Link Layer: Wired and Wireless

Multi-Access Communication

Bandwidth sharing: two approaches

- contention-free
  - → main: TDMA, FDMA, mixture of FDMA + TDMA, CDMA
  - → other: token ring, FDDI, SDMA
  - → note: OFDM is a special case of FDMA
- contention-based
  - → main: CSMA/CD, CSMA/CA
  - → used in Ethernet, WLAN, RFID, etc.

Also called MAC (medium access control)

Now: multi-access link, hence need for names or addresses

→ 48-bit address hardware address

→ separate from IP address: software address

→ ultimately all IP addresses need to be translated to MAC addresses

Contention-free MAC:

→ emphasis on orderly deterministic sharing

→ reservation of network resources by manager

→ typically centralized

→ e.g., TDMA: who gets what time slots

→ e.g., FDMA: who gets what carrier frequency

→ e.g., CDMA: who gets what code

Contention-based MAC:

→ single carrier frequency shared by multiple devices

→ orderly in the sense that devices obey rules, i.e., follow protocol

→ unorderly in the sense that "you get what you get"

→ performance is variable since resources are not reserved

→ simultaneous access: collision

→ likely results in corrupted bits

Thus requires

→ error detection (e.g., checksum)

→ error correction (e.g., ARQ, FEC)

Contention-free MAC: we already know TDMA, FDMA, CDMA

→ specific real-world examples will be discussed for wireless systems

Look at contention-based MAC.

Basic features:

- when NIC has data to send
  - → just send: called multiple access (MA)
  - → only send if link is idle: carrier sense (CS)
- if two or more users send at the same time, data can become corrupted
  - → interference between electromagnetic waves makes decoding bits difficult at receiver
  - → e.g., bit flips
  - → called collision

Collision need not always cause bit flips

→ if two packets collide and one packet has much stronger signal strength than the other: stronger packet may be successfully decoded

→ because of different power levels

→ called capture effect

→ "survival of the strongest"

Clearly much less orderly than contention-free MACs.

Simplest content-based MAC: MA

→ just send if there is something to send

→ not even CS

Used in real systems?

→ yes!

→ ALOHA (early 1970s)

→ packet network connecting Univ. of Hawaii island campuses

→ deployed system solving real-world problem

→ ∼40 years before boom of wireless data networks

→ visionary work by Norman Abramson

→ later adopted by Ethernet (Metcalfe), and today, WLANs

Question: why not use carrier sense (CS)?

Additional features:

- NIC can detect if someone else is using the channel
  - → carrier sense (CS)
  - → rule: if someone else talks, don't talk
  - → imposes gentlemanly (i.e., cooperative) behavior
  - → not always practically feasible
- NIC can detect if collision has occurred
  - → called collision detection (CD)
  - → not always feasible: especially wireless
- NIC attempts to avoid collision by sending probe packet
  - → called collision avoidance (CA)
  - → probe packet reserves bandwidth for following data packet
  - → problem with this method?

Two example real-world systems:

- $\longrightarrow$ Ethernet: MA, CS, CD
- $\longrightarrow$ WLAN: MA, CS, CA

Why not just use TDMA, FDMA or CDMA?

When is it better to use TDMA, FDMA, CDMA?

Benefits of contention-based MAC:

- when not too many users, faster response time
  - → minimal coordination overhead
  - → e.g., in TDMA need to request and reserve slots
  - → management/signaling packets incur delay and consume bandwidth
- decentralized
  - → minimal configuration overhead
  - → to join: just send
  - → except for security concerns (e.g., Purdue's PAL)
  - → a good idea?

Drawbacks of contention-based MAC:

- when many users share, degraded throughput

  → collision wastes bandwidth

- lack of QoS (quality of service) assurances

  → "you get what you get"

  → called best effort

  → problematic for real-time traffic (e.g., VoIP, video conferencing)

  → IEEE 802.11 WLAN standard has provisions to suppport telephony: not used in practice

When to use what?

⟶ contention-free vs. contention-based