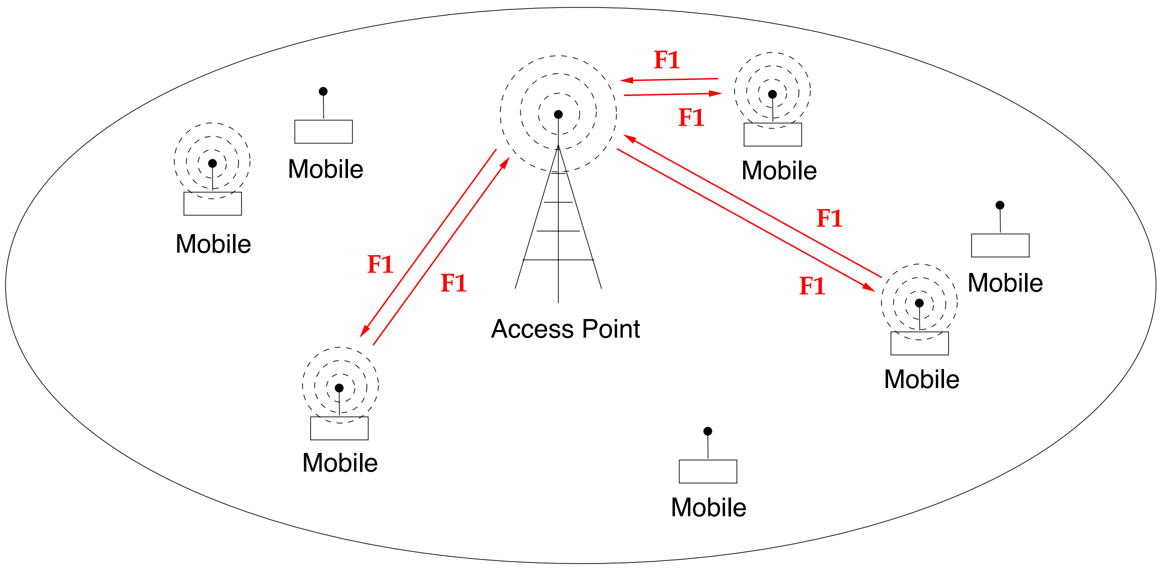
# Wireless LAN (WLAN): infrastructure mode

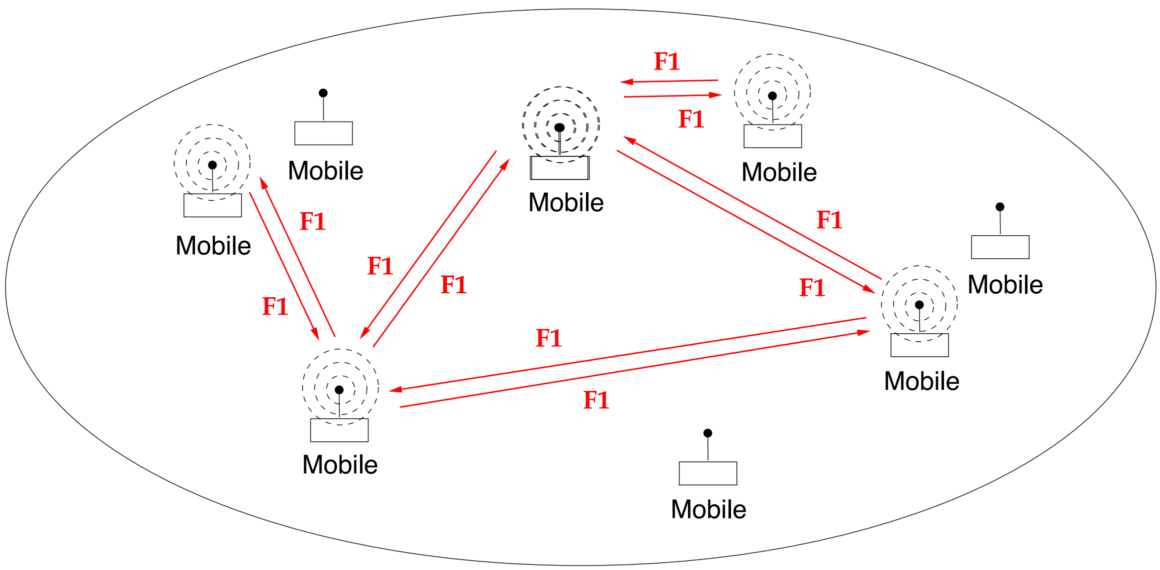



WLAN: Infrastructure Network

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

- basic service set (BSS)
- SSID (service set identifier): name/label of BSS
- base station: access point (AP)
- mobile stations must communicate through AP

# WLAN: ad hoc mode




WLAN: Ad Hoc Network

$\longrightarrow$ homogeneous: no base station

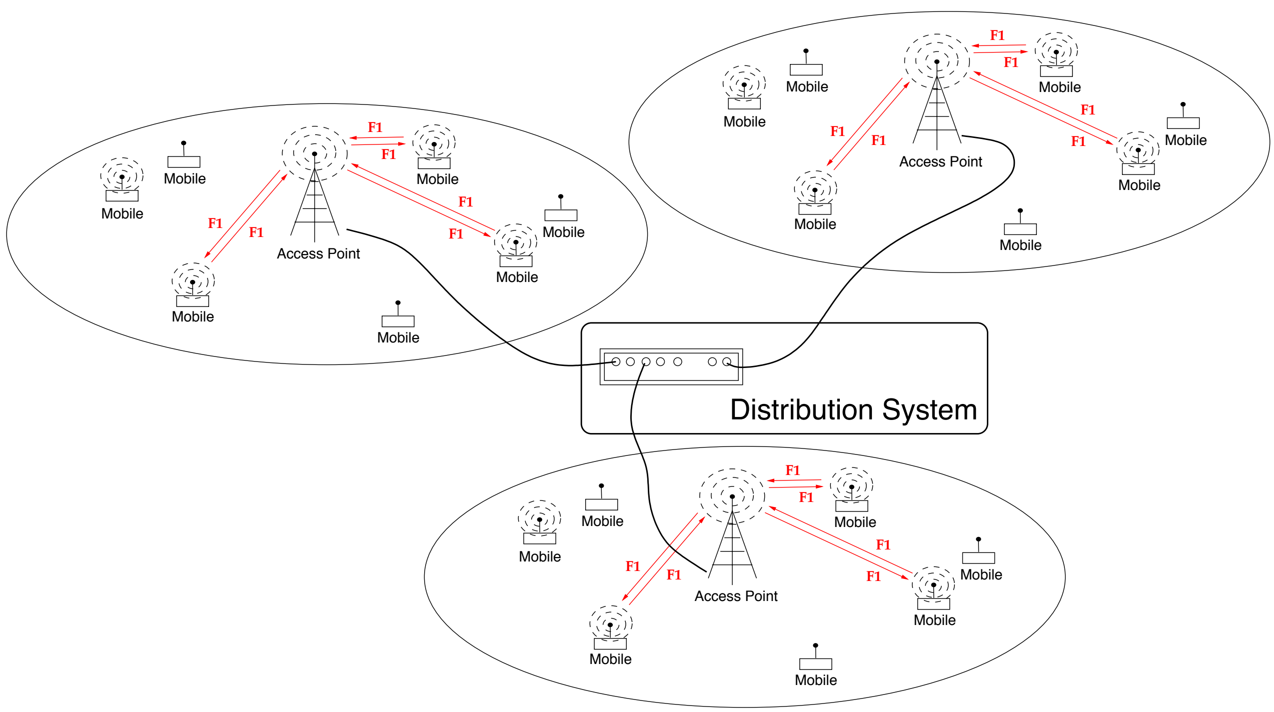
$\longrightarrow$ everyone is the same

$\longrightarrow$ share forwarding responsibility

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

$\rightarrow$ 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): shared SSID
- APs are connected by distribution system (DS)

  → typically: Ethernet switch

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

  → spanning tree

  → IEEE 802.1 (Perlman's algorithm)

  → learning bridge: source address discovery

  → per interface: log source MAC address of incoming frames

  → initially or if unclear: broadcast

  → a very simple form of routing

  → adequate for small systems

Additional headache: mobility

$\longrightarrow$ also called roaming

$\longrightarrow$ how to perform handoff

$\longrightarrow$ mobility management at MAC vs. IP

Mobility between BSS's in an ESS

- association

  $\rightarrow$ registration process

  $\rightarrow$ AP sends out periodic beacon frame

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

- disassociation

  $\rightarrow$ upon permanent departure: notification

Handoff from old to new AP:

- reassociation

  → movement of MS from one AP to another

  → client initiated

  → e.g., AP's signal strength is low

  → passive (beacon) or active (probe) scanning to find alternate AP

  → go through association process

  → inform new AP of old AP

  → forwarding of buffered frames from old to new AP in ESS

Note: when and parts of how to perform handoff are not part of IEEE standard

→ vendor dependent

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

- $\longrightarrow$ 11 channels (U.S.)
- $\longrightarrow$ 2.412 GHz, 2.417 GHz, . . ., 2.462 GHz
- $\longrightarrow$ unlicensed ISM (Industrial, Scientific, Medical) band
- $\longrightarrow$ global: 2.4–2.4835 GHz
- $\longrightarrow$ up to 14 channels (e.g., Japan)

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

- $\longrightarrow$ UNNI (unlicensed National Information Infrastructure)
- $\longrightarrow$ non-global

IEEE 802.11n: both 2.4 and 5 GHz

- $\longrightarrow$ 2.4 GHz: backward compatible
- $\longrightarrow$ also uses multiple antennae
- $\longrightarrow$ called MIMO (multiple input multiple output)
- $\longrightarrow$ 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...

IEEE 802.11 WLAN MAC: uses CSMA

→ multi-user bandwidth sharing

However:

- 802.11b: uses DSSS CDMA

  → 11-bit chip sequence (Barker sequence)

  → single-user DSSS

  → why?

- 802.11a/g/n: uses OFDM

  → single-user OFDM (i.e., not OFDMA)

  → also called single-carrier (vs. multi-carrier)

  → 802.11g: 48 carrier frequencies

  → subcarrier separation: 312.5 KHz

  → bits of single frame are distributed across 48 subcarriers

  → first bit on subcarrier 1, second bit on subcarrier 2, etc.

  → but: transmission is sequential—not parallel!

  → similar to FHSS

  → why use OFDM without parallel speed-up?

Why not use OFDMA?

## 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)

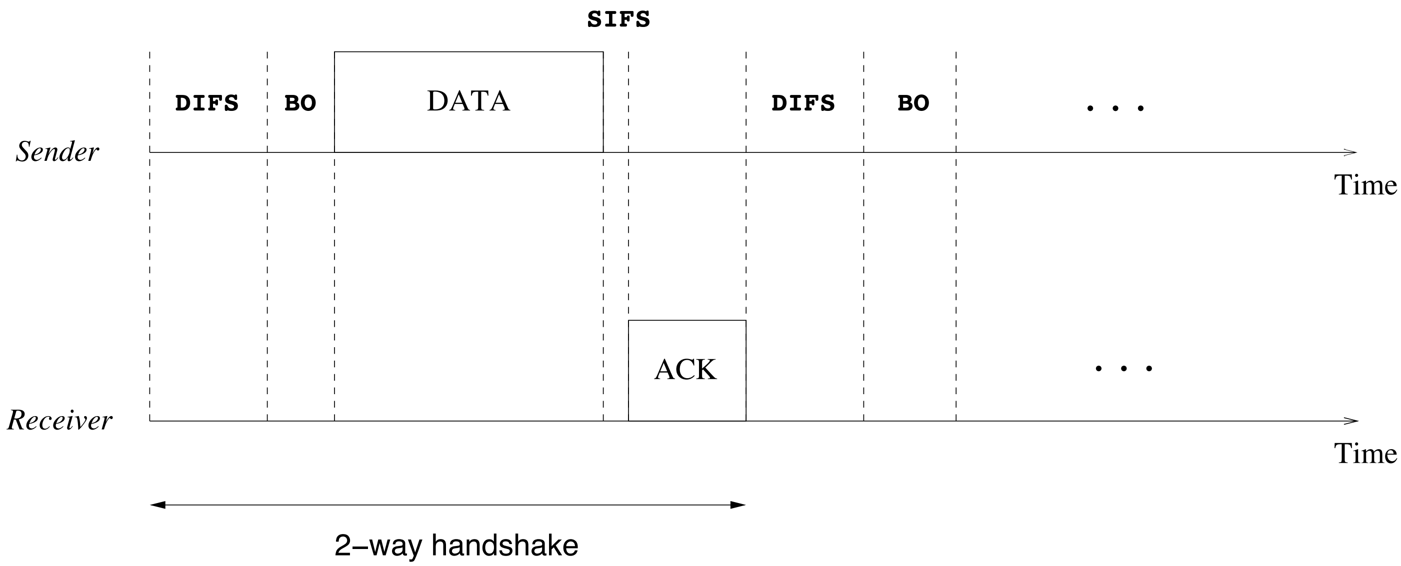
  → multiple access (default mode)

- Point coordination function (PCF)

  → polling-based priority

. . . neither PCF nor CA used in practice

Timeline without collision:



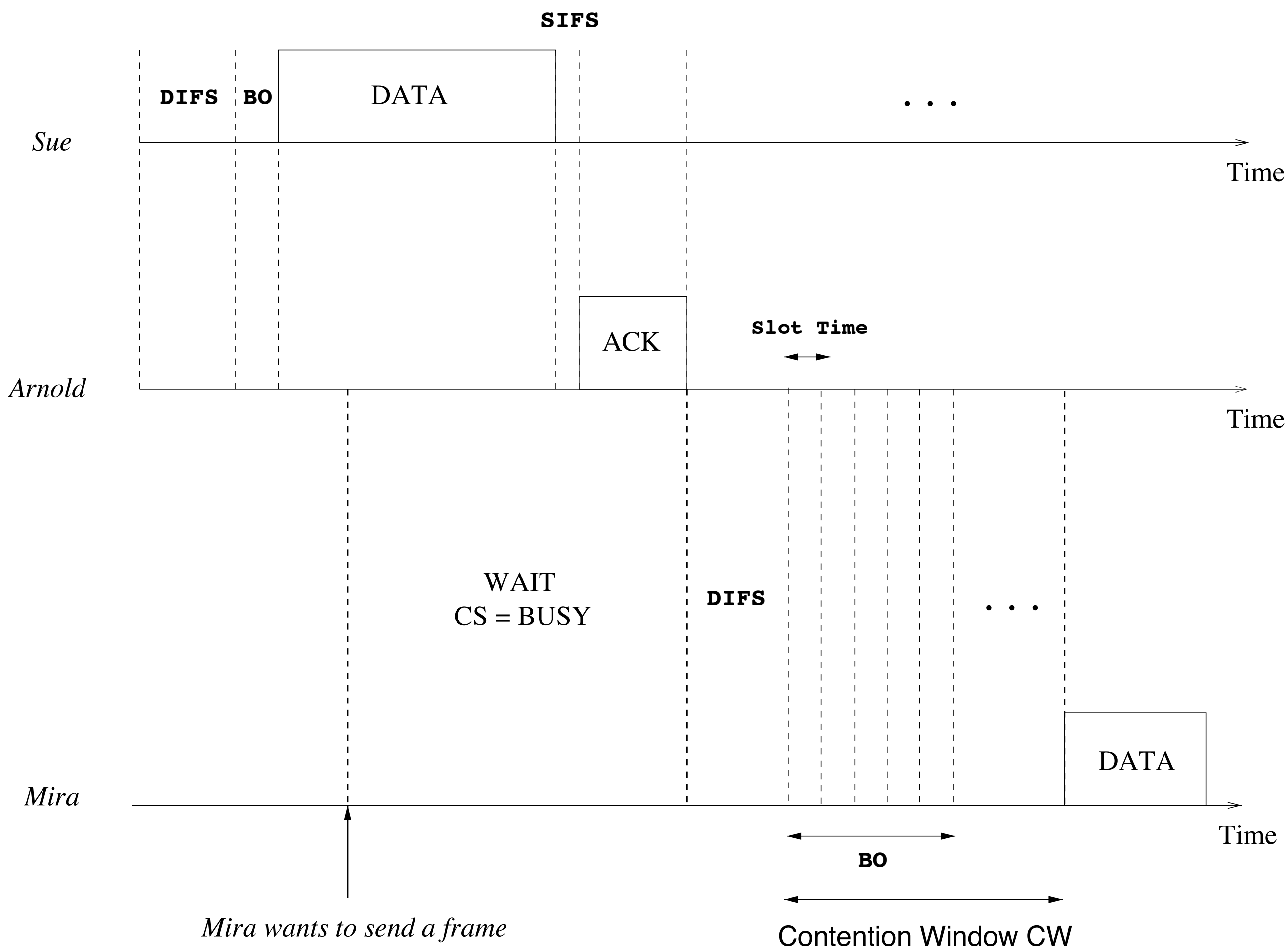

- SIFS (short interframe space): 10 $\mu$s
- Slot Time: 20 $\mu$s
- DIFS (distributed interframe space): 50 $\mu$s

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

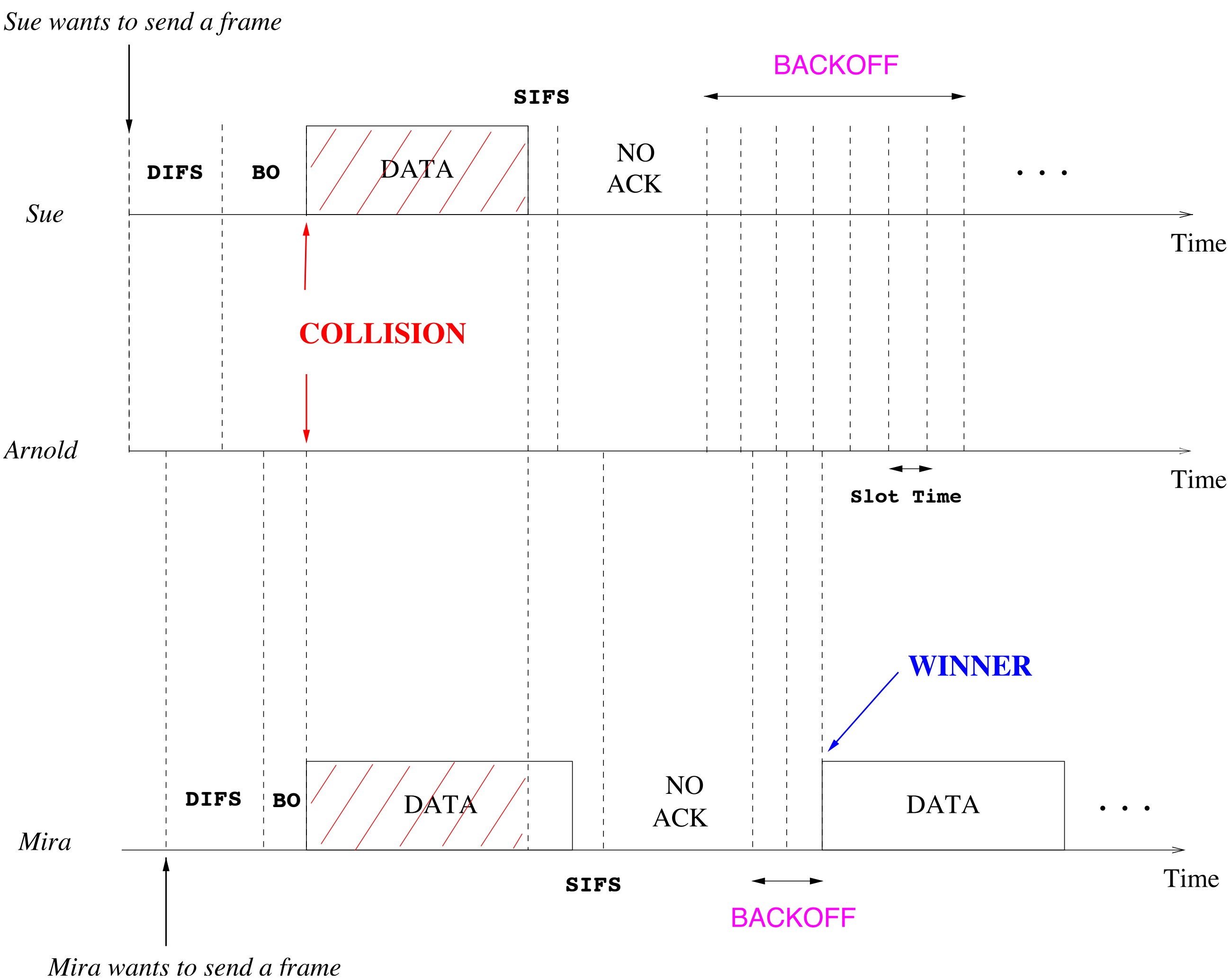
  $\rightarrow$ `CWmin`: 31; `CWmax`: 1023

Time snapshot with Mira-come-lately:

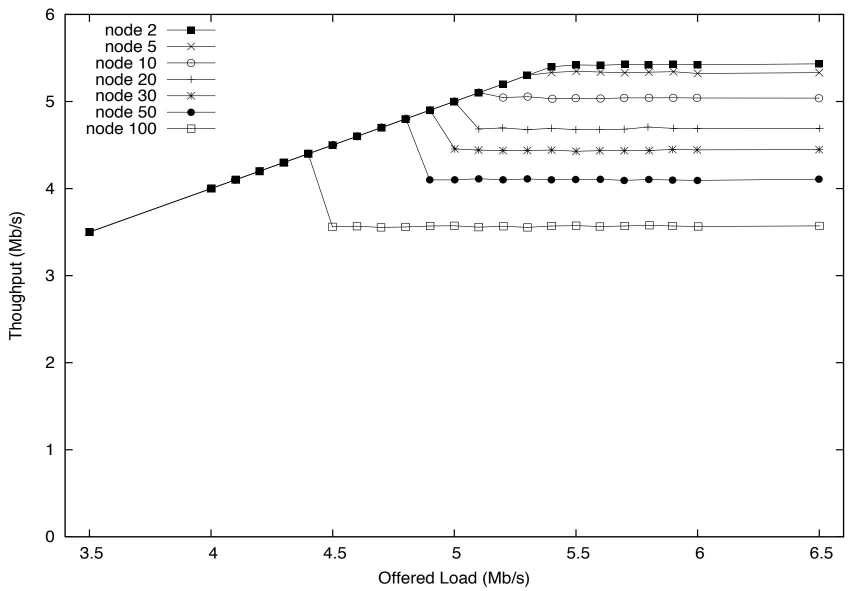
⟶ Sue sends to Arnold

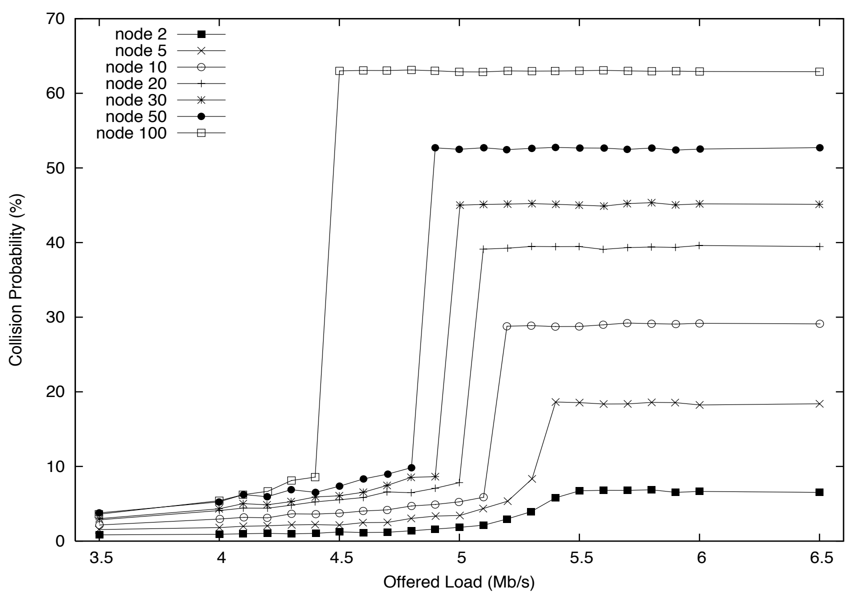


# Time snapshot with collision (Sue & Mira):



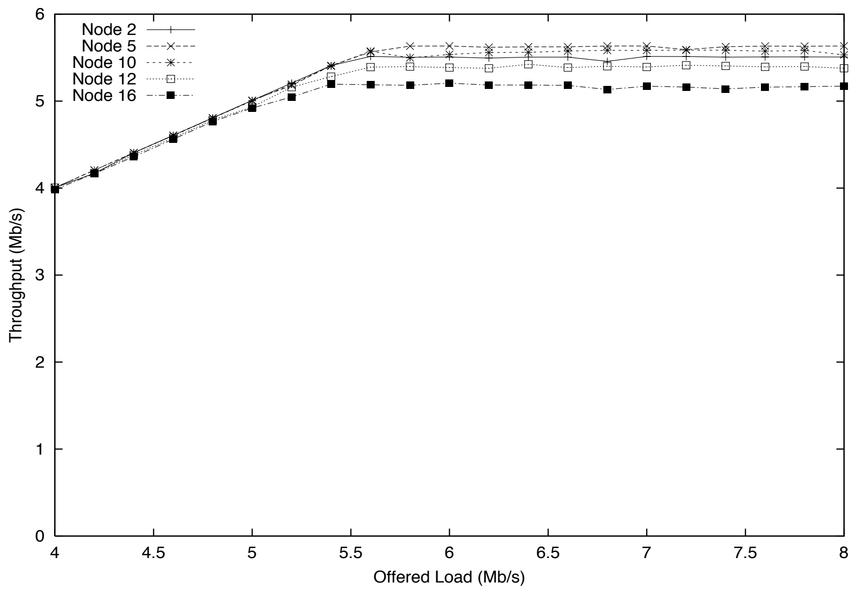
# MAC throughput and collision (simulation):



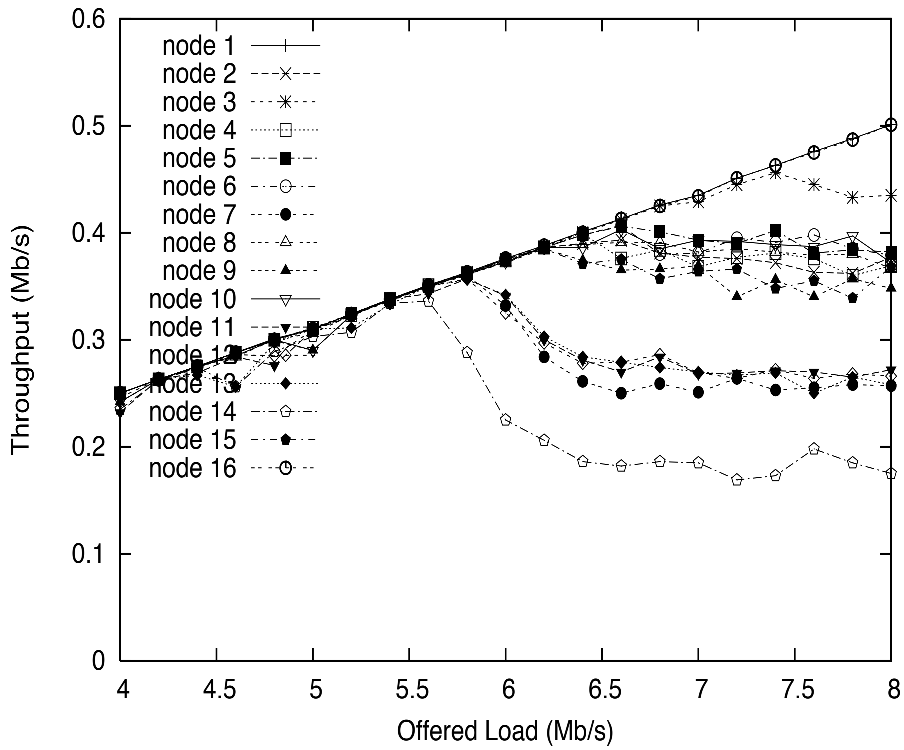
MAC throughput (experiment):

$\longrightarrow$ HP iPAQ pocket PC running Linux



Throughput share of 16 HP/Compaq pocket PCs:

→ uplink CSMA competition

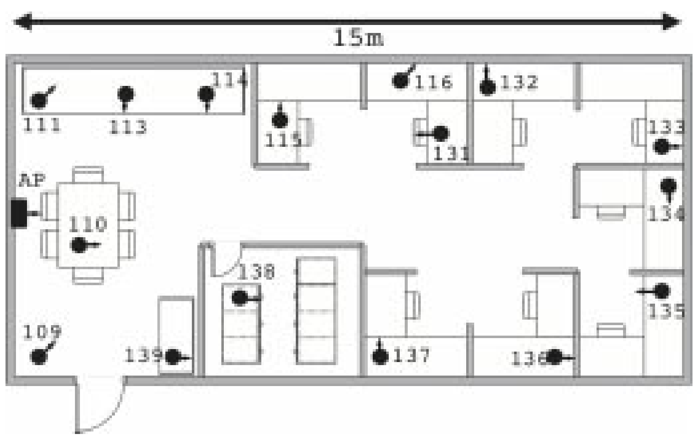



→ significant unfairness: why?

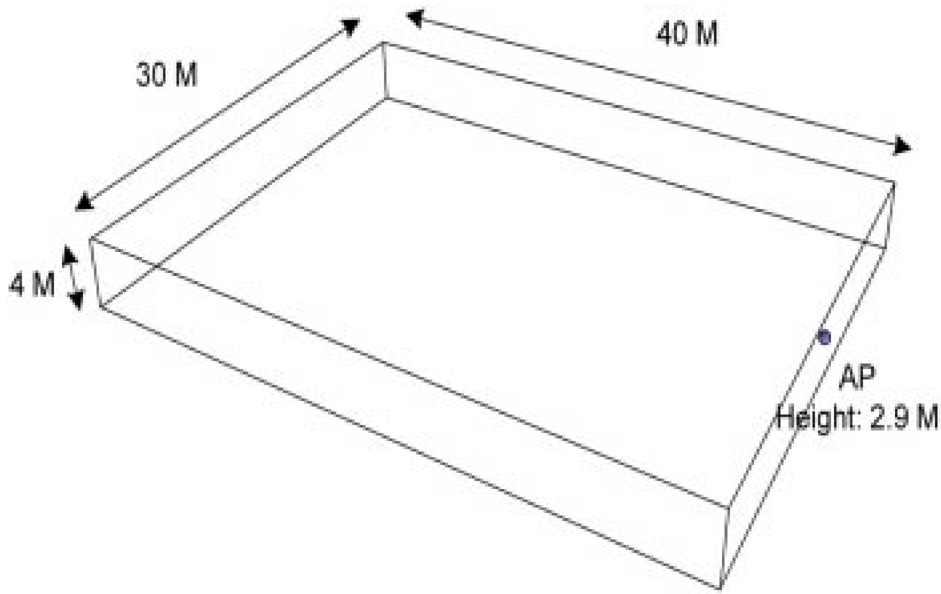
→ persistent unfairness

→ location (not distance from AP) is determining factor

Indoor office 802.11 WLAN hot spot (HAAS G50):



Consider empty room with no obstructions:




→ large lecture room

→ e.g., 802.11 WLAN hot spot

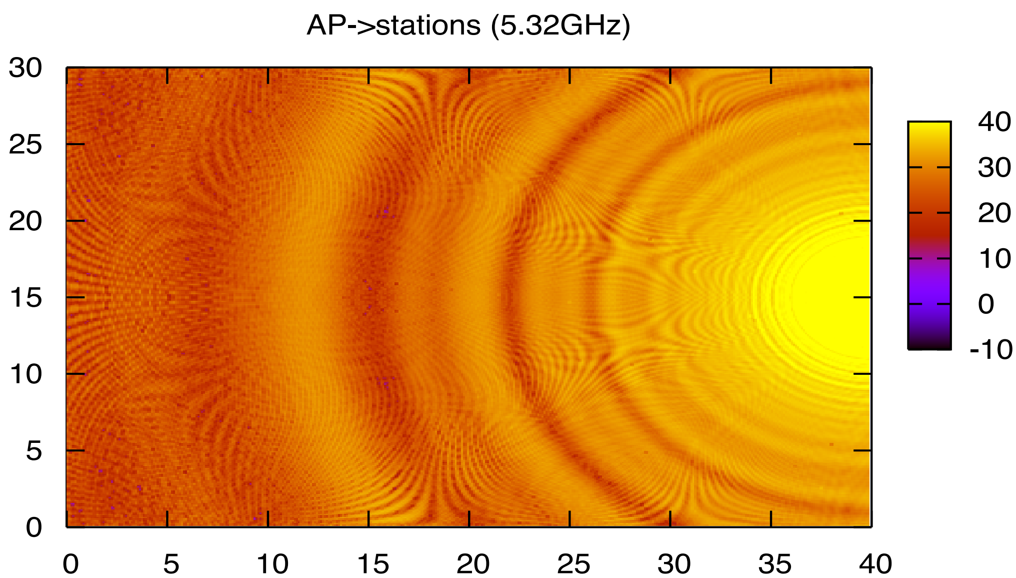
→ AP sends out signal at 2.4 (802.11b/g) or 5 GHz (802.11a/n) frequency

→ how does indoor signal reception look like?

Signal strength reception at table height 0.7 m:

→ carrier frequency: 5.32 GHz

→ channel 8 in U.S. (12 channels in 5 GHz 802.11a/n)




→ called spatial diversity