IEEE 802.11 MAC

$\longrightarrow$ CSMA/CA with exponential backoff

$\longrightarrow$ almost like CSMA/CD

$\longrightarrow$ drop CD

$\longrightarrow$ CSMA with explicit ACK frame

$\longrightarrow$ added optional feature: CA (collision avoidance)

Two modes for MAC operation:

- Distributed coordination function (DCF)

  $\rightarrow$ multiple access

- Point coordination function (PCF)

  $\rightarrow$ polling-based priority

. . . neither PCF nor CA used in practice

CSMA: (i) explicit ACK and (ii) exponential backoff

Sender:

- MAC (firmware in NIC) receives frame from upper layer (i.e., device driver)
- Goto `Backoff` procedure
- Transmit frame
- Wait for ACK
- If timeout, goto `Backoff` procedure

Receiver:

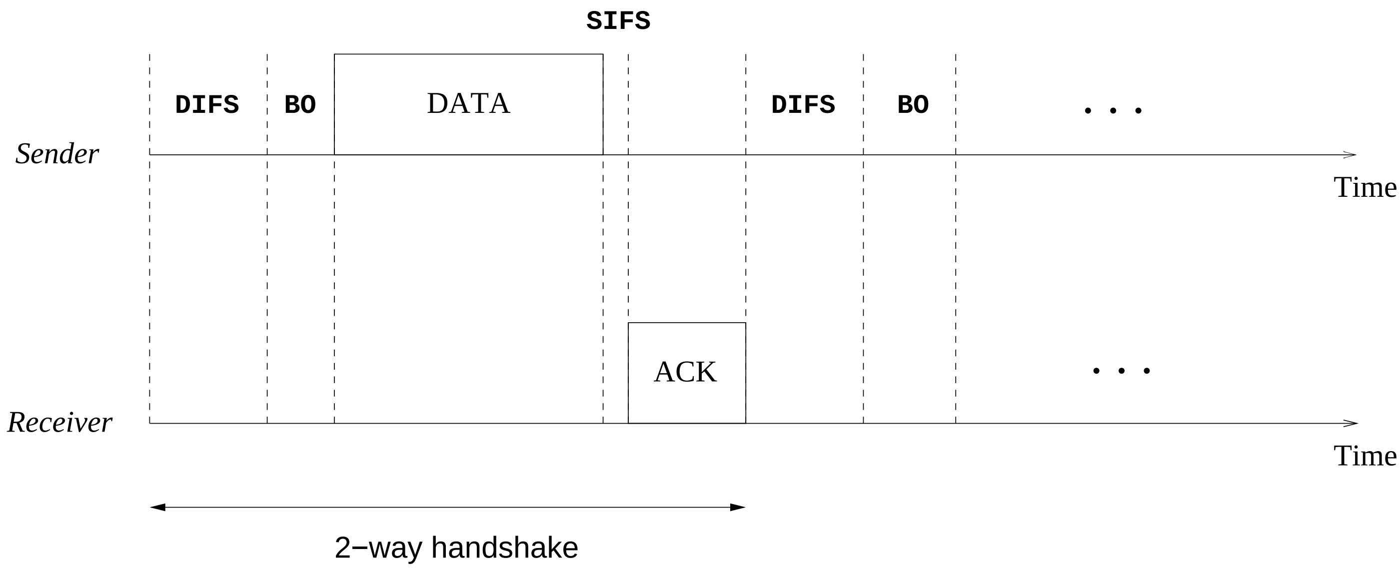
- Check if received frame is ok
- Wait for SIFS
- Transmit ACK

`Backoff`:

- If due to timeout, double contention window (`CW`)
- Else wait until channel is idle plus an additional DIFS
- Choose random waiting time between [1, `CW`]

  → `CW` is in units of slot time
- Decrement `CW` when channel is idle
- Return when `CW` = 0

Timeline without collision:



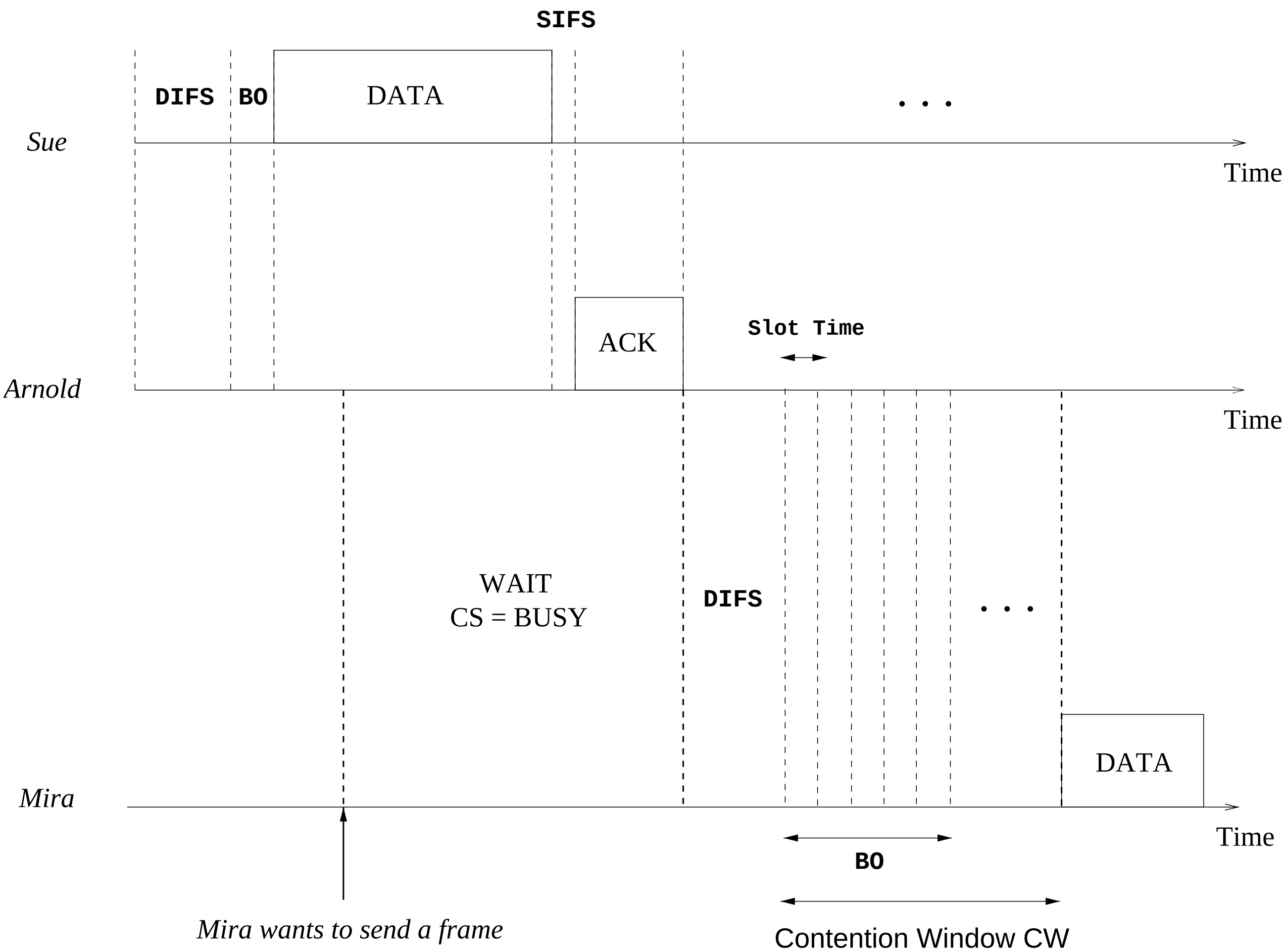
- SIFS (short interframe space): 10 μs
- Slot Time: 20 μs
- DIFS (distributed interframe space): 50 μs

  $\rightarrow$ DIFS = SIFS + 2 $\times$ slot time
- BO: variable back-off (within one `CW`)

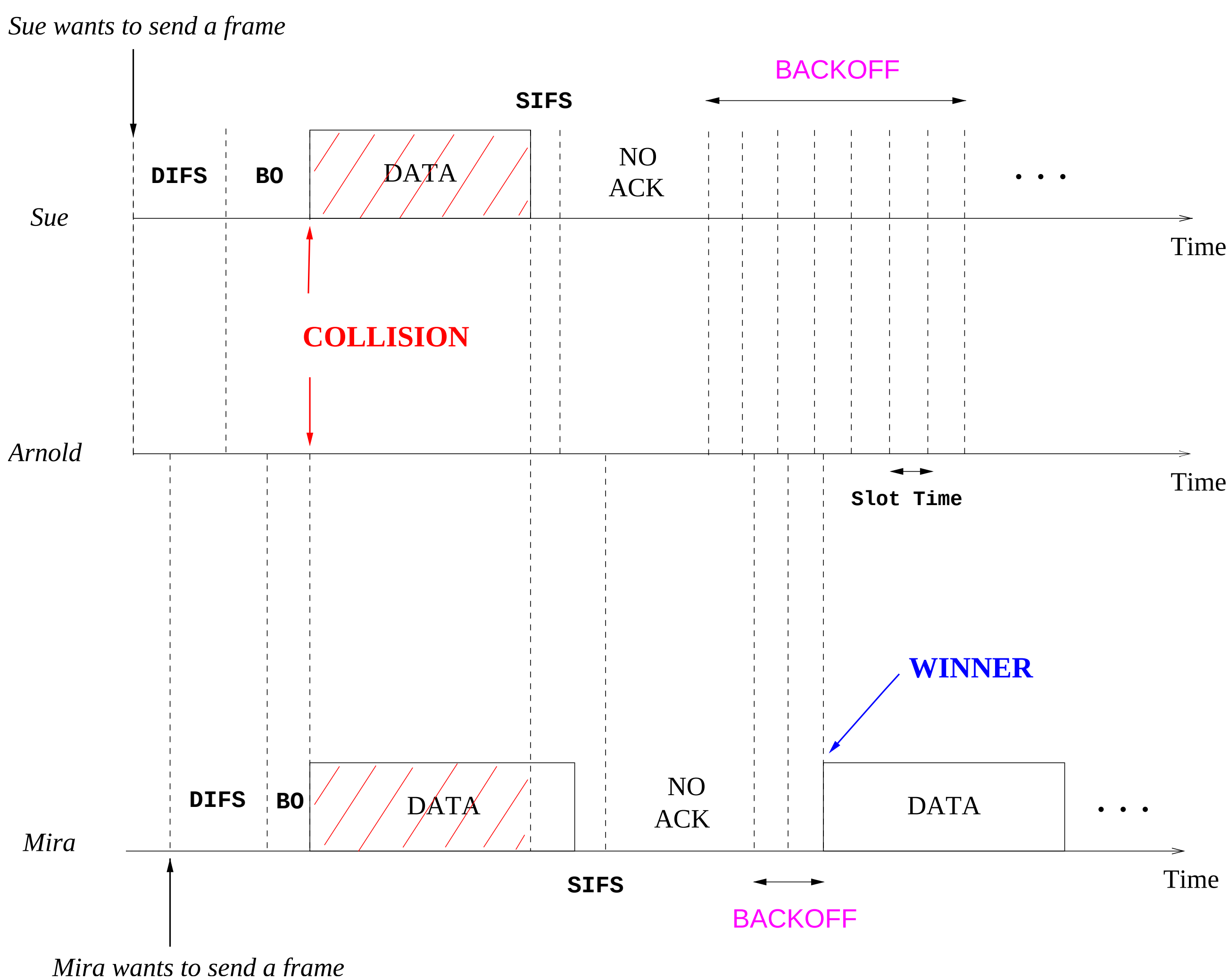
  $\rightarrow$ `CWmin`: 31; `CWmax`: 1023

Time snapshot with Mira-come-lately:

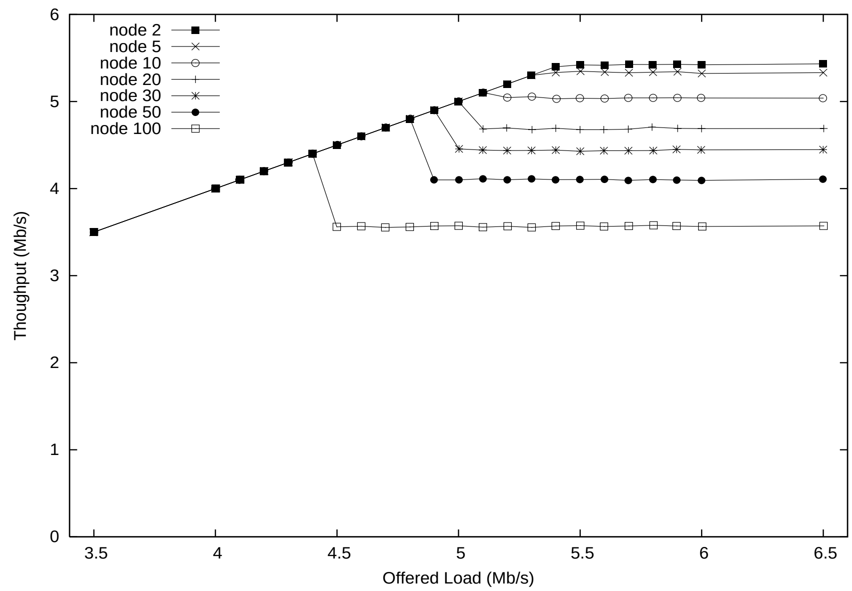
⟶ Sue sends to Arnold

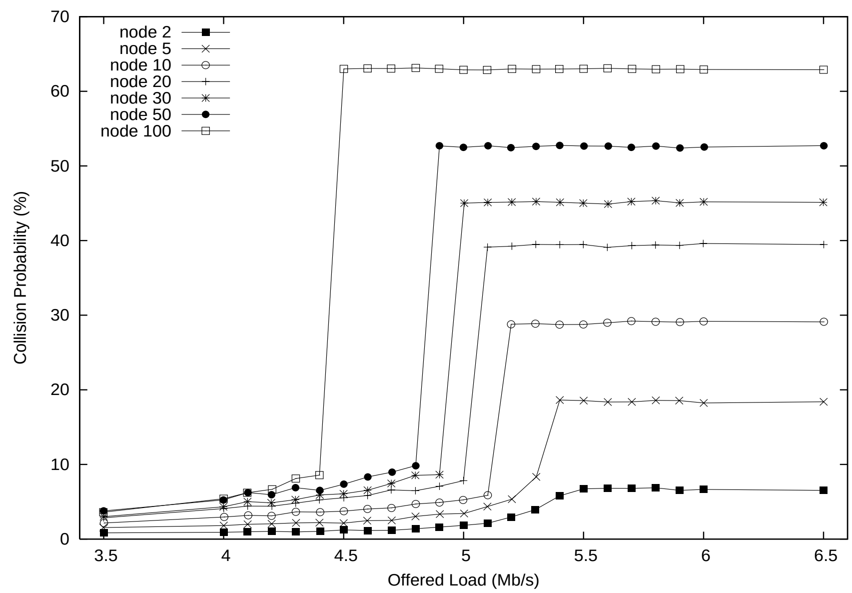


Time snapshot with collision (Sue & Mira):



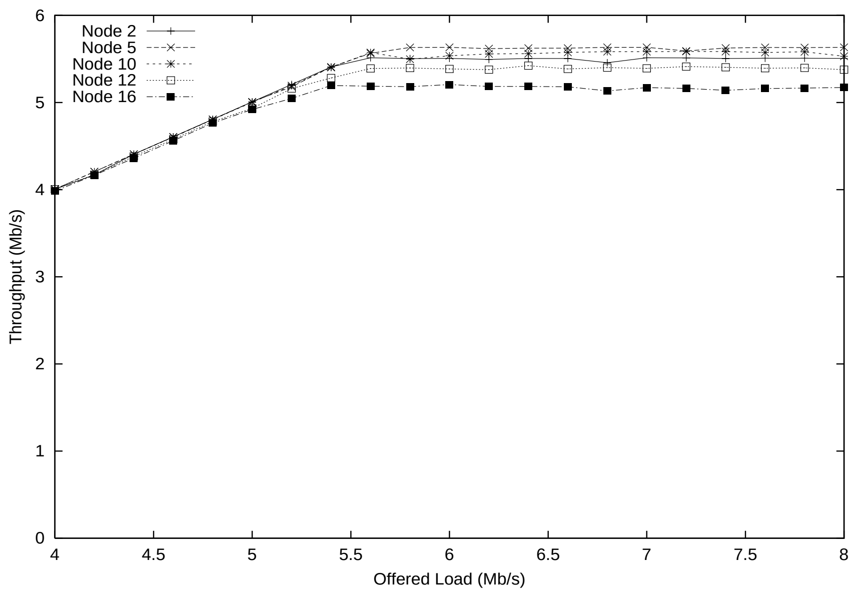
MAC throughput and collision (*ns* simulation):





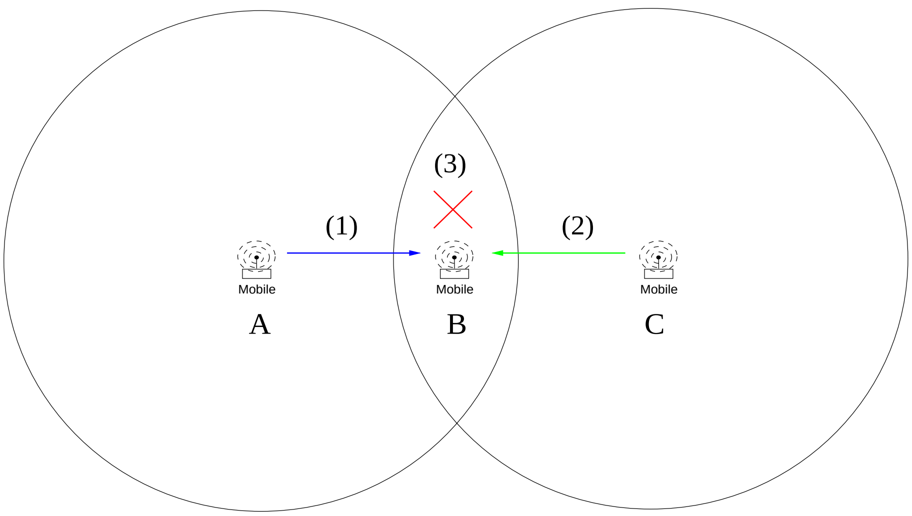
MAC throughput:

⟶ experiment: iPAQ running Linux



Additional issues with CSMA in wireless media:

Hidden station problem:



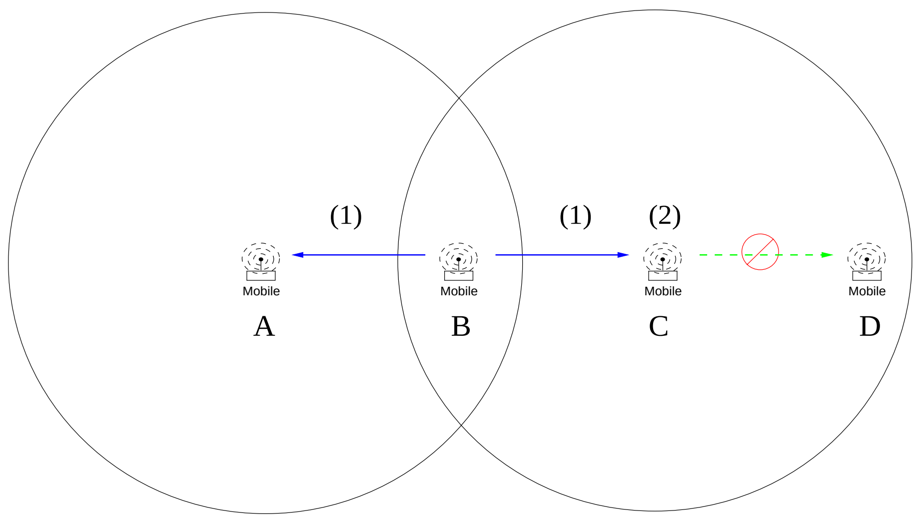
Hidden Station Problem

(1) A transmits to B

(2) C does not sense A; transmits to B

(3) interference occurs at B: i.e., collision

Exposed station problem:



Exposed Station Problem

(1) B transmits to A

(2) C wants to transmits to D but senses B

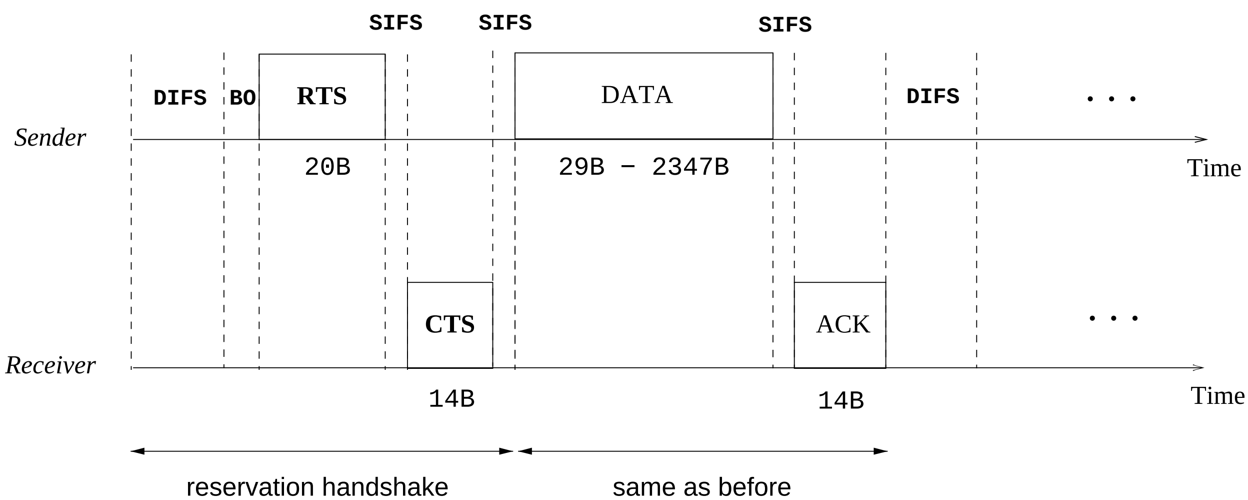
$\longrightarrow$ C refrains from transmitting to D

$\longrightarrow$ omni-directional antenna

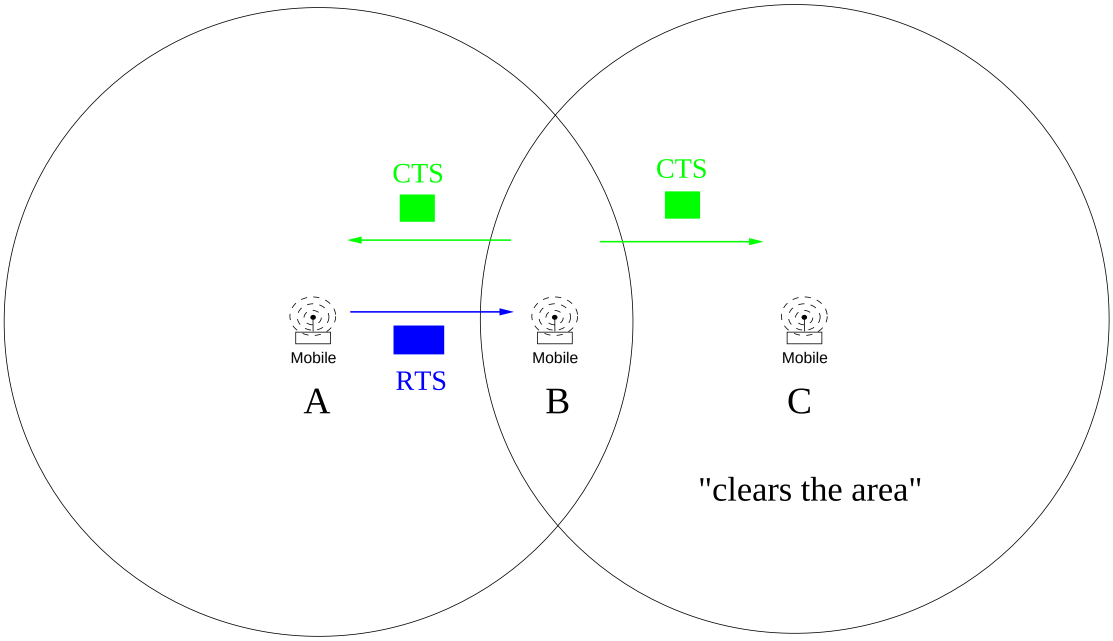
Solution: CA (congestion avoidance)

$\longrightarrow$ RTS/CTS reservation handshake

- Before data transmit, perform RTS/CTS handshake
- RTS: request to send
- CTS: clear to send



Hidden station problem: RTS/CTS handshake "clears" hidden area



`RTS/CTS Handshake`

RTS/CTS perform only if data > RTS threshold

$\longrightarrow$ why not for small data?

. . . feature available but not actively used

Additional optimization: virtual carrier sense

- transmit connection duration information
- stations maintain NAV (network allocation vector)

  $\longrightarrow$ decremented by clock
- if NAV $>$ 0, then do not access even if physical CS says channel is idle

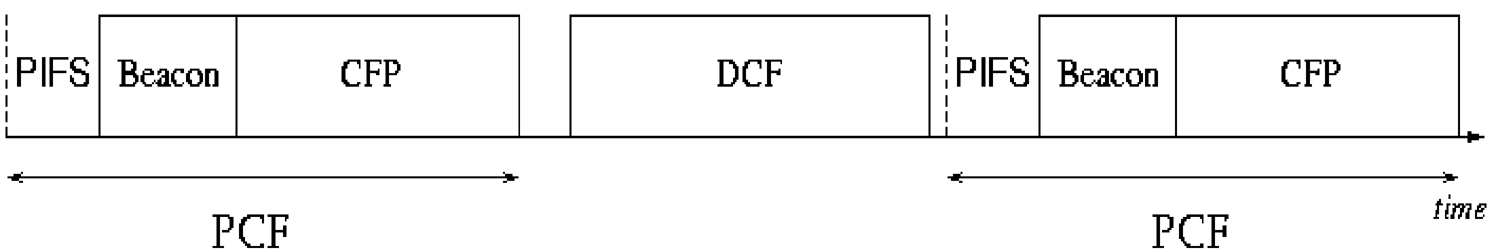
PCF (point coordination function):

$\longrightarrow$ support for real-time traffic

- Periodically inject contention free period (CFP)

  $\rightarrow$ after BEACON
- Under the control of point coordinator: AP

  $\rightarrow$ polling



PIFS (priority IFS):

$\longrightarrow$ SIFS < Slot Time < PIFS < DIFS

Properties of PCF:

- BEACON period is not precise

  → has priority (PIFS < DIFS) but cannot preempt DCF

- During CFP services stations on polling list

  → delivery of frames

  → polling: reception of frames

  → must maintain polling list: group membership

- Uses NAV to maintain CFP

- BEACON: separate control frame used to coordinate BSS

  → time stamp, SSID, etc.

IEEE 802.11 wireless LAN standard:

- ratified in 1997: 1/2 Mbps using either DSSS or FHSS

  → 11 bit chip sequence
- uses IEEE 802 address format along with LLC

  → 4 address fields for forwarding/management
- uses 2.4–2.4835 GHz ISM band in radio spectrum

  → ISM (industrial, scientific and medical): unlicensed
- IEEE 802.11b ratified: 5.5/11 Mbps using DSSS only

  → less coding overhead: good for low BER

  → BER (bit error rate) and FER (frame error rate)
- others: e.g., IEEE 802.11a and 802.11g at 54 Mbps

  → 5.725–5.85 vs. 2.4–2.4835 GHz band

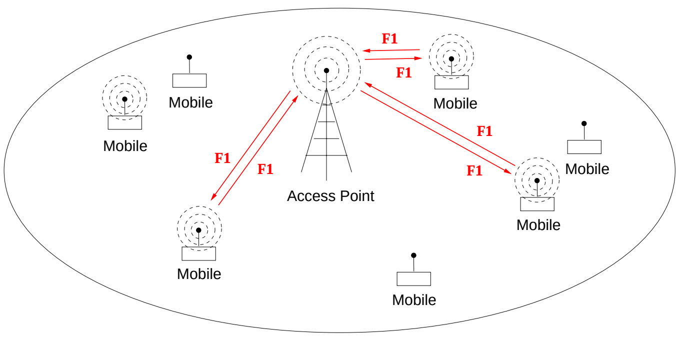
  → both use OFDM

Bluetooth, 802.16, etc.; uncertain future . . .

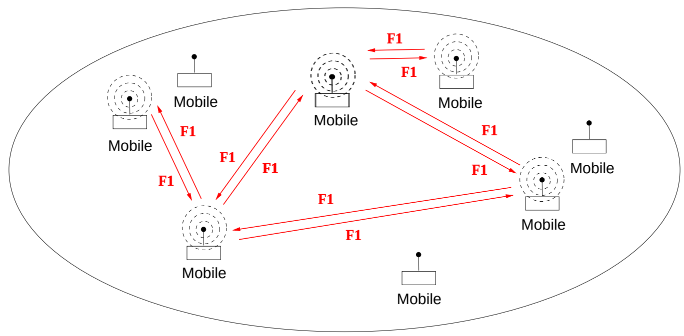
WLAN: ad hoc vs. infrastructure mode

$\longrightarrow$ a.k.a. why ad hoc, in general, is a bad idea

$\longrightarrow$ why. . .



WLAN: Infrastructure Network



WLAN: Ad Hoc Network

Two key reasons:

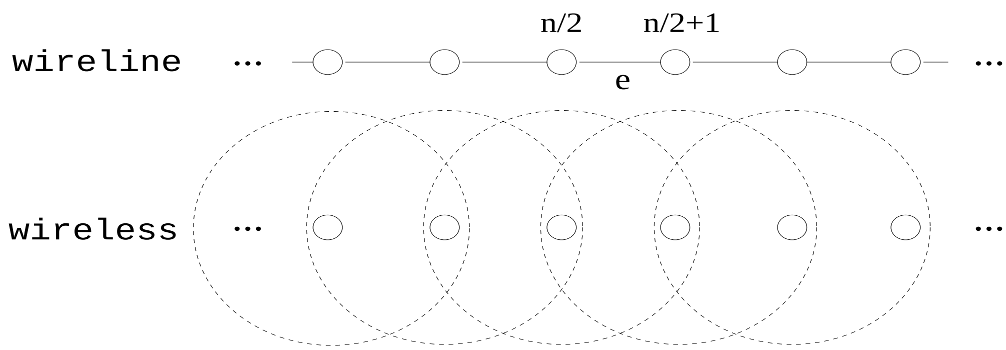
- nothing to do with wireless

  $\rightarrow$ i.e., common to wireline networks

  $\rightarrow$ "double duty"

- specifically to do with wireless LANs

Consider "corridor" configuration: linear chain



$\longrightarrow$ connectivity-wise: equivalent

Assume:

- there are n nodes
- link bandwidth: B Mbps
- every node picks a random destination to talk

  $\rightarrow$ data rate of each node: 1 Mbps
- consider middle link $e = (n/2, n/2 + 1)$

  $\rightarrow$ how much traffic must go through e?

  $\rightarrow$ inherent load or stress on link e

Fixing direction (left or right, i.e., half-duplex):

$\longrightarrow$ average load on e: $L(e) = n/4$

$\longrightarrow$ note: still linear in n (i.e., $L(e) = O(n)$)

To satisfy traffic demand:

$\longrightarrow$ bandwidth on e: $B = n/4$ Mbps

$\longrightarrow$ else: cannot send or must buffer

Main observation: under ad hoc mode in both wireline & wireless networks, individual link bandwidth must increase with system size n

$\longrightarrow$ due to forwarding duty!

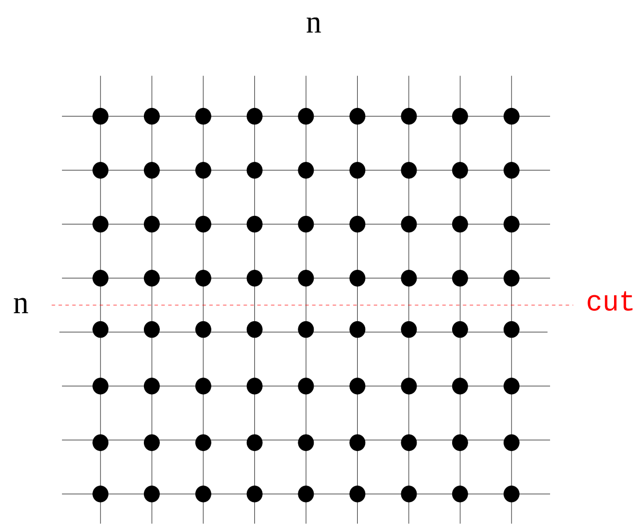
$\longrightarrow$ not scalable w.r.t. system size

Remarks:

- link $e = (n/2, n/2 + 1)$ is typical

  $\rightarrow$ majority of links are near the middle

- how does link bandwidth requirement X increase in 2-D grid/lattice configuration?



$\longrightarrow$ when side is n long: total n^2 nodes

$\longrightarrow$ hence with $\sqrt{n}$ side: total n nodes

$\longrightarrow$ note: link e was a cut dividing into 2 halves

$\longrightarrow$ average load on each link in 2-D cut?

Average link load: $L(e) = \sqrt{n}/4$

$\longrightarrow$ under assumption of perfect load balancing

$\longrightarrow$ note: $\sqrt{n}$ number of links in the cut

Thus in grid topologies, bandwidth requirement increases as: $O(\sqrt{n})$

$\longrightarrow$ still not scalable

$\longrightarrow$ in wireline networks: use switches/routers

$\longrightarrow$ else must upgrade link bandwidth constantly

ad hoc WLANs: additional impact of collision/interference

$\longrightarrow$ throughput goes down even more

$\longrightarrow$ Gupta and Kumar '99