Wireless MACs

• How do wireless nodes share a single link? (Yes, this is WiFi!)
  • Build on our simple, wired model
Wireless Complications

• Wireless is more complicated than wired (surprise!)
  1. Media is infinite – can’t reliably Carrier Sense
  2. Nodes usually can’t hear while sending – can’t Collision Detect

≠ CSMA/CD
No CS: Different Coverage Areas

- Wireless signal is broadcast and received nearby, where there is sufficient SNR
No CS: Hidden Terminals

- Node C is a **hidden terminal** when A sends to B
  - Similarly, A is a hidden terminal when C sends to B
  - A, C can’t hear each other (to coordinate) yet collide at B
  - We want to avoid the inefficiency of collisions
No CS: Exposed Terminals

• B, C are **exposed terminals** when sending to A, D
  • Can hear each other yet don’t collide at receivers A and D
  • We want to send concurrently to increase performance
Nodes Can’t Hear While Sending

• With wires, detecting collisions (and aborting) lowers their cost
• With wireless, more wasted time
Wireless Problems:

• Ideas?
MACA: Multiple Access w/ Collision Avoidance

• MACA uses a short handshake instead of CSMA (Karn, 1990)
  • 802.11 uses a refinement of MACA (later)

• Protocol rules:
  1. A sender node transmits a RTS (Request-To-Send, with frame length)
  2. The receiver replies with a CTS (Clear-To-Send, with frame length)
  3. Sender transmits the frame while nodes hearing the CTS stay silent

• Collisions on the RTS/CTS are still possible, but less likely
MACA – Hidden Terminals

• A → B with hidden terminal C
  1. A sends RTS, to B
MACA – Hidden Terminals (2)

• A→B with hidden terminal C
  2. B sends CTS to A, and C overhears
MACA – Hidden Terminals (3)

• A→B with hidden terminal C
  3. A sends frame while C defers

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MACA – Exposed Terminals

• B→A, C→D as exposed terminals
  • B and C send RTS to A and D
MACA – Exposed Terminals (2)

• B → A, C → D as exposed terminals
  • A and D send CTS to B and C
MACA – Exposed Terminals (3)

• B → A, C → D as exposed terminals
  • A and D send CTS to B and C
802.11, or WiFi

• Very popular wireless LAN started in the 1990s
• Clients get connectivity from a (wired) AP (Access Point)
• It’s a multi-access problem 😊
• Various flavors have been developed over time
  • Faster, more features
802.11 Physical Layer

• Uses 20/40 MHz channels on ISM (unlicensed) bands
  • 802.11b/g/n on 2.4 GHz
  • 802.11 a/n on 5 GHz

• OFDM modulation (except legacy 802.11b)
  • Different amplitudes/phases for varying SNRs
  • Rates from 6 to 54 Mbps plus error correction
  • 802.11n uses multiple antennas
    • Lots of fun tricks here
802.11 Link Layer

- Multiple access uses CSMA/CA (next); RTS/CTS optional
- Frames are ACKed and retransmitted with ARQ
- Funky addressing (three addresses!) due to AP
- Errors are detected with a 32-bit CRC
- Many, many features (e.g., encryption, power save)
Centralized MAC: Cellular

- Spectrum suddenly very scarce
  - We can’t waste all of it sending JAMs
- We have QoS requirements
  - Can’t be as loose with expectations
  - Can’t have traffic fail
- We also have client/server
  - Centralized control
  - Not peer-to-peer/decentralized
GSM MAC

- FDMA/TDMA
- Use one channel for coordination – Random access w/BEB (no CSMA, can’t detect)
- Use other channels for traffic
  - Dedicated channel for QoS
Recap: MAC layer ideas

• Random wait times upon collisions
• Carrier sense
  • Persistence
• Collision detection
• Binary exponential backoff
• RTS-CTS for hidden and exposed terminals
Link Layer: Switching
Switching

• How do we connect nodes with a **switch** instead of multiple access
  - Uses multiple links/wires
  - Basis of modern (switched) Ethernet
Switched Ethernet

• Hosts are wired to Ethernet switches with twisted pair
  • Switch serves to connect the hosts
  • Wires usually run to a closet
What’s in the box?

• Remember from protocol layers:

Hub, or repeater

Switch

Router

All look like this:
Inside a Hub

- All ports are wired together; more convenient and reliable than a single shared wire
Inside a Repeater

• All inputs are connected; then amplified before going out
Inside a Switch

- Uses frame addresses (MAC addresses in Ethernet) to connect input port to the right output port; multiple frames may be switched in parallel.
Inside a Switch (2)

- Port may be used for both input and output (full-duplex)
  - Just send, no multiple access protocol
Inside a Switch (3)

• Need buffers for multiple inputs to send to one output
Inside a Switch (4)

- Sustained overload will fill buffer and lead to frame loss

![Diagram of a switch with input and output buffers and fabric, highlighting a loss point](image-url)
Advantages of Switches

• Switches and hubs (mostly switches) have replaced the shared cable of classic Ethernet
  • Convenient to run wires to one location
  • More reliable; wire cut is not a single point of failure that is hard to find

• Switches offer scalable performance
  • E.g., 100 Mbps per port instead of 100 Mbps for all nodes of shared cable / hub