Wire
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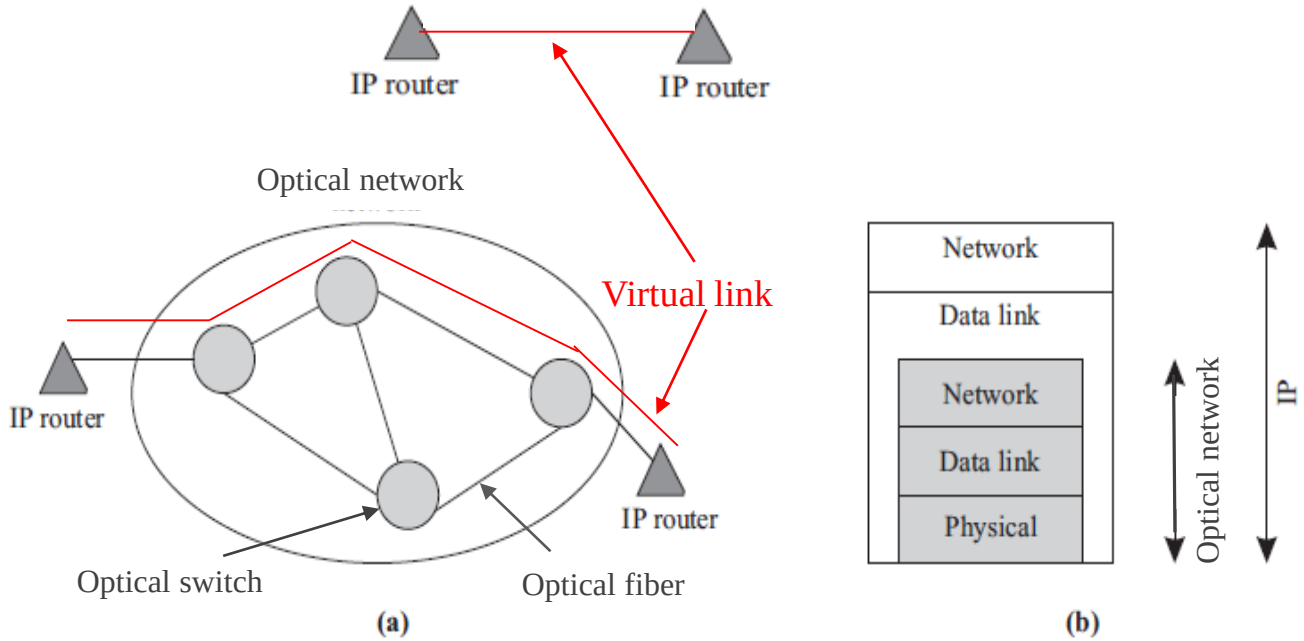
  - Local Area Network (LAN) (layer-2): e.g., Ethernet network, WiFi network
  - Wide Area Network (WAN) (Virtual link). Example:



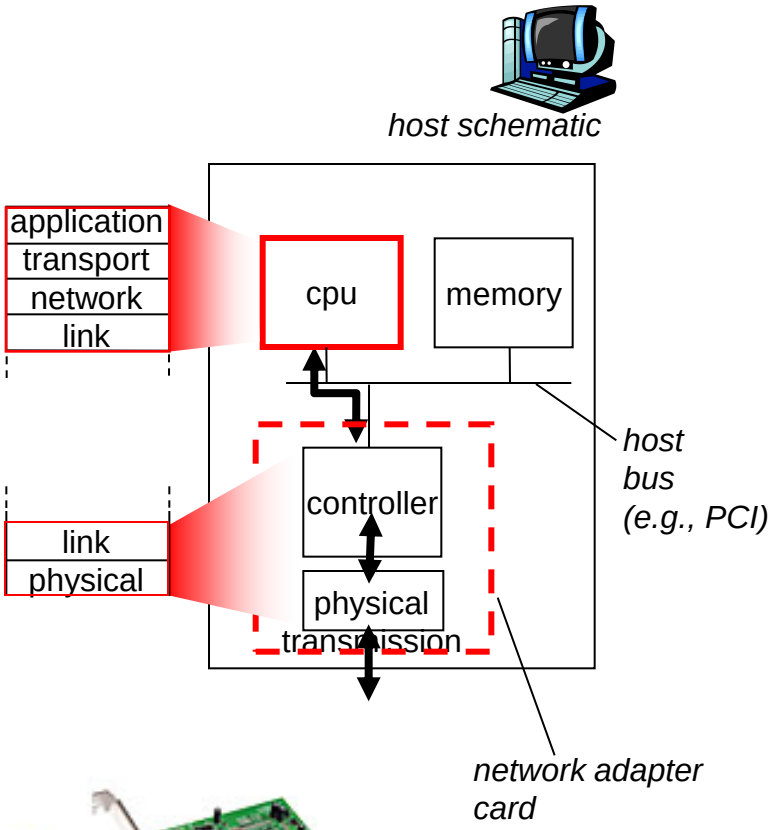
- IP network treats the optical network as providing it with point-to-point links between IP routers.
- The optical network itself, however, internally routes and switches connections, and in a sense, incorporates its own link, physical, and network layers (as shown in Fig (b))
- Examples of optical networks:
  - WDM (Wavelength Division Multiplexing) optical networks
    - IP/MPLS-over-WDM
  - SONET (Synchronous Optical Network)
    - IP-over-SONET

More on 'optical networks': CO514 Optical Communication Networks

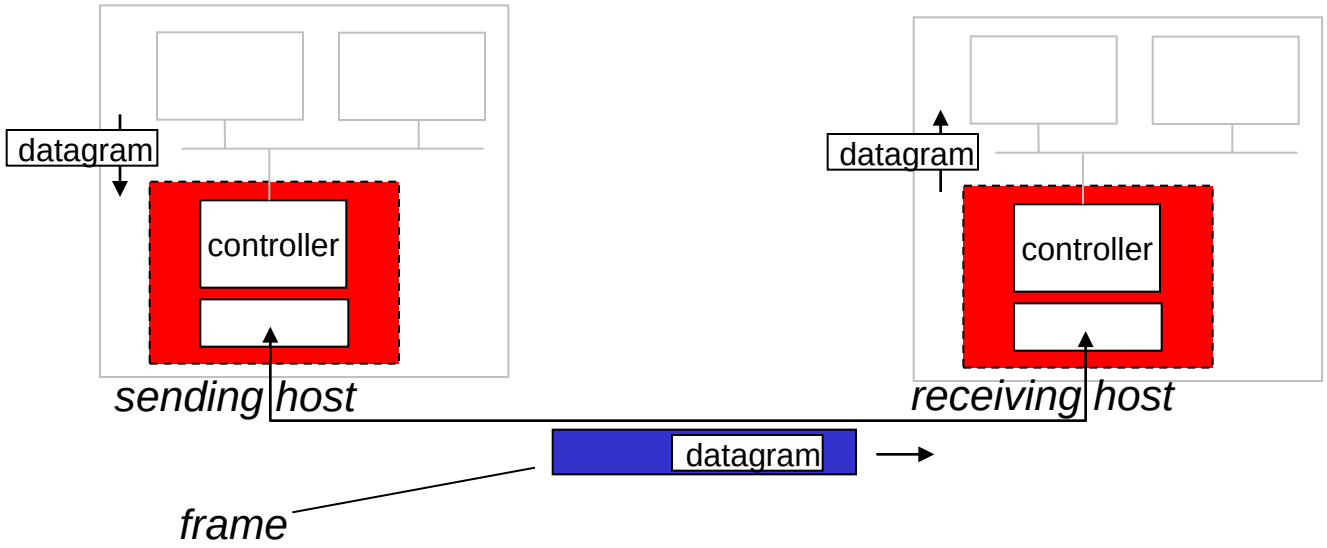
Similar virtual link concept can be seen in MPLS networks and Telephone networks connecting IP devices. Internet virtualizes the MPLS (and telephone) network, viewing the MPLS (telephone) network as a link-layer technology providing link-layer connectivity between two Internet hosts.

Where is the link layer implemented?

- in each and every host
- link layer implemented in "adaptor" (aka *network interface card* NIC)
  - Ethernet card, PCMCI card, 802.11 card
  - implements link, physical layer
- attaches into host's system buses
- combination of hardware, software, firmware



Adaptors Communicating



- sending side:
  - encapsulates datagram in frame
  - adds error checking bits, rdt, flow control, etc.
- receiving side
  - looks for errors, rdt, flow control, etc
  - extracts datagram, passes to upper layer at receiving side

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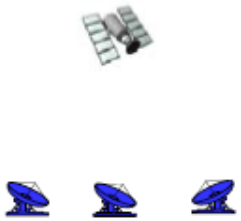
Links and Multiple Access Protocols

Two types of "links":

- point-to-point
  - fiber optic link
  - link between Ethernet switch and host
- broadcast (shared wire or medium)
  - old-fashioned Ethernet
  - shared coax cable in HFC (hybrid fiber cable)
  - wireless (802.11 LAN and others), etc.

shared cable (e.g., old Ethernet)

shared RF (e.g., 802.11 WiFi)



shared RF (satellite)

humans at a party (shared air, acoustics)

Multiple Access protocols

single shared broadcast channel

- two or more simultaneous transmissions by nodes may interfere with each other
  - ***collision*** if a node receives two or more signals at the same time

Multiple access or medium access control (MAC) protocols

- Need a protocol to determine when nodes can transmit
  - no out-of-band channel for coordination

MAC Protocols: a taxonomy

Three broad classes:

- Channel Partitioning
  - divide channel into smaller "pieces" (time slots, frequency bands, codes)
  - allocate a piece to each node for exclusive use
- Random Access
  - shared channel, collisions allowed
  - "recover" from collisions
- "Taking turns"
  - nodes take turns
  - a node with more to send can take a longer turn

Summary of MAC protocols

- channel partitioning
  - TDMA: Time Division **Multiple Access***
  - FDMA: Frequency Division Multiple Access
  - CDMA: Code Division Multiple Access

- random access (dynamic)
  - ALOHA, S-ALOHA
  - CSMA (Carrier Sense Multiple Access)
  - CSMA/CD (collision detection) used in Ethernet
  - CSMA/CA (collision avoidance) used in 802.11 (WiFi)

- taking turns
  - polling from central site
  - token passing
  - e.g., Bluetooth, FDDI, IBM Token Ring

* *there are multiple transmitters*

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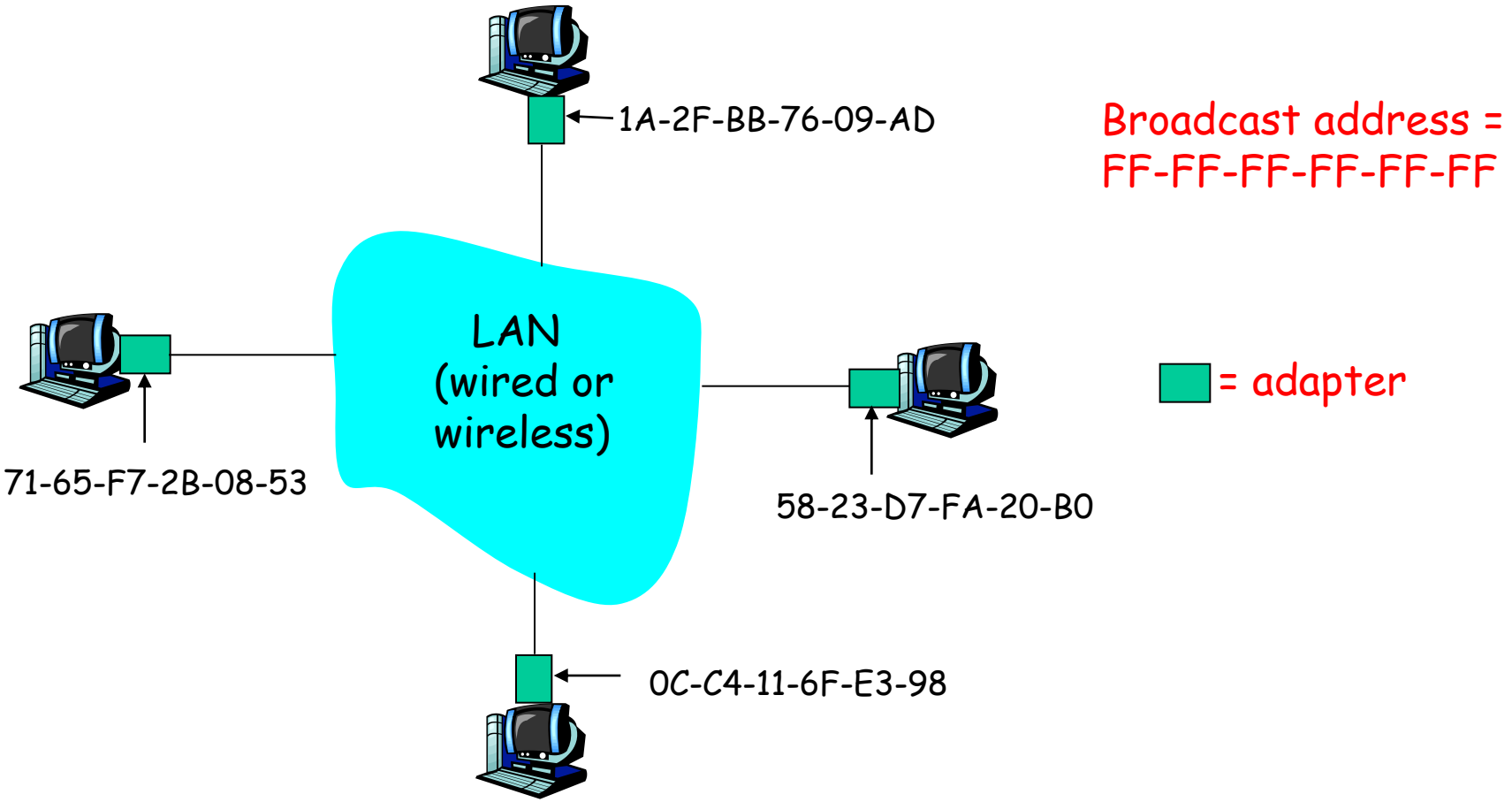
MAC and IP Addresses

- 32-bit IP address:
  - *network-layer* address
  - used to get datagram to destination IP subnet
- 48 bit MAC address (or LAN or *Ethernet* or link-layer address):
  - e.g.: 1A-2F-BB-76-09-AD (hexadecimal notation)
  - burned in NIC ROM (also sometimes software settable)
  - used to *get frame from one interface to another interface in same subnet*

LAN Addresses and ARP

Each adapter on LAN has unique LAN address

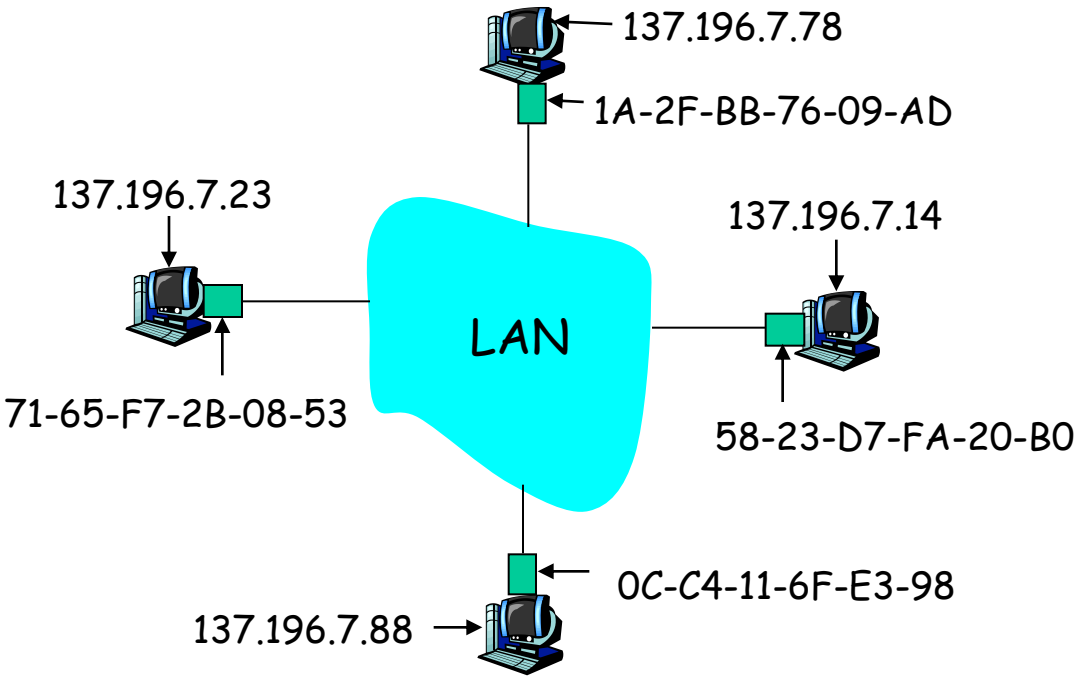


LAN Address (more)

- MAC address allocation administered by IEEE
- manufacturer buys portion of MAC address space (to assure uniqueness)
- analogy:
  - (a) MAC address: like Social Security Number
  - (b) 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 MAC address of B knowing B's IP address?



- Each IP node (host, 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 min)

ARP protocol: Same LAN (network)

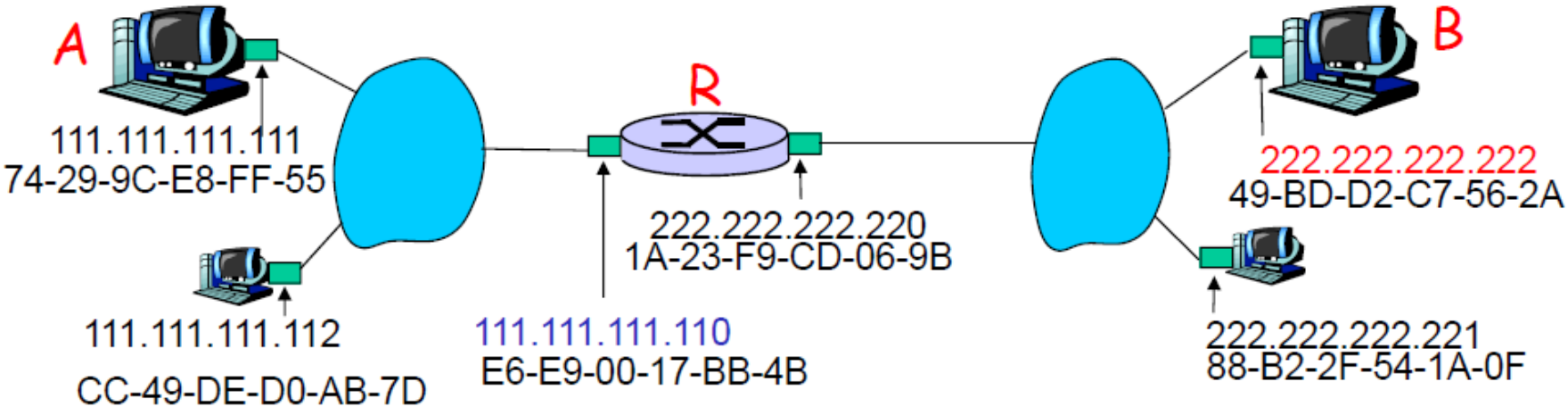
- A wants to send datagram to B, and B's MAC address not in A's ARP table.
- A broadcasts ARP query packet, containing B's IP address
  - dest MAC address = FF-FF-FF-FF-FF-FF
  - all machines on LAN receive ARP query
- B receives ARP packet, replies to A with its (B's) MAC address
  - frame sent to A's 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*

* ARP message is encapsulated within a link layer frame
* ARP: which layer?

Addressing: routing to another LAN

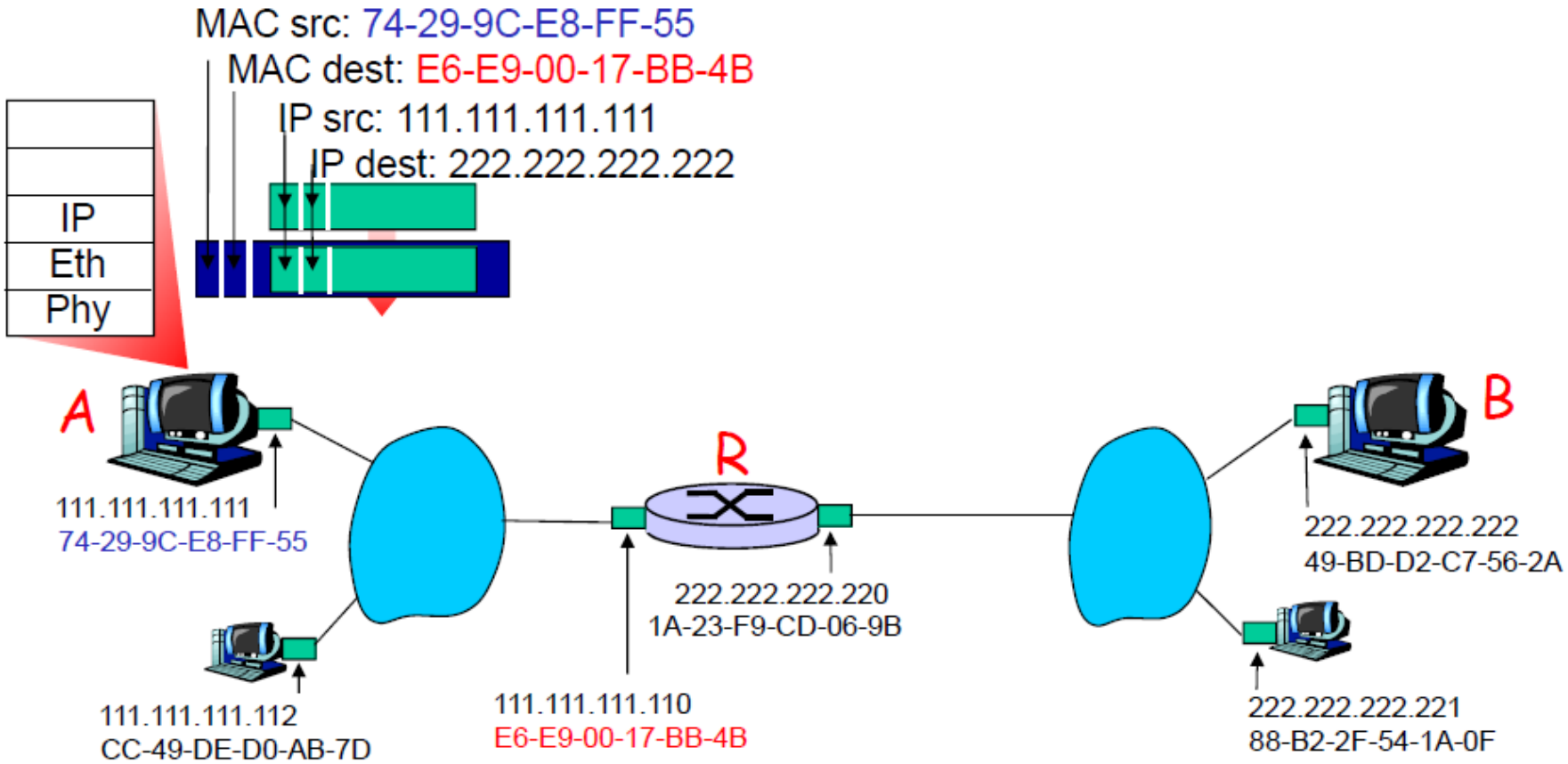
walkthrough: A sends datagram to B via R.

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



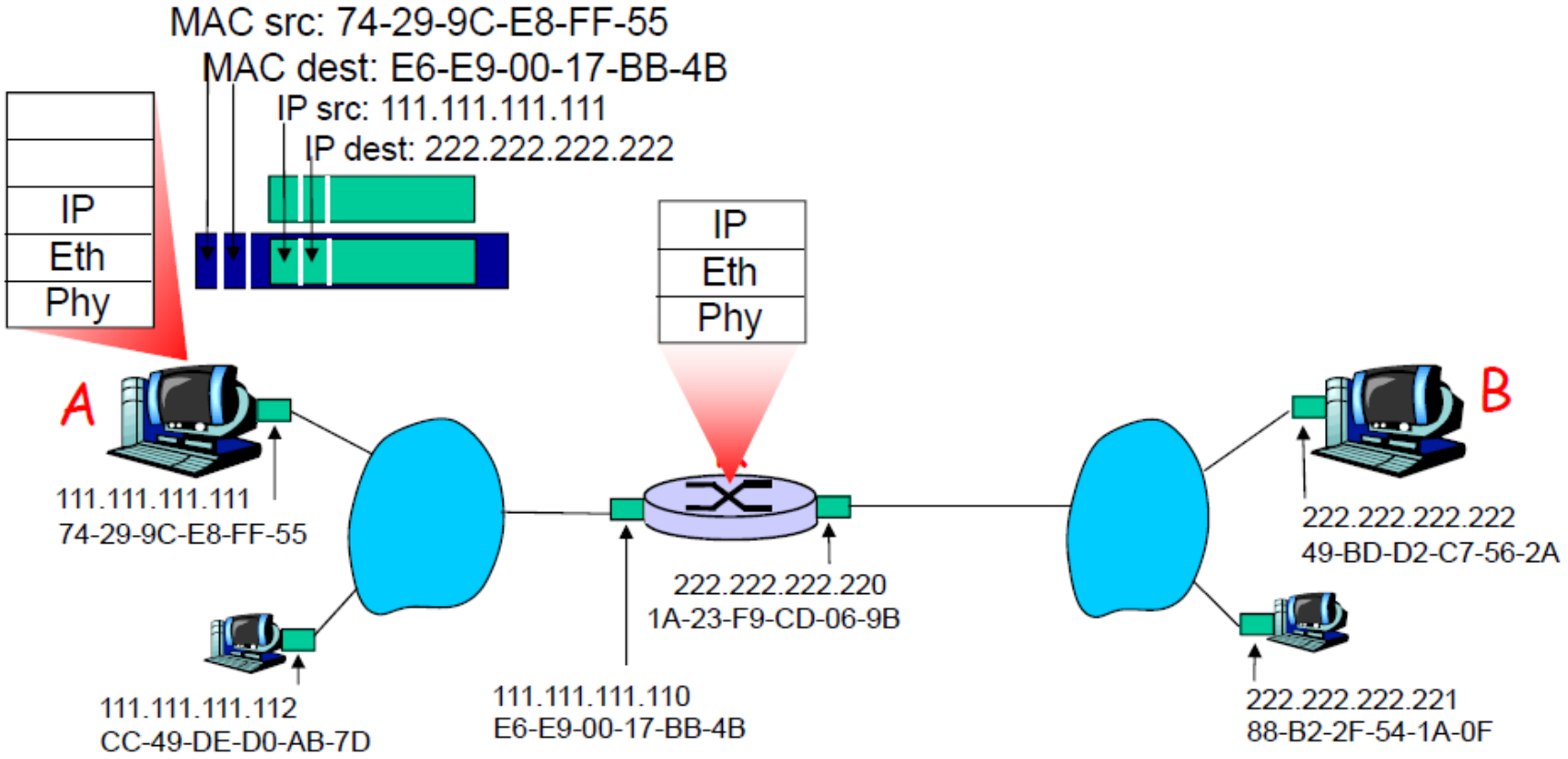
Addressing: routing to another LAN

- 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



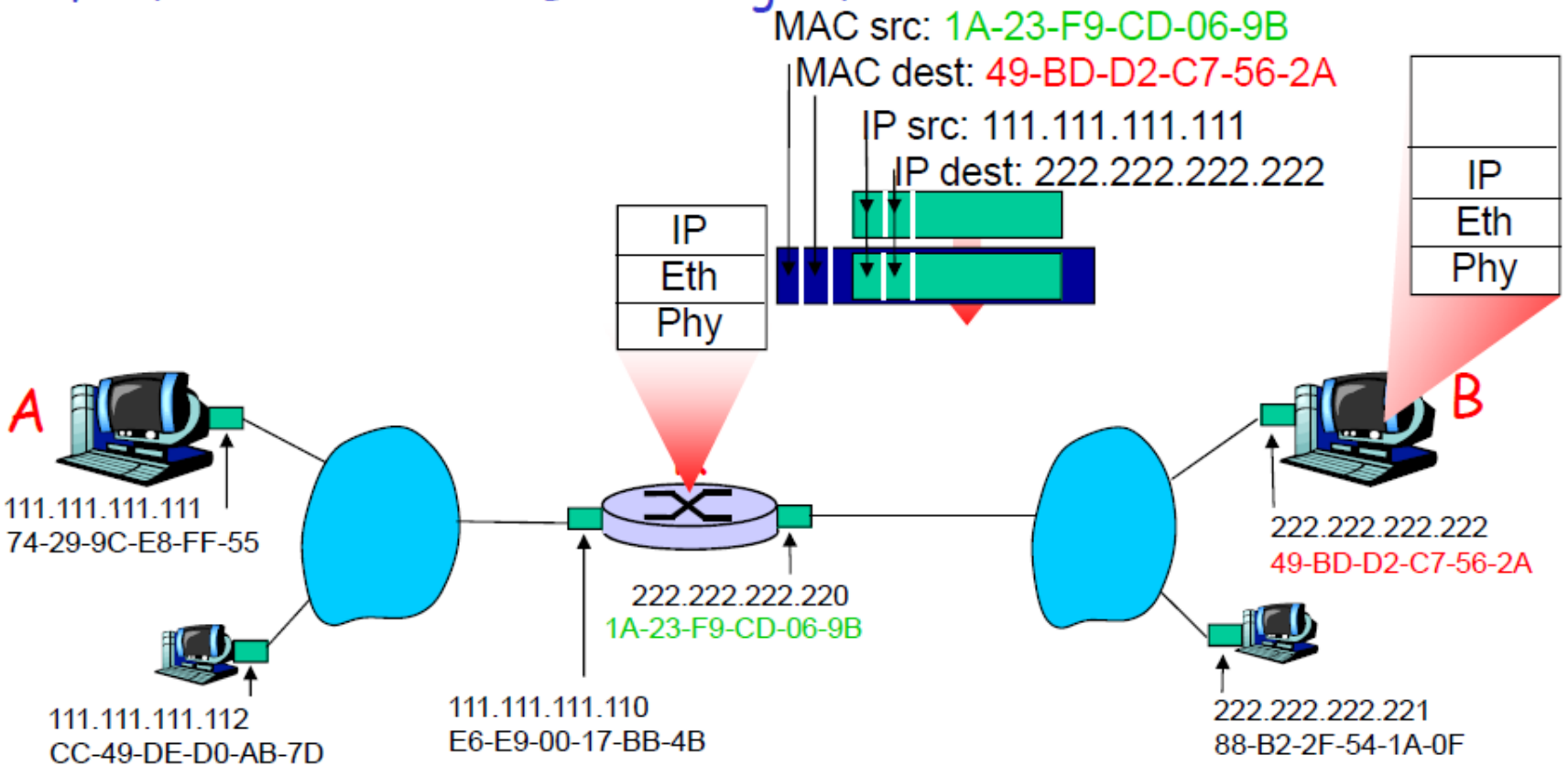
Addressing: routing to another LAN

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



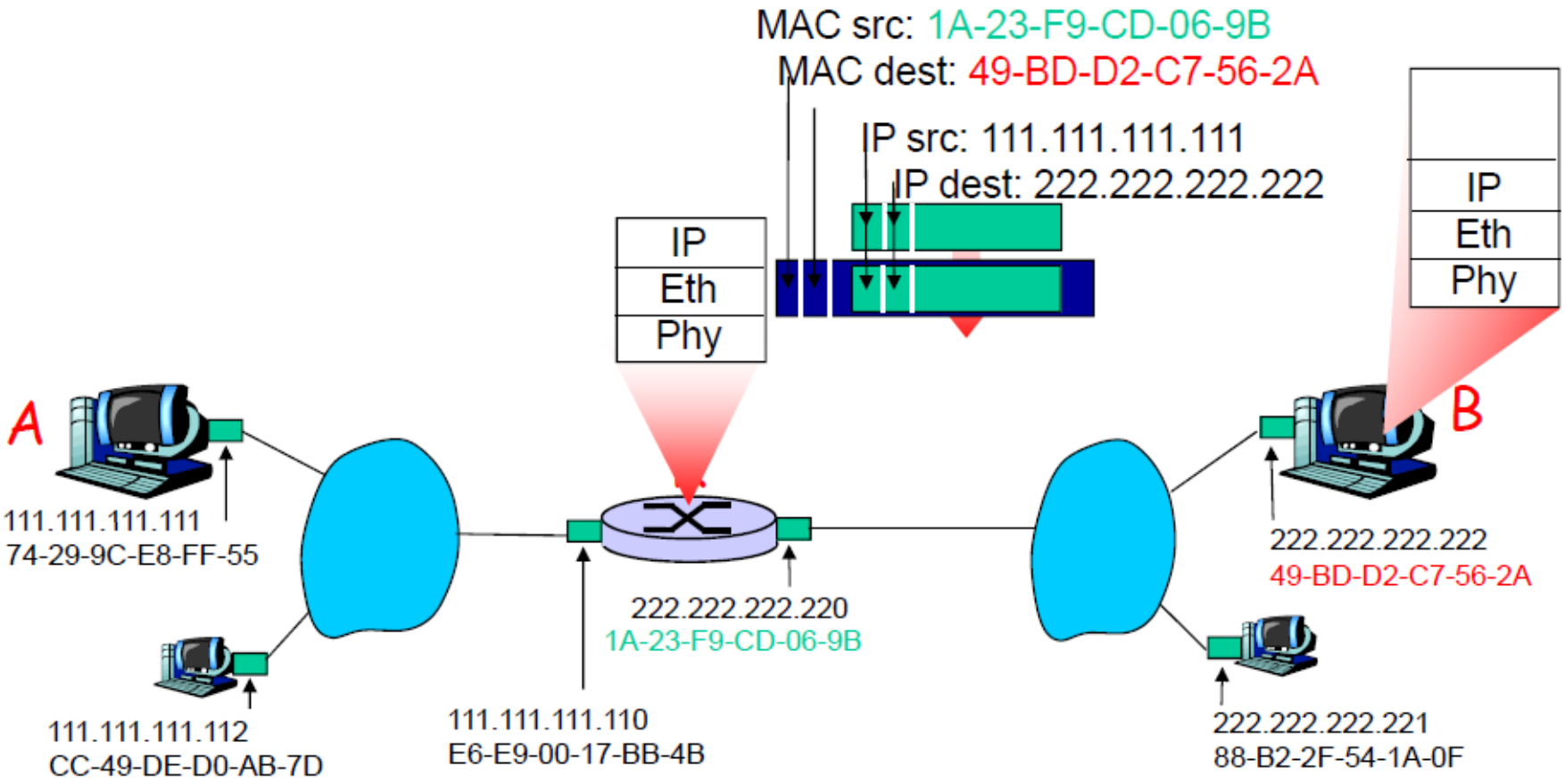
Addressing: routing to another LAN

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



Addressing: routing to another LAN

- R sends frame to B



Addressing: routing to another LAN

- R sends frame to B
- B's IP layer receives datagram