

Link Layer II: MACA and MACAW

Wireless Networks L08
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Medium access: Timeline

Packet radio

Wireless LAN

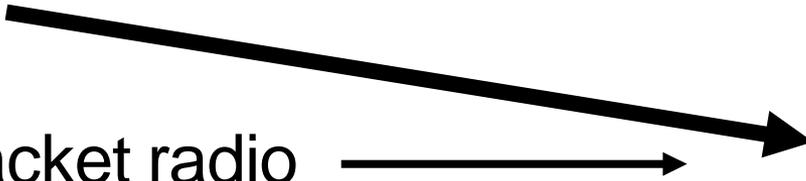
Wired LAN

ALOHAnet

1960s



Amateur packet radio



Ethernet

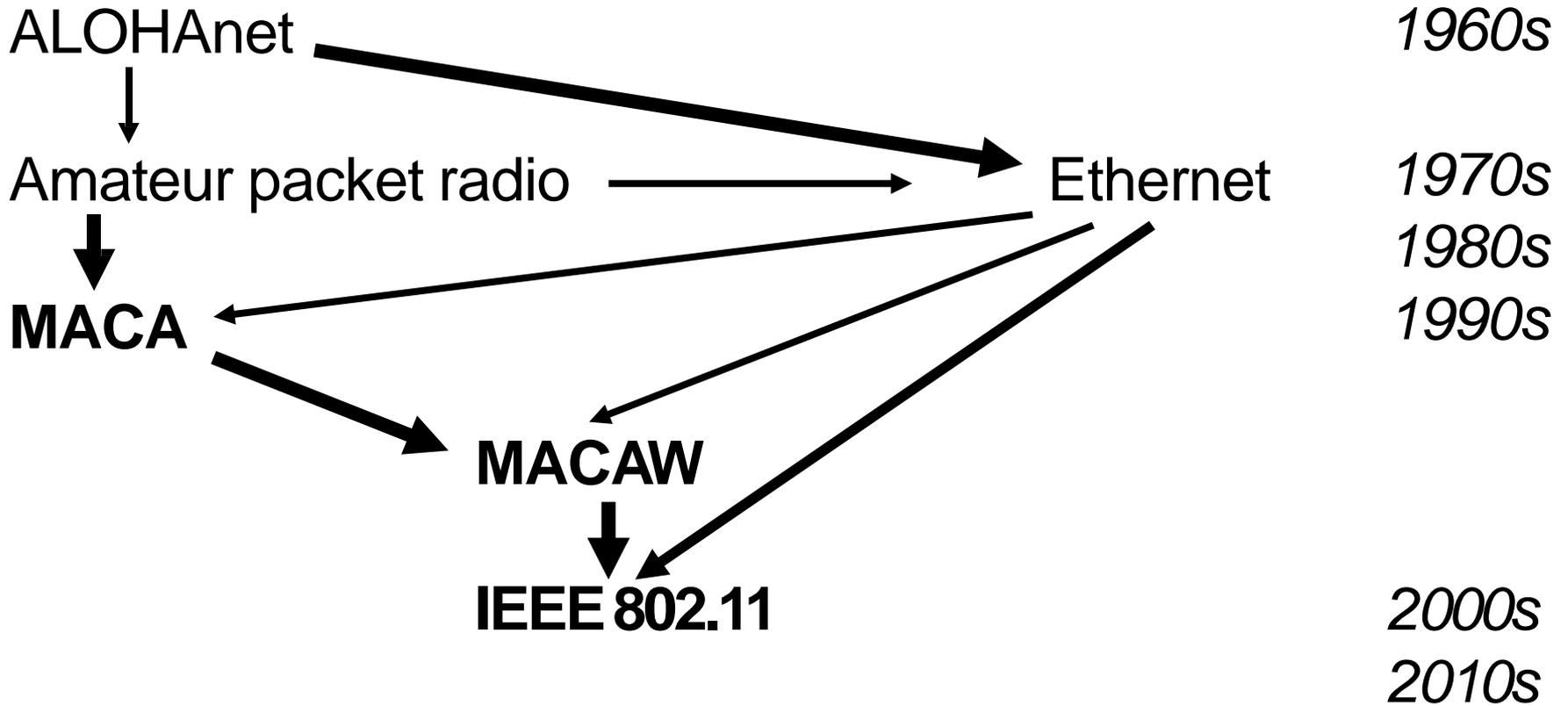
1970s

Medium access: Timeline

Packet radio

Wireless LAN

Wired LAN



Today: Wi-Fi Above the PHY

1. MACA

- Carrier sense in the wireless medium
- Hidden and exposed terminal problems

2. MACAW

3. 802.11 MAC layer

Fundamentals: Spectrum and Capacity

- A particular radio transmits over some range of frequencies; its **bandwidth**, in the physical sense
- When we've many senders near one another, how do we allocate spectrum among senders? Goals:
 - Support for arbitrary communication patterns
 - Simplicity of hardware
 - Robustness to interference
- **Shannon's Theorem:** there's a fundamental limit to channel capacity over a given spectrum range

Multi-channel

- Suppose we have 100 MHz of spectrum to use for a wireless LAN
- **Strawman:** Subdivide into **50** channels of **2 MHz** each: FDMA, narrow-band transmission
 - Radio hardware simple, channels don't mutually interfere, **but**
 - **Multi-path fading** (mutual cancellation of out-of-phase reflections)
 - Base station can allocate channels to users. How do you support **arbitrary communication patterns?**

Idea: Use a single, shared channel

- Spread transmission across whole 100 MHz of spectrum
 - **Remove constraints** assoc. w/one channel per user
 - **Robust to multi-path fading**
 - Some frequencies likely to arrive intact
 - **Supports peer-to-peer communication**
- **Collisions:** Receiver must hear ≤ 1 strong transmission at a time
- So adopt **carrier sense** and **deference** from Ethernet
 - **Listen** before sending, **defer** to ongoing

Assumptions and goals

- Assumptions
 - **Uniform, circular** radio propagation
 - Fixed transmit power, all same ranges
 - **Equal** interference and **transmit** ranges

**Radios modeled as “conditionally connected”
wires based on circular radio ranges**

- Goals
 - Fairness in sharing of medium
 - Efficiency (total bandwidth achieved)
 - Reliability of data transfer at MAC layer

Concurrency versus Taking Turns

- Far-apart links should **send concurrently**:

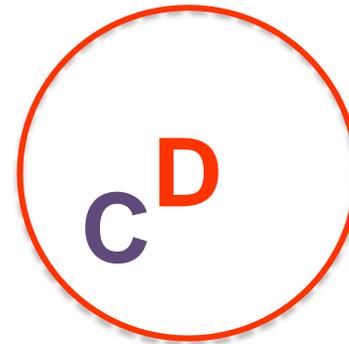
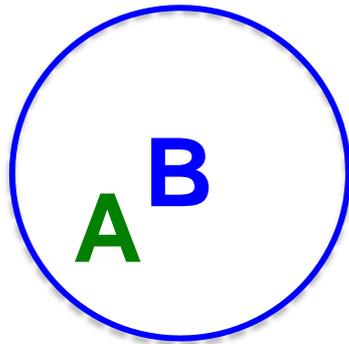


- Nearby links should **take turns**:



When Does CS Work Well?

- Two transmission pairs are **far away** from each other
 - **Neither sender** carrier-senses the other

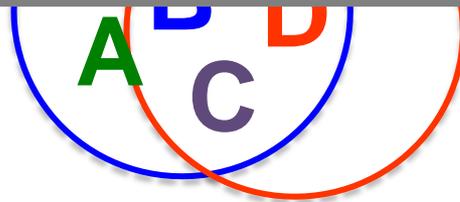


B transmits to A, **while** D transmits to C.

When Does CS Work Well?

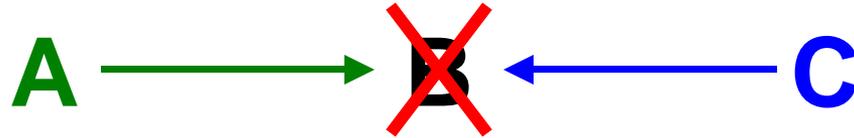
- Both transmitters **can carrier sense** each other
 - Carrier sense uses **thresholded correlation value** to determine if medium occupied

But what about cases in between these extremes?



B transmits to A, D transmits to C, taking turns.

Hidden Terminal Problem



- C can't hear A, so will transmit while A transmits
 - **Result: Collision at B**
- **Carrier Sense** insufficient to detect all transmissions on wireless networks!
- **Key insight:** Collisions are **spatially located** at the receiver

Exposed Terminal Problem



- If C transmits, does it cause a collision at A?
 - **Yet C cannot transmit while B transmits to A!**
- **Same insight: Collisions spatially located at receiver**
- One possibility: **directional antennas** rather than omnidirectional. **Why does this help? Why is it hard?**

MACA: Multiple Access with Collision Avoidance

- **Carrier sense** became adopted in packet radio
- But **distances** (cell size) remained large
- **Hidden and Exposed terminals abounded**
- **Simple solution:** use **receiver's** medium state to determine **transmitter** behavior

RTS/CTS

- Exchange of two short messages: **Request to Send (RTS)** and **Clear to Send (CTS)**
- **Algorithm**
 1. A sends an **RTS** (tells B to prepare)
 2. B replies an **CTS** (echoes message length)
 3. A sends its **Data**



Deference to CTS

- Hear CTS → Defer for **length of expected data** transmission time
 - **Solves hidden terminal** problem



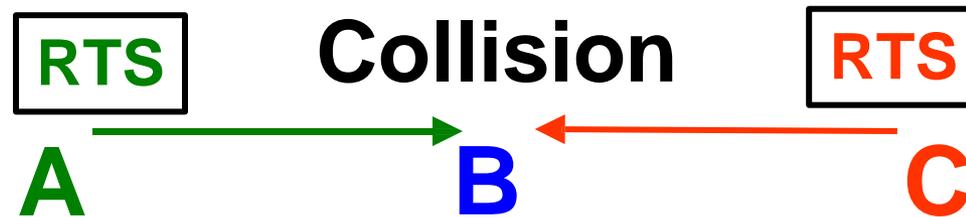
Deference to RTS

- Hear RTS → Defer **one CTS-time** (*why?*)
- **MACA: No carrier sense before sending!**
 - Karn concluded useless because of **hidden** terminals
- So **exposed** terminals **can transmit concurrently:**



Collision!

- A's RTS collides with C's RTS, both are lost at B
 - B will not reply with a CTS



- Might collisions involving data packets occur?
 - Not according to our **(unrealistic)** assumptions
 - But Karn **acknowledges interference range > communication range**

BEB in MACA

- When collisions arise, MACA senders **randomly backoff** like Ethernet senders then **retry the RTS**
- How long do collisions take to **detect** in the Experimental Ethernet?
- **What size** should we make MACA backoff slots?

BEB in MACA

- Current backoff constant: CW
- MACA sender:
 - $CW_0 = 2$ and $CW_M = 64$
 - Upon **successful** RTS/CTS, $CW \leftarrow CW_0$
 - Upon **failed** RTS/CTS, $CW \leftarrow \min[2CW, CW_M]$
- Before retransmission, wait a uniform random **number of RTS lengths** (30 bytes) in **[0, CW]**
 - 30 bytes = 240 μs