Lecture 26

- Sections 6.3.2, 6.3.3, 6.4 and 6.4.1
  - Multiple access protocols
    - Random access protocols
    - Taking turns protocols
  - Switched local area networks
    - Link-layer addressing and ARP

CSMA (Carrier Sense Multiple Access)

CSMA:

listen before transmit:

- If channel sensed idle: transmit entire frame
- If channel sensed busy: defer transmission

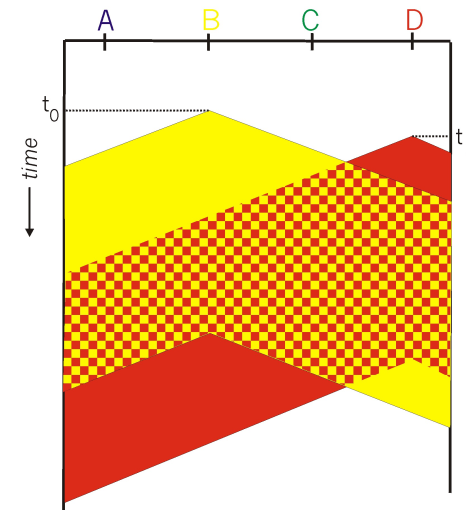
- human analogy: don't interrupt others!

Can collisions still occur?

CSMA collisions

collisions *can* still occur:
propagation delay means two nodes may not hear each other's transmission

collision:
entire packet transmission time wasted

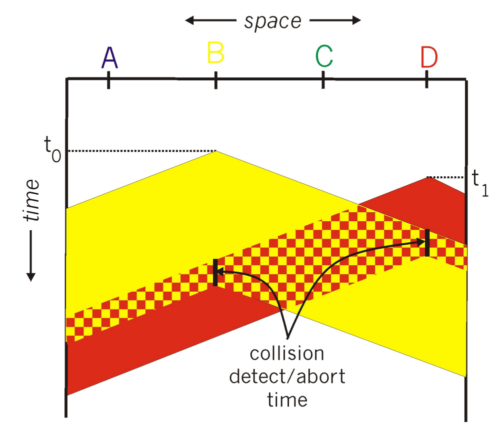


CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing, deferral as in CSMA

- listen after transmission for collisions:
  - if there is a collision:
    - collision *detected* within short time, and stop transmission (colliding transmissions aborted), hence reducing channel wastage
    - reschedule collided transmission after some random time
- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: received signal strength overwhelmed by local transmission strength

CSMA/CD collision detection



What is the maximum time to detect a collision, if any?

"Taking Turns" MAC protocols

channel partitioning MAC protocols:

- share channel *efficiently* and *fairly* at high load
- inefficient at low load: delay in channel access, 1/N bandwidth allocated even if only 1 active node!

random access MAC protocols

- efficient at low load: single node can fully utilize channel
- high load: collision overhead

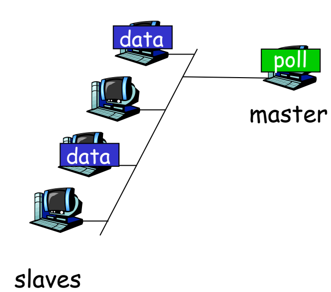
"taking turns" protocols

look for best of both worlds!

"Taking Turns" MAC protocols

Polling:

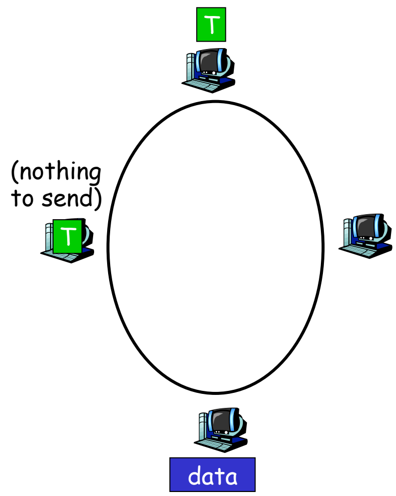
- master node "invites" slave nodes to transmit in turn
- asymmetric node capabilities
- concerns:
  - polling overhead
  - latency
  - single point of failure (master)



"Taking Turns" MAC protocols

Token passing:

- control **token** passed from one node to next sequentially.
- token message
- concerns:
  - token overhead
  - latency
  - single point of failure (token)



Summary of MAC protocols

- *channel partitioning* (static):
  - Time Division, Frequency Division
- *random access* (dynamic),
  - ALOHA, S-ALOHA, CSMA, CSMA/CD
  - carrier sensing: easy in some technologies (wire), hard in others (wireless)
  - CSMA/CD used in Ethernet
  - CSMA/CA used in 802.11
- *taking turns*
  - polling from central site (master-slave operation), token passing
  - Bluetooth, FDDI, IBM Token Ring

Link Layer

6.1 Introduction and services

6.2 Error detection and correction

6.3Multiple access protocols

6.4 Switched Local Area Networks

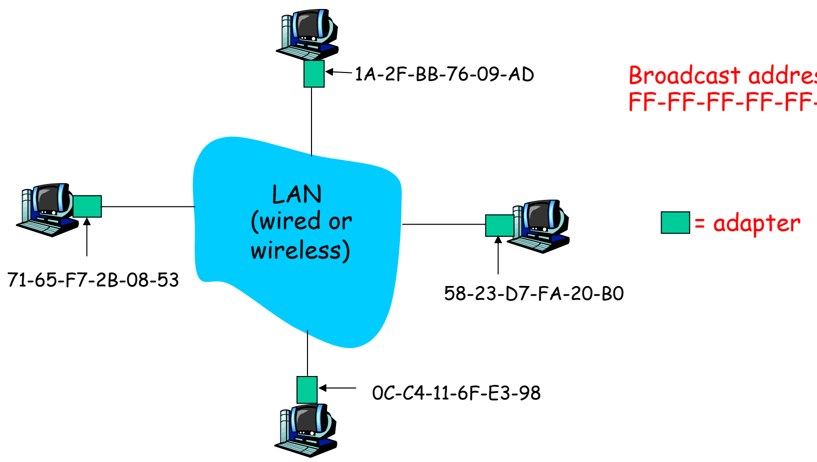
  6.4.1 Link-Layer Addressing and ARP

MAC Addresses and ARP

- 32-bit IP address:
  - *network-layer* address
  - used to get datagram to destination IP subnet
- MAC (or LAN or physical or Ethernet) address:
  - function: *get frame from one interface to another physically-connected interface (same network)*
  - 48 bit MAC address (for most LANs)
    - burned in NIC ROM, also sometimes software settable

LAN Addresses and ARP

Each adapter on LAN has unique LAN address



Broadcast address = FF-FF-FF-FF-FF-FF

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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

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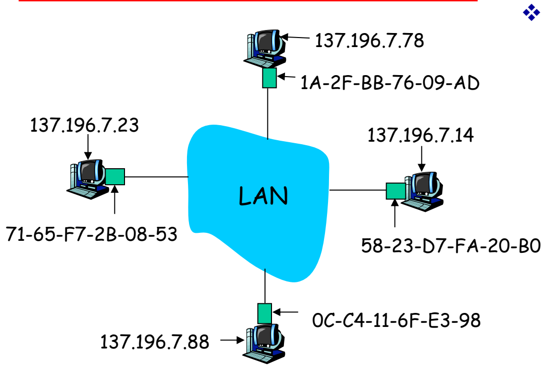
ARP: Address Resolution Protocol

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)

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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*

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ARP Packet Fromat

<table>
<tr><td colspan="4">32 BITS</td></tr>
<tr><td>8</td><td>8</td><td>8</td><td>8</td></tr>
<tr><td colspan="2">HARDWARE TYPE</td><td colspan="2">PROTOCOL TYPE</td></tr>
<tr><td>HARDWARE ADDRESS LENGTH</td><td>PROTOCOL ADDRESS LENGTH</td><td colspan="2">OPERATION</td></tr>
<tr><td colspan="4">SENDER HARDWARE ADDRESS (OCTETS 0 - 3)</td></tr>
<tr><td colspan="2">SENDER HARDWARE ADDRESS (OCTETS 4-5)</td><td colspan="2">SENDER IP ADDRESS (OCTETS 0-1)</td></tr>
<tr><td colspan="2">SENDER IP ADDRESS (OCTETS 2-3)</td><td colspan="2">TARGET HARDWARE ADDRESS (OCTETS 0-1)</td></tr>
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<tr><td colspan="4">TARGET IP ADDRESS</td></tr>
</table>

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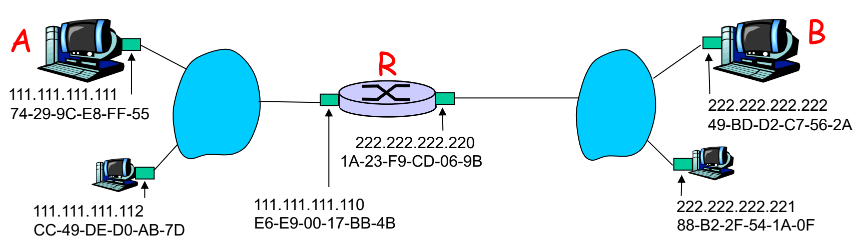
Addressing: routing to another LAN

walkthrough: send datagram from A to B via R.

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



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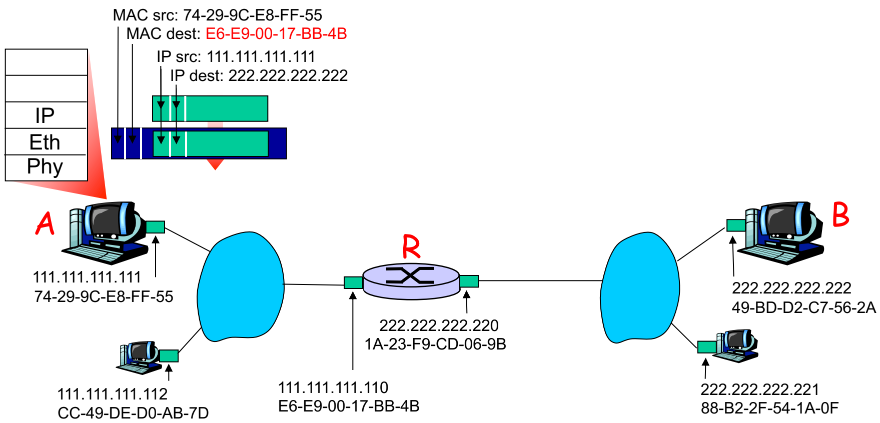
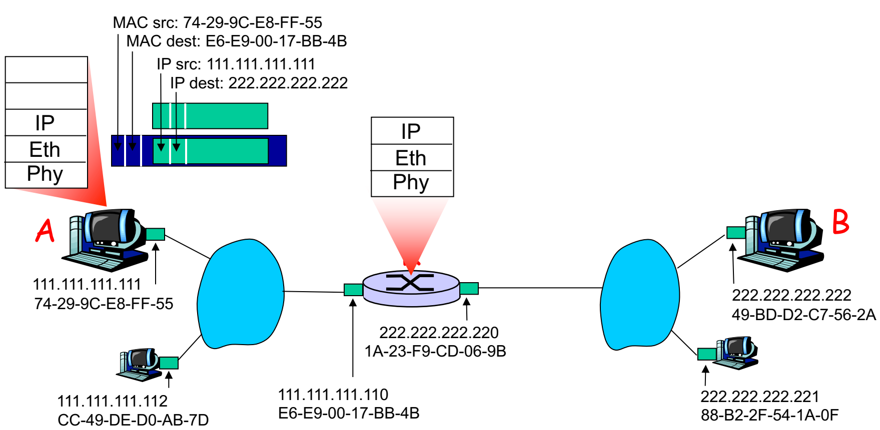
Addressing: routing to another LAN

- 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



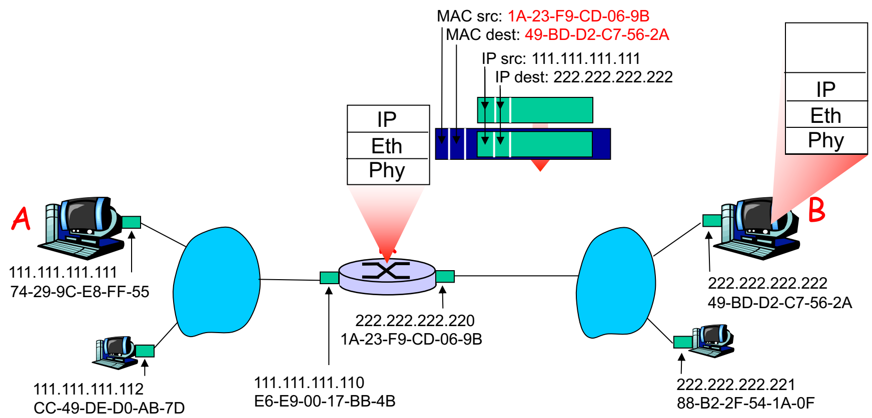
Addressing: routing to another LAN

- 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



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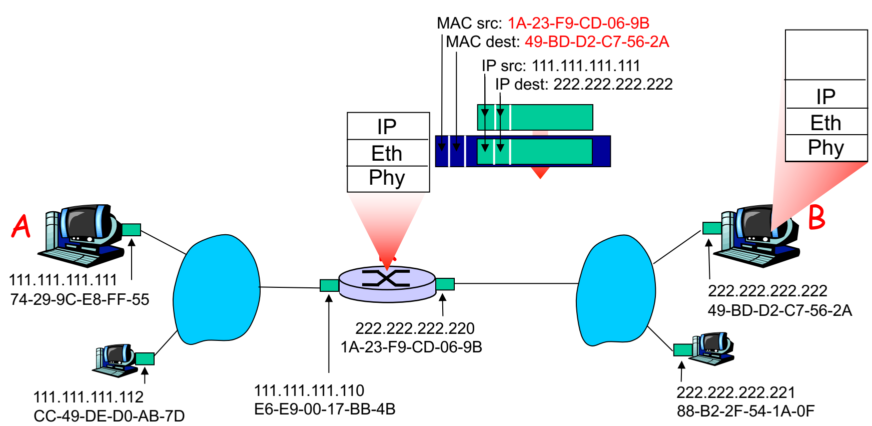

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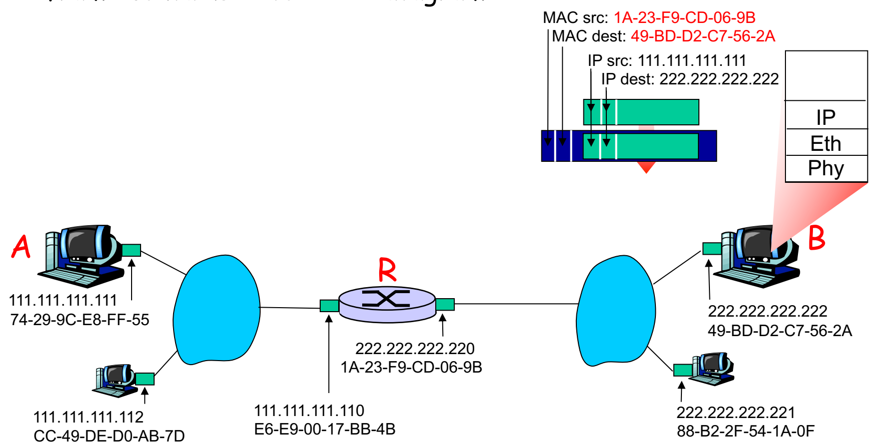

Link Layer

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  6.4.1 Link-Layer Addressing and ARP
  6.4.2 Ethernet