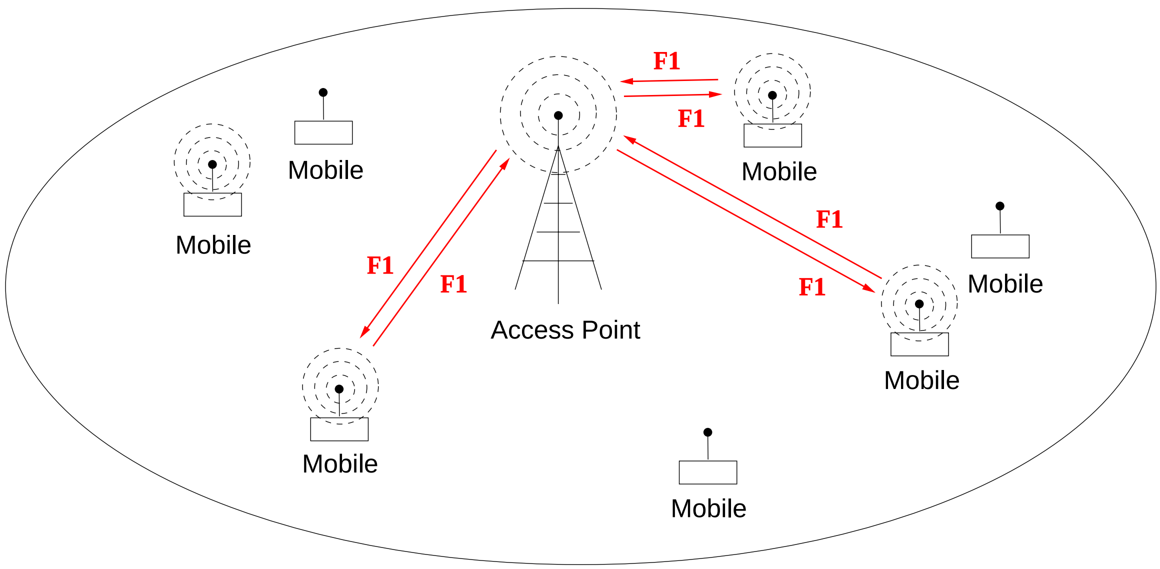
Wireless LAN (WLAN): infrastructure mode



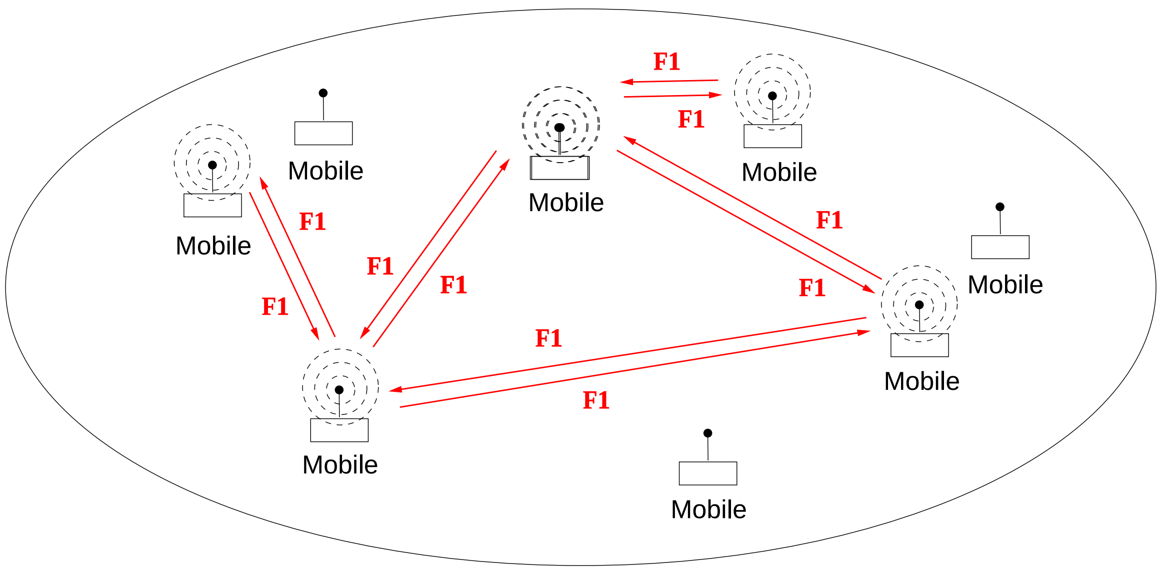
WLAN: Infrastructure Network

$\longrightarrow$ shared uplink & downlink channel $F1$

$\longrightarrow$ single baseband channel

- basic service set (BSS)
- base station: access point (AP)
- mobile stations must communicate through AP

WLAN: ad hoc mode



WLAN: Ad Hoc Network

⟶ homogeneous: no base station

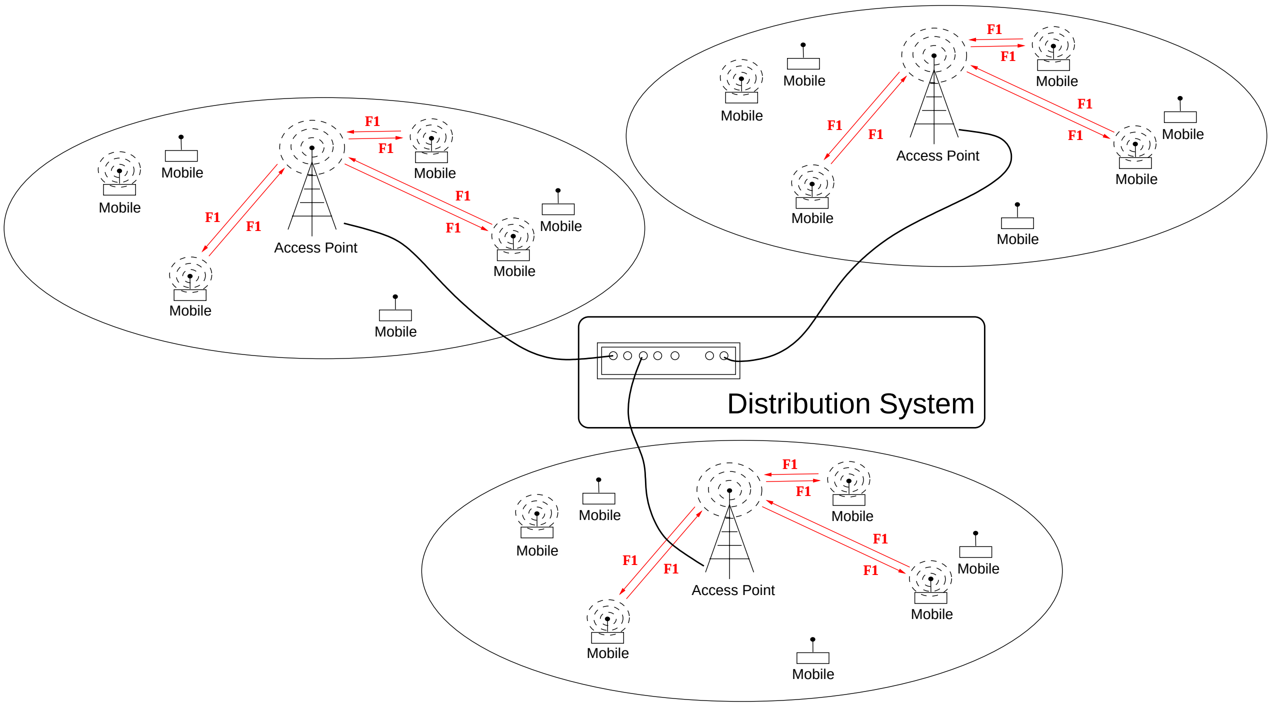
⟶ everyone is the same

⟶ share forwarding responsibility

- independent basic service set (IBSS)
- mobile stations communicate peer-to-peer

→ also called peer-to-peer mode

WLAN: internetworking



WLAN: Extended Service Set

⟶ internetworking between BSS's through APs

⟶ mobility and handoff

- extended service set (ESS)
- APs are connected by distribution system (DS)

  → typically: Ethernet switch

- How do APs and Ethernet switches know where to forward frames?

  $\longrightarrow$ spanning tree

  $\longrightarrow$ IEEE 802.1 (Perlman's algorithm)

  $\longrightarrow$ learning bridge: source address discovery

  $\longrightarrow$ if unclear: broadcast

Additional headache: mobility

$\longrightarrow$ how to perform handoff

$\longrightarrow$ mobility management at MAC vs. IP

Mobility between BSSes in an ESS

- association

  $\rightarrow$ registration process

  $\rightarrow$ AP sends out periodic beacon

  $\rightarrow$ mobile station (MS) associates with one AP

- disassociation

  $\rightarrow$ upon permanent departure: notification

- reassociation

  $\rightarrow$ movement of MS from one AP to another

  $\rightarrow$ inform new AP of old AP

  $\rightarrow$ forwarding of buffered frames

IEEE 802.11b/g WLAN spectrum 2.4–2.4835 GHz:

⟶ 11 channels (U.S.)

⟶ 2.412 GHz, 2.417 GHz, . . ., 2.462 GHz

⟶ unlicensed ISM (Industrial, Scientific, Medical) band

⟶ global: 2.4–2.4835 GHz

⟶ up to 14 channels

IEEE 802.11a: 5.15–5.35 GHz and 5.725–5.825 GHz

⟶ UNNI (unlicensed National Information Infrastructure)

⟶ non-global

IEEE 802.11n: both 2.4 and 5 GHz

⟶ 2.4 GHz: backward compatible

⟶ also uses multiple antennae

⟶ called MIMO (multiple input multiple output)

⟶ e.g., Apple's 802.11n has 3 antennae

Non-interference specification for 802.11b:

- each channel has 22 MHz bandwidth
- require 25 MHz channel separation

$\longrightarrow$ thus, only 3 concurrent channels possible

$\longrightarrow$ e.g., channels 1, 6 and 11

$\longrightarrow$ 3-coloring...

Examples:

Purdue Univ.: IEEE 802.11b (11 Mbps) WLAN network

$\longrightarrow$ PAL (Purdue Air Link)

$\longrightarrow$ partial mobility: MAC roaming (within ESS)

$\longrightarrow$ no mobile IP

$\longrightarrow$ football scores at Ross-Ade through PDAs

Dartmouth College: IEEE 802.11b WLAN (500+ APs)

$\longrightarrow$ full VoIP

$\longrightarrow$ free long distance

Seattle, SF, San Diego, Boston, etc.: WiFi communities

$\longrightarrow$ "free" Internet access

$\longrightarrow$ city: lamp-post; called mesh networks

$\longrightarrow$ private: roof-top

$\longrightarrow$ cable & DSL companies don't like it

IEEE 802.11 MAC

⟶ CSMA/CA with exponential backoff

⟶ almost like CSMA/CD

⟶ drop CD

⟶ explicit positive ACK frame

⟶ added optional feature: CA (collision avoidance)

Two modes for MAC operation:

- Distributed coordination function (DCF)

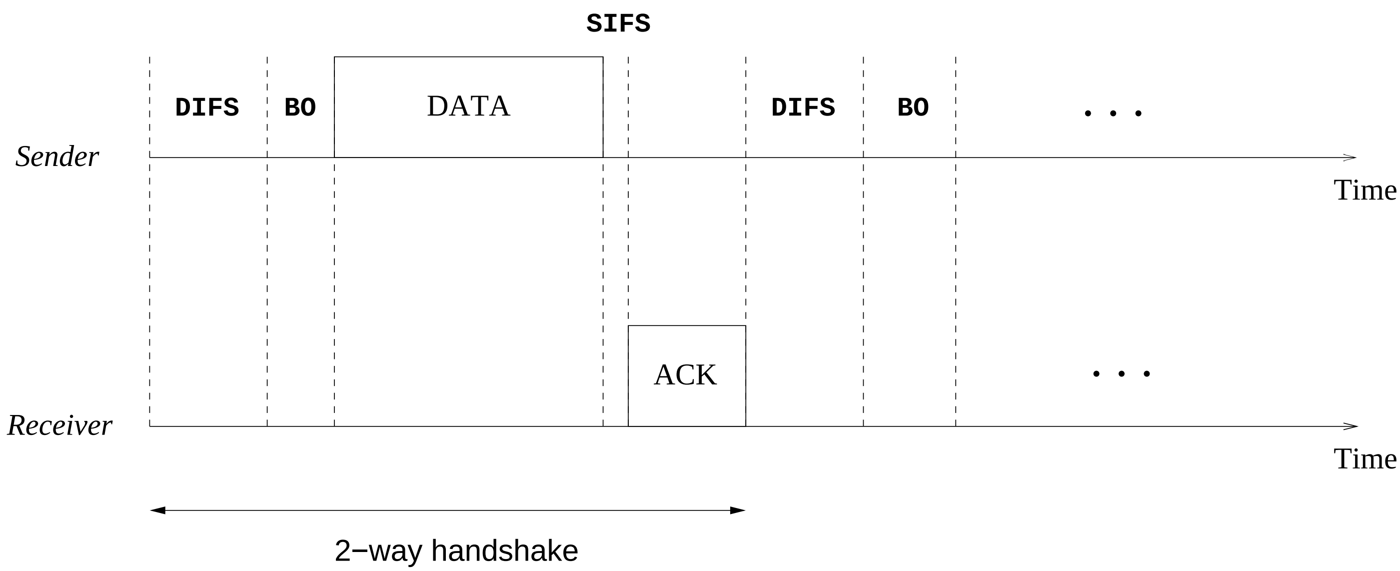
  → multiple access (default mode)

- Point coordination function (PCF)

  → polling-based priority

. . . neither PCF nor CA used in practice

Timeline without collision:



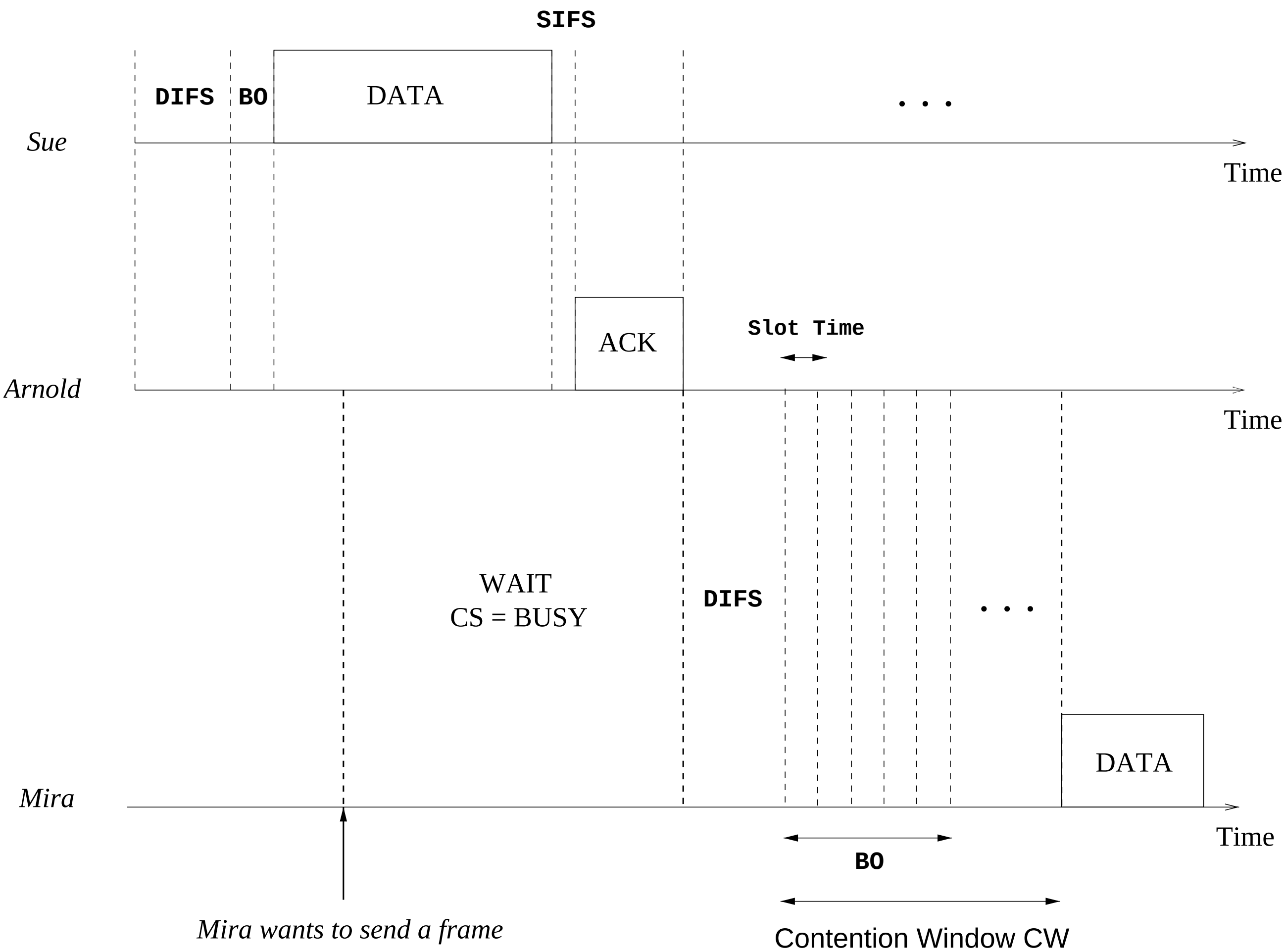
- SIFS (short interframe space): 10 μs
- Slot Time: 20 μs
- DIFS (distributed interframe space): 50 μs

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

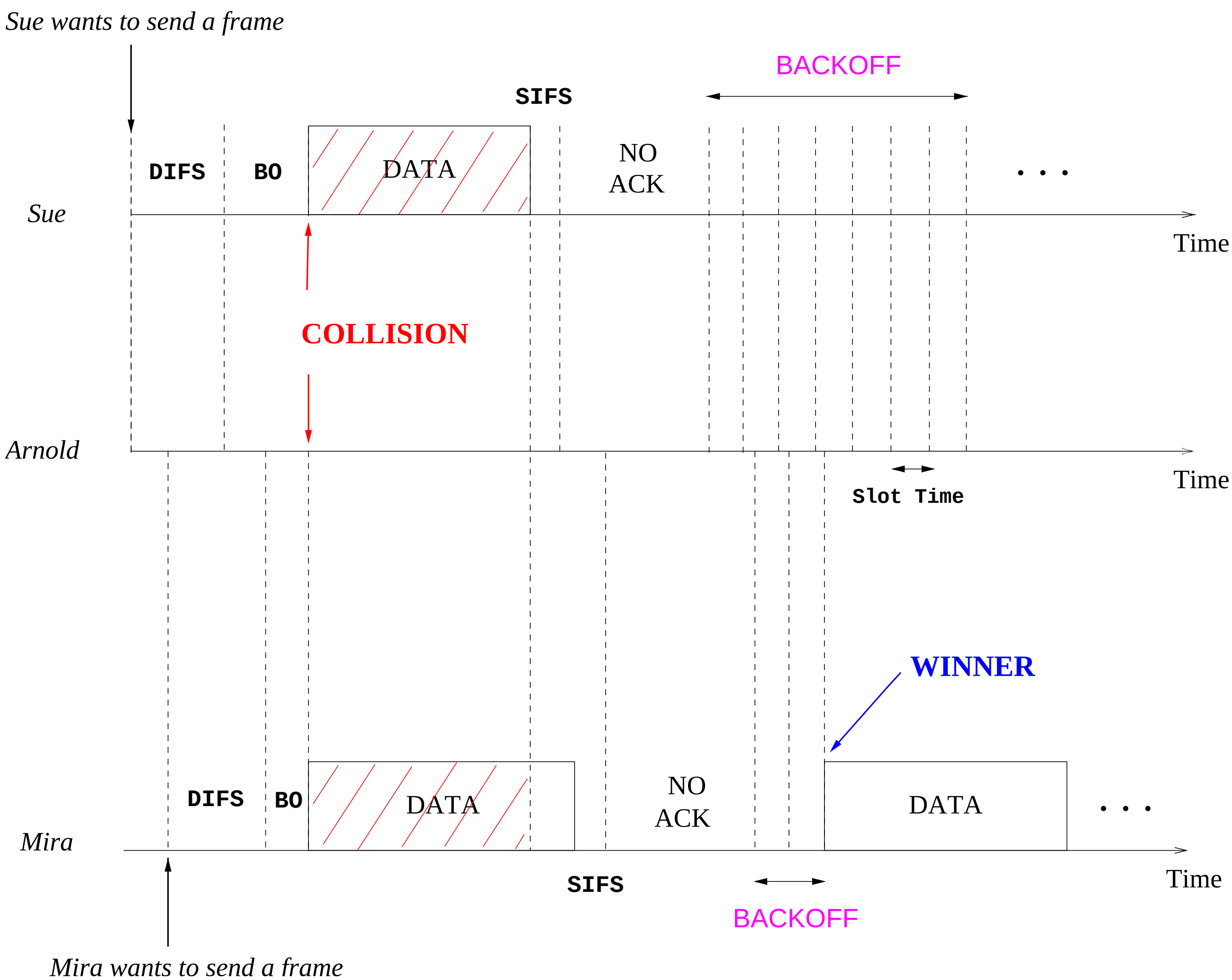
  $\rightarrow$ `CWmin`: 31; `CWmax`: 1023

Time snapshot with Mira-come-lately:

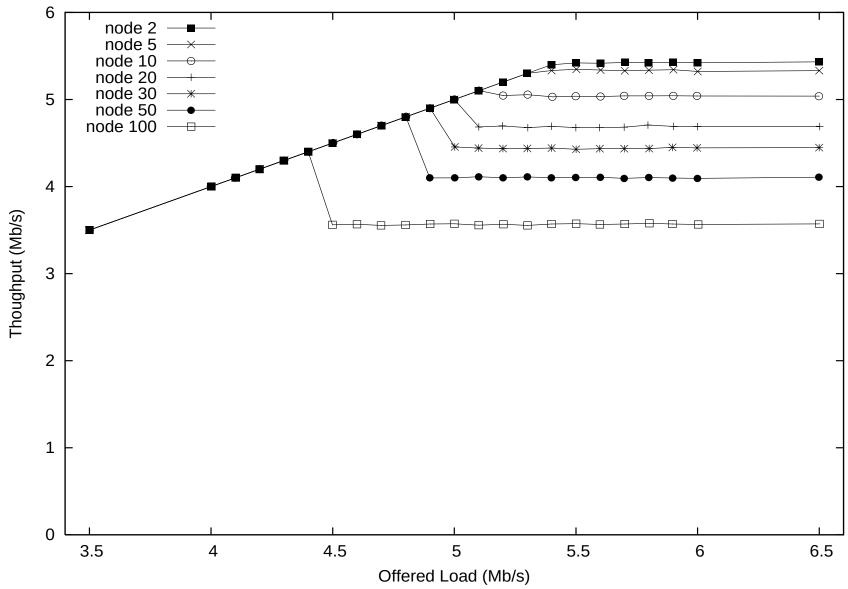
⟶ Sue sends to Arnold

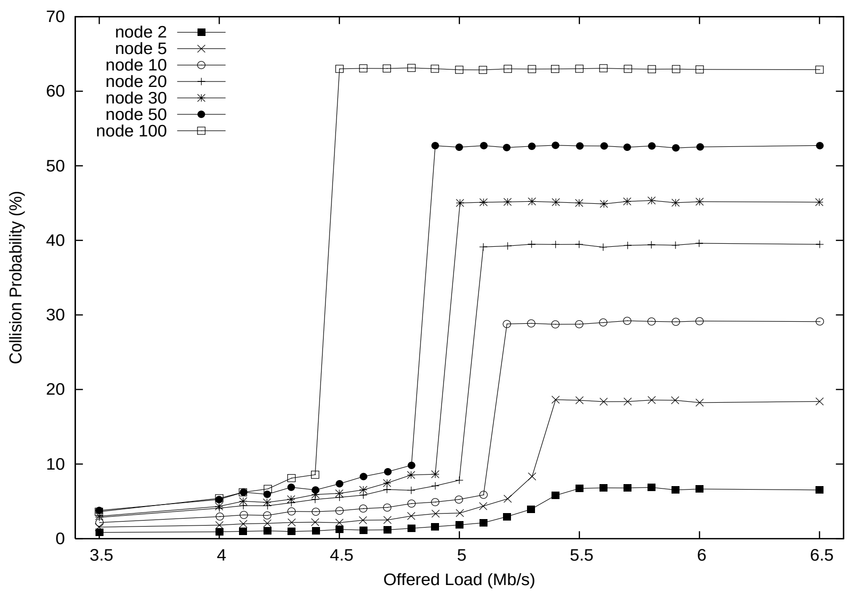


Time snapshot with collision (Sue & Mira):



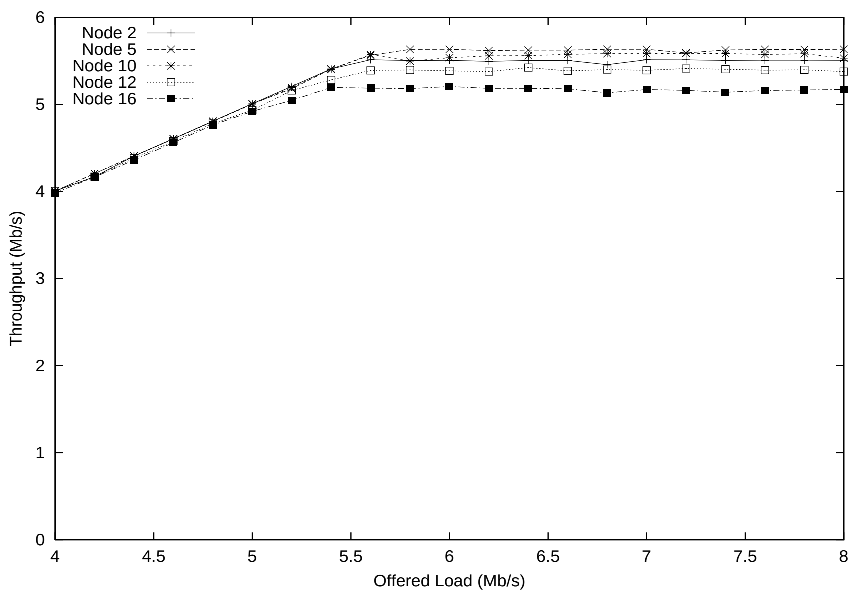
MAC throughput and collision (simulation):





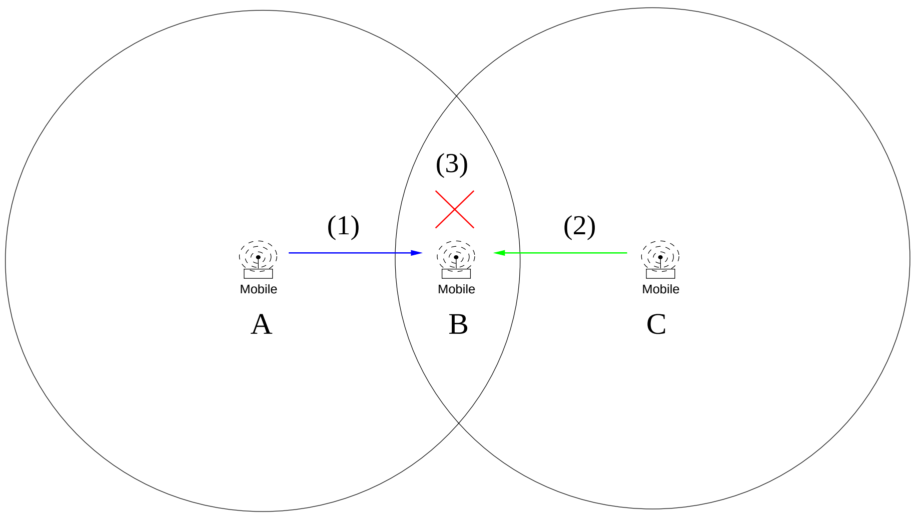
MAC throughput (experiment):

⟶ HP iPAQ pocket PC 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

But: collision does not always mean junk

$\longrightarrow$ i.e., transmission failure

For example:

if A's frame has stronger signal strength than C's frame, B may still be able to successfully decode A's frame

but not C's frame

$\longrightarrow$ called capture effect

Biggest problem: starvation problem

$\longrightarrow$ related to hidden station problem

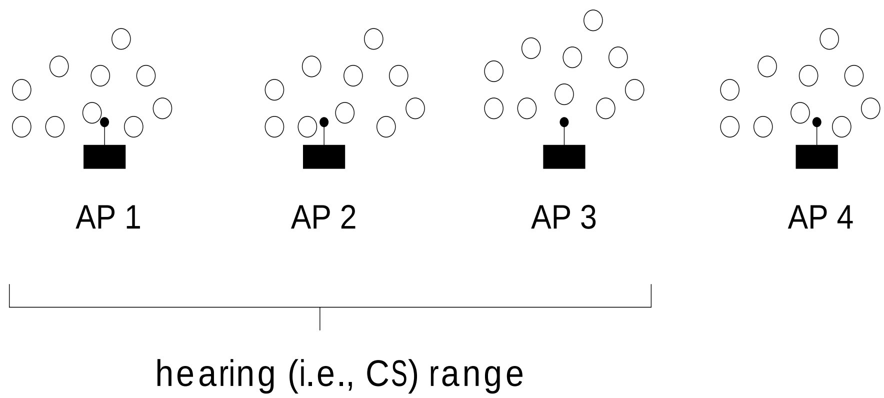
$\longrightarrow$ A cannot hear C, C cannot hear A

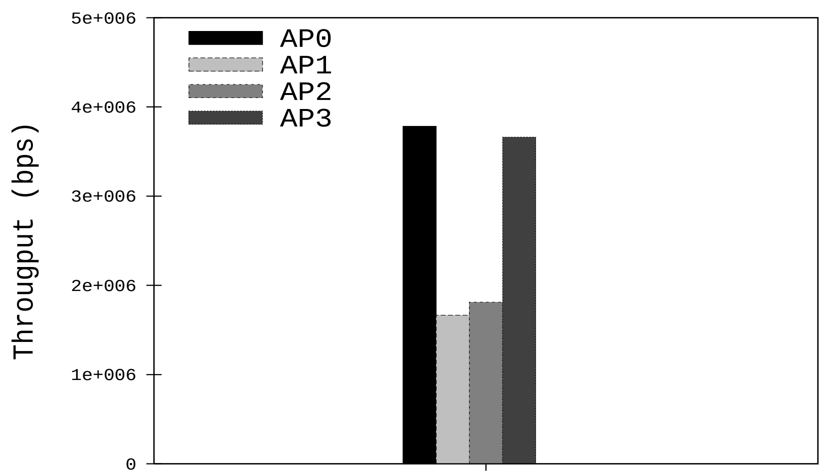
$\longrightarrow$ B can hear both A and C

$\longrightarrow$ by CS, B gets little chance to speak

$\longrightarrow$ hence "sandwiched" B may starve

Consider 4 APs, each with 10 laptops (i.e., 4 adjacent BSS):





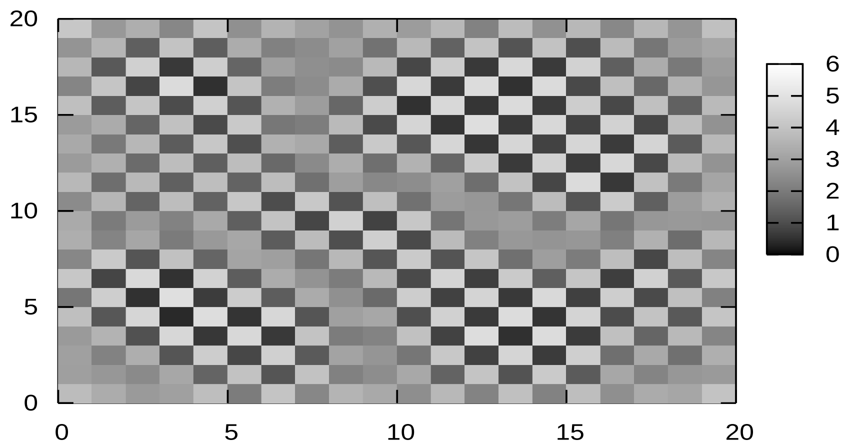
⟶ middle two APs get half the throughput

400-AP (20×20) mesh network:

$\longrightarrow$ campus-scale wireless network

$\longrightarrow$ could be city block

$\longrightarrow$ large residential community



$\longrightarrow$ black squares: regions of near-starvation

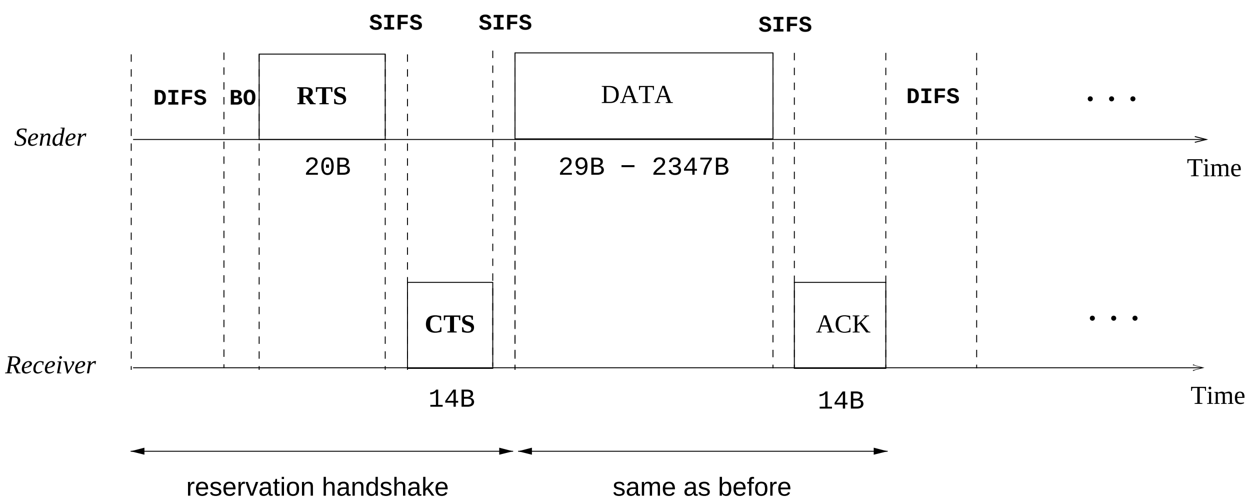
$\longrightarrow$ note alternating checker pattern

$\longrightarrow$ solution?

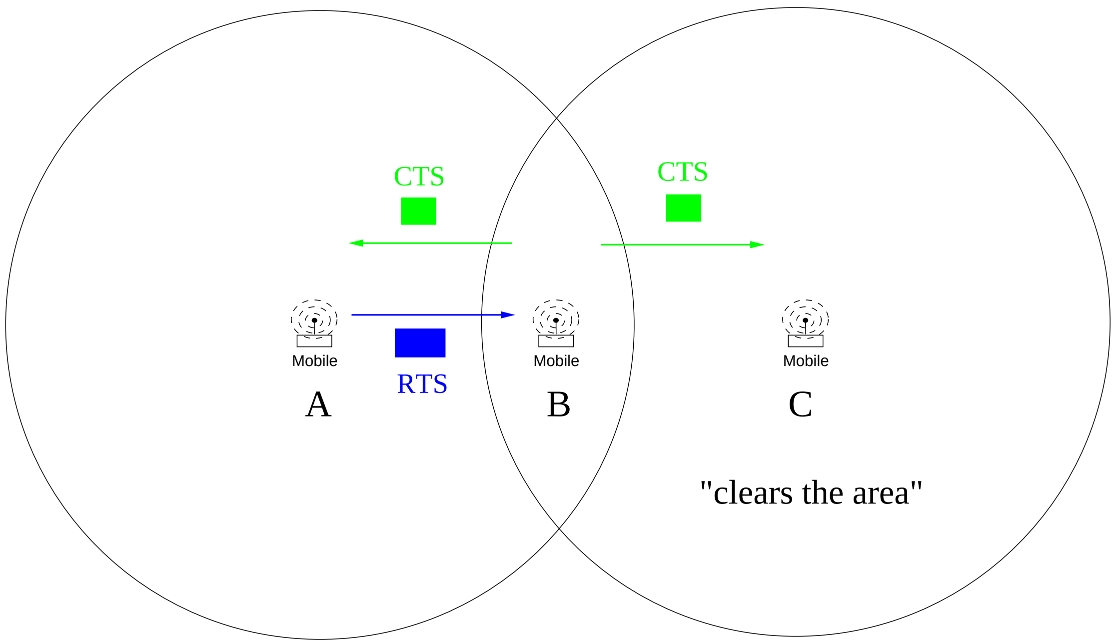
Hidden station problem: CA (congestion avoidance)

⟶ 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 used