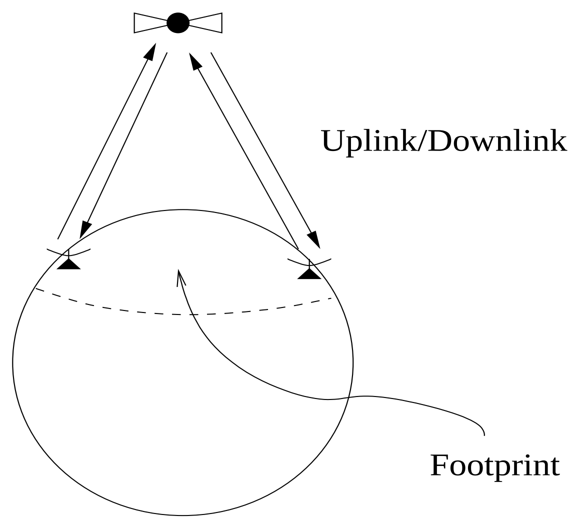
Long Distance Wireless Communication

Principally satellite communication:



- LOS relay
- Effective for broadcast
- Limited bandwidth for multi-access

$\longrightarrow$ not scalable for multi-access

Multi-access protocols:

- FDMA + TDMA: dominant

  $\longrightarrow$ broadband

  $\longrightarrow$ GSM cellular
- CDMA: e.g., GPS and defense related systems

  $\longrightarrow$ CDMA cellular (Qualcomm)
- CSMA/CA: impractical due to large RTT

  $\longrightarrow$ low utilization/throughput

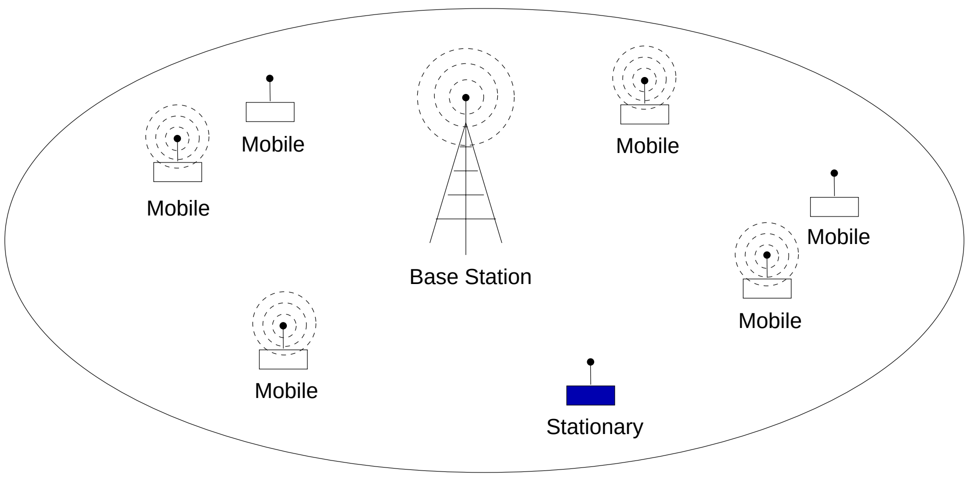
Long-distance wireless communication: effective when broadcasting

$\longrightarrow$ special applications, e.g., TV, GPS

Short Distance Wireless Communication

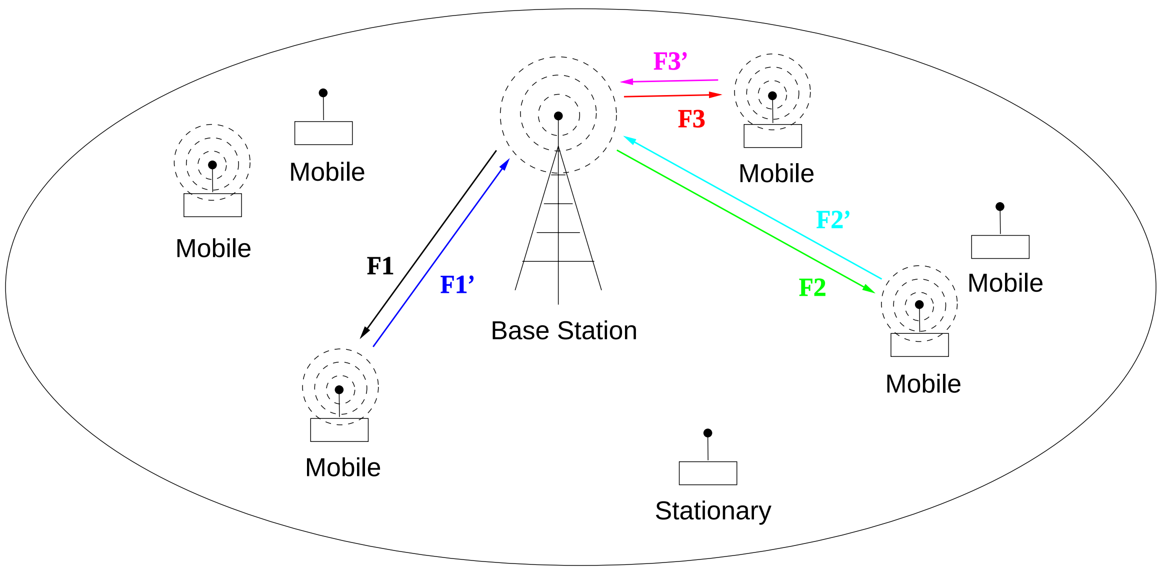
Basic communication problem

⟶ shared frequency spectrum (e.g., 2.4–2.4835 GHz)



- TDMA
- FDMA
- CDMA
- multiple access
- polling

Cellular telephony: frequency & time division



FDMA & TDMA

Ex.: GSM (U.S. IS-136)

- uplink: 890–915 MHz
- downlink: 935–960 MHz

  → 25 MHz frequency band
- 125 channels 200 kHz wide each ($= 25000 \div 200$)

  → FDM portion

- 8 time slots within each channel

  → TDM portion

- total of 1000 possible user channels $(= 125 \times 8)$

  → 124×8 realized

- codec: 13.4 kb/s

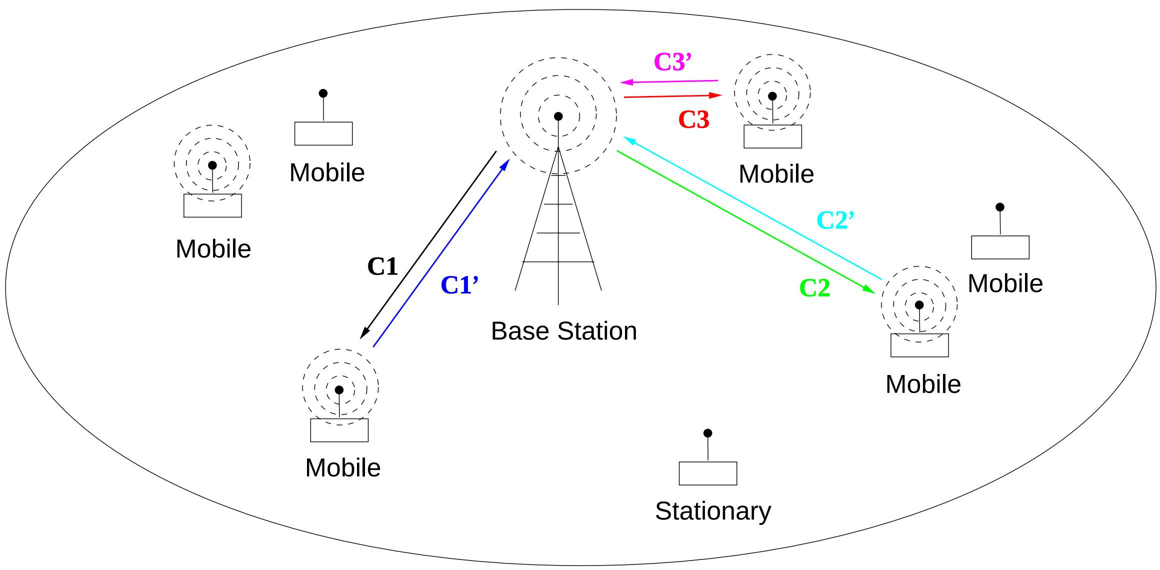
Dedicated channels workable because traffic is speech:

- Low bit rate & approximately CBR (constant bit rate)
- Not so for:

  → VBR (variable bit rate), e.g., MPEG video

  → data files (why?)

Cellular telephony: code division



CDMA

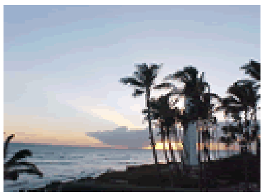
⟶ same frequency band; different codes

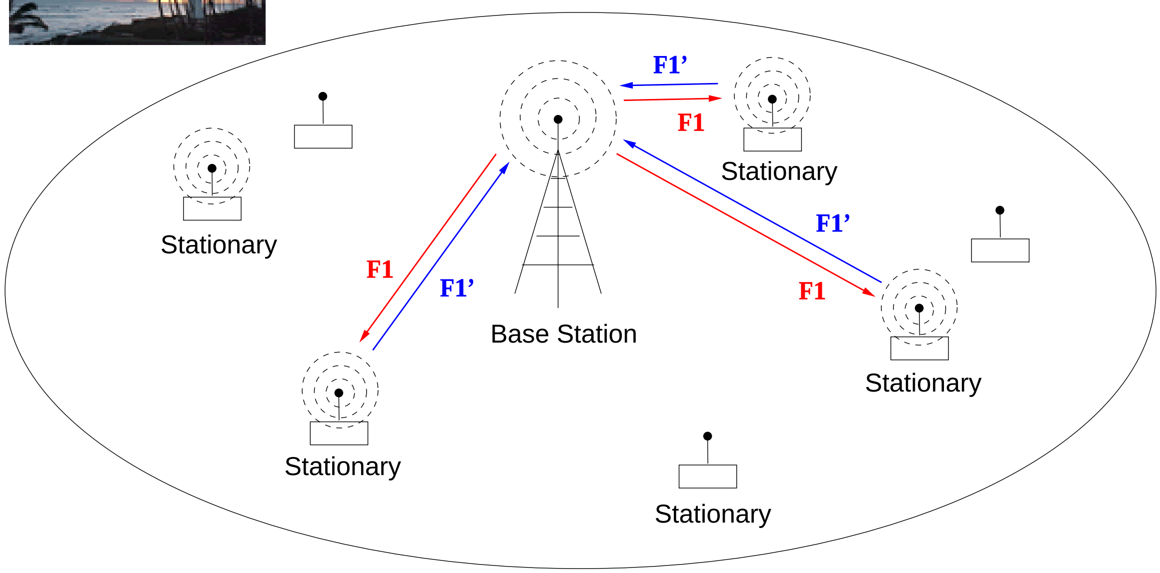
Ex.: IS-95 CDMA

- uplink: 824–849 MHz
- downlink: 869–894 MHz

  → 25 MHz frequency band
- codec: 9.6 kb/s

Packet radio: ALOHA





ALOHA

$\longrightarrow$ downlink broadcast channel $F1$

$\longrightarrow$ shared uplink channel $F1'$

Ex.: ALOHANET

- data network
- Univ. of Hawaii, 1970; 4 islands, 7 campuses

- Norm Abramson (precursor to Ethernet; Bob Metcalfe)
- FM radio carrier frequency

  → uplink: 407.35 MHz; downlink: 413.475 MHz
- bit rate: 9.6 kb/s
- Multiple access method: MA

  → plain and simple

ALOHA protocol:

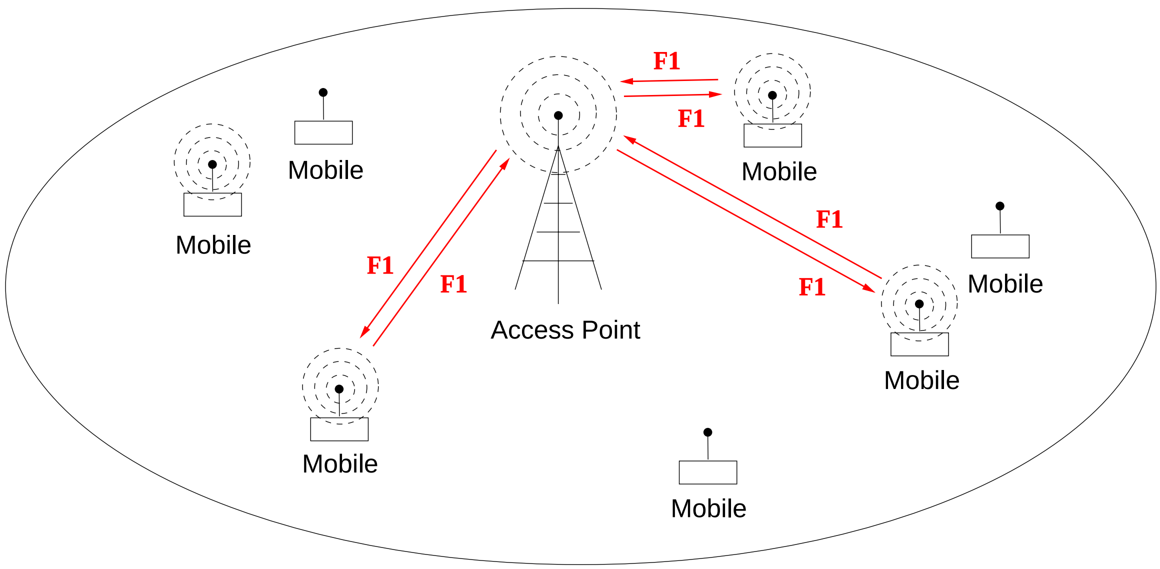
- send frame (no carrier sense)
- wait for ACK

  → "collision detection" through explicit ACK

  → different from Ethernet CSMA/CD
- if timeout, reattempt with probability p

  $\longrightarrow$ looks familiar...

Wireless LAN (WLAN): infrastructure mode



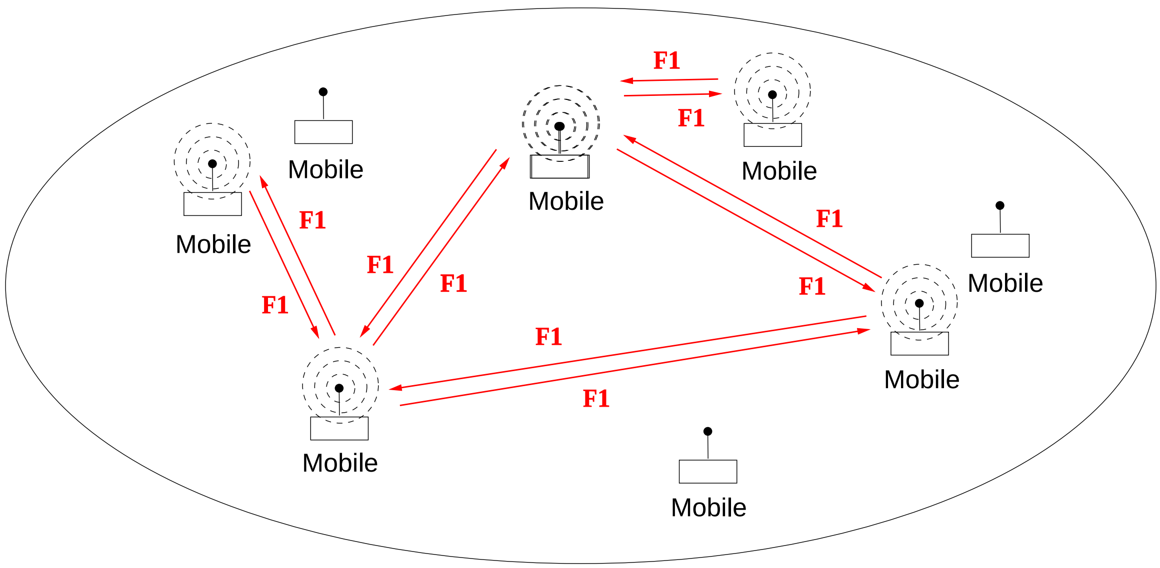
WLAN: Infrastructure Network

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

$\longrightarrow$ bus!

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

WLAN: ad hoc mode



WLAN: Ad Hoc Network

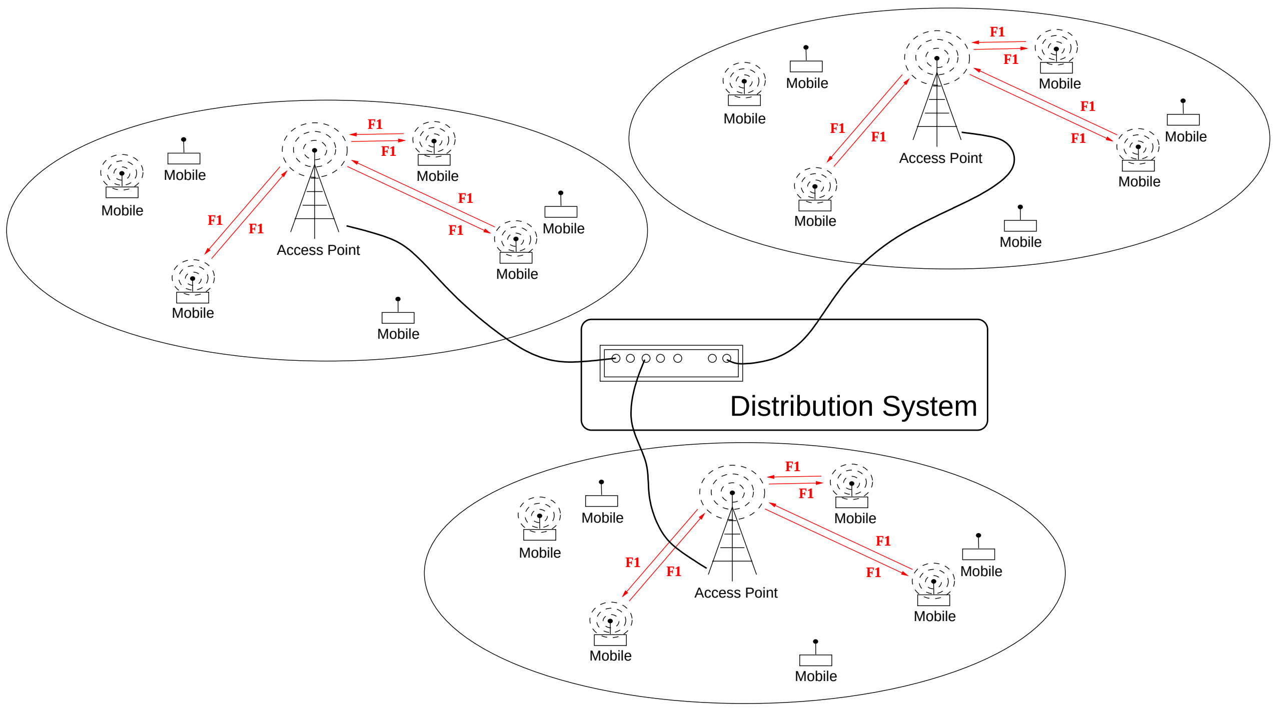
⟶ homogeneous: no base station

⟶ everyone is the same (kind of like KaZaA)

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

→ also called peer-to-peer mode

WLAN: internetworking



WLAN: Extended Service Set

$\longrightarrow$ internetworking between BSS's through APs

$\longrightarrow$ mobility and handoff

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

- DS: wireless or wireline

  → most common: Ethernet switch

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

  → learning bridge: source address discovery

  → spanning tree: IEEE 802.1 (Perlman's algorithm)

Additional headache: mobility

⟶ how to perform handoff

⟶ mobility management at MAC

⟶ mobility management at IP (Mobile IP)

Examples:

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

$\longrightarrow$ PAL (Purdue Air Link)

$\longrightarrow$ partial mobility: MAC roaming

$\longrightarrow$ no mobile IP

$\longrightarrow$ but 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.: Wi-Fi communities

$\longrightarrow$ free Internet access

$\longrightarrow$ roof-top mesh networks

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

Graffiti: warchalking

⟶ some cities

⟶ benevolent kids with lots of free time

Soon: integrated WLAN + cellular phones

⟶ use VoIP when near WLAN network

⟶ use cellular when outside WLAN coverage

⟶ automatic switch-over

WLAN spectrum 2.4–2.4835 GHz:

$\longrightarrow$ 11 channels (U.S.)

$\longrightarrow$ 2.412 GHz, 2.417 GHz, . . ., 2.462 GHz

Non-interference specification:

- 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 MAC

$\longrightarrow$ CSMA/CA with exponential backoff

$\longrightarrow$ almost like CSMA/CD

$\longrightarrow$ instead of CD, use CA (collision avoidance)

$\longrightarrow$ CA is optional (CD is not)

Two modes for MAC operation:

- Distributed coordination function (DCF)

  $\rightarrow$ multiple access

- Point coordination function (PCF)

  $\rightarrow$ polling-based priority scheme

CSMA with exponential backoff operation:

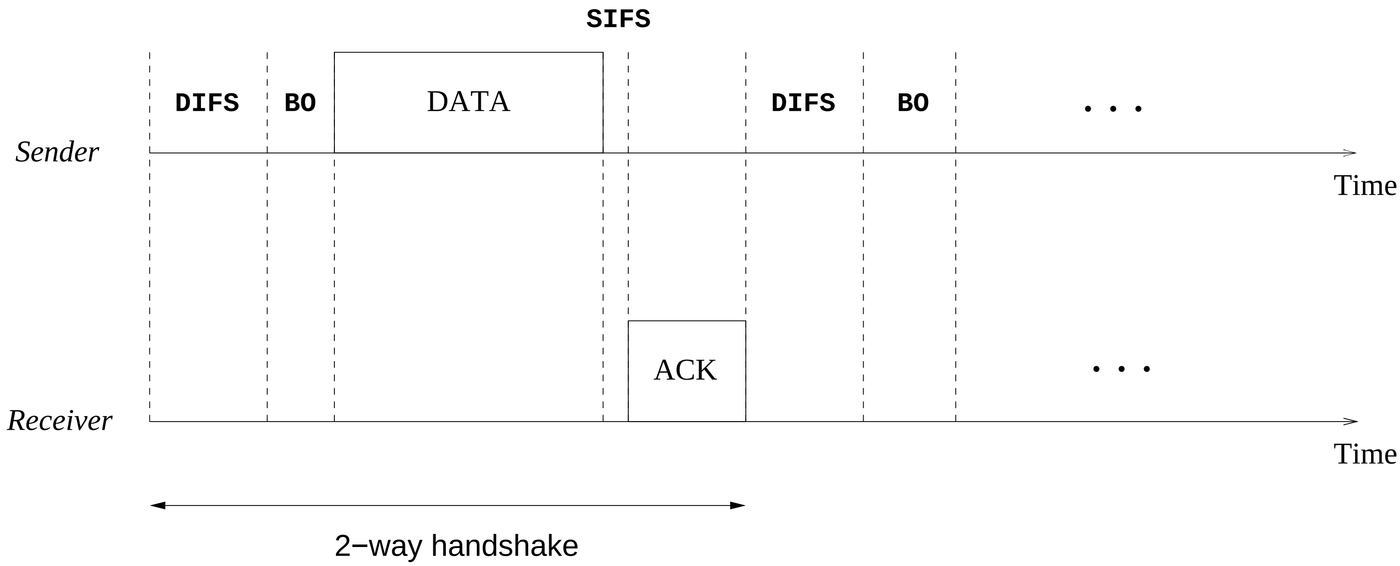
Sender:

- MAC (firmware in NIC) receives frame from upper layer
- Check if channel is idle (CS)
  - If busy, goto `Backoff` procedure
  - If idle, wait for DIFS duration, then goto `Backoff`
- Transmit frame
- Wait for ACK
- If timeout, goto `Backoff` procedure

Receiver:

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

Timeline without collision:



Time units:

- 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`)

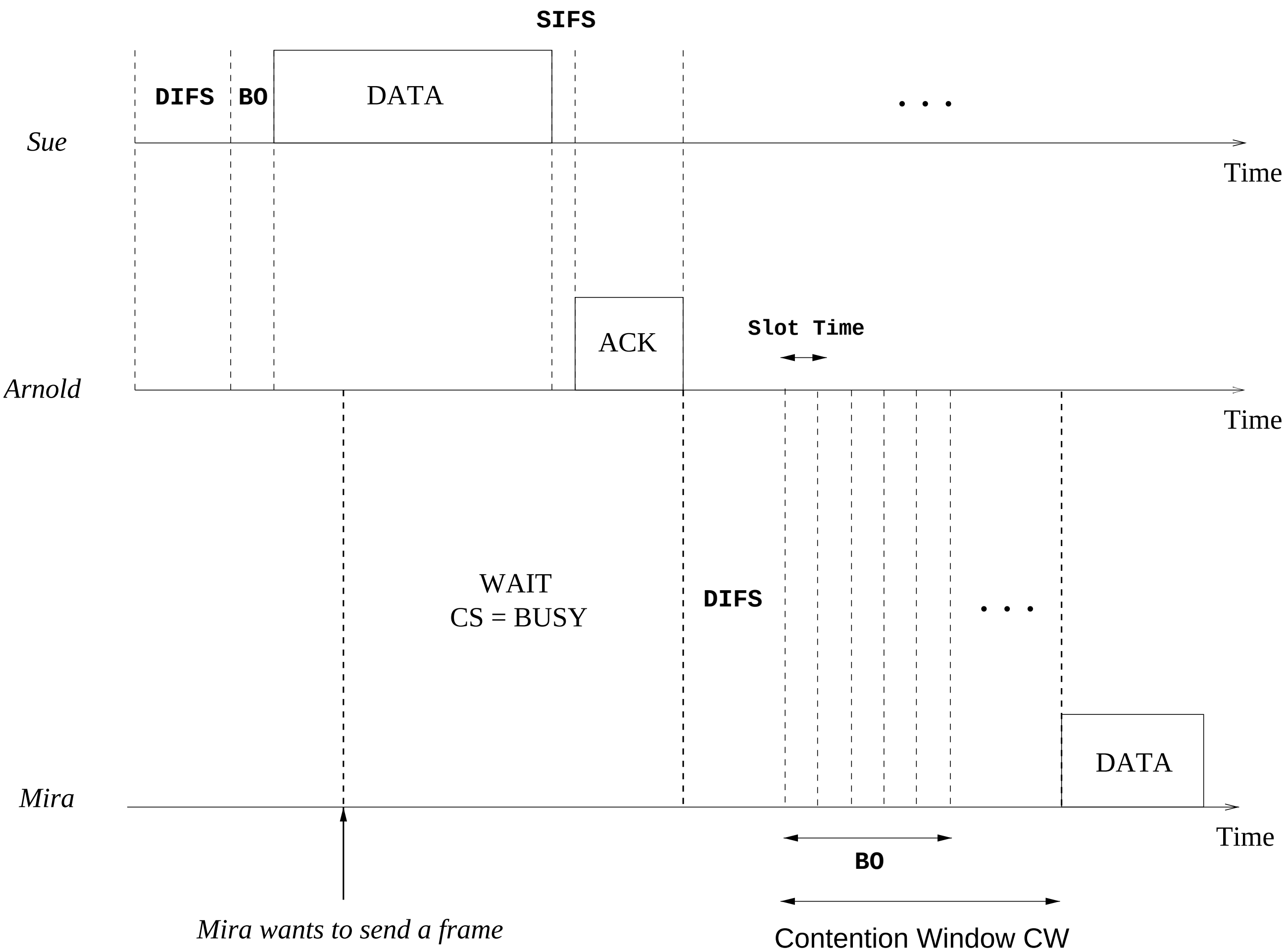
`Backoff`:

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

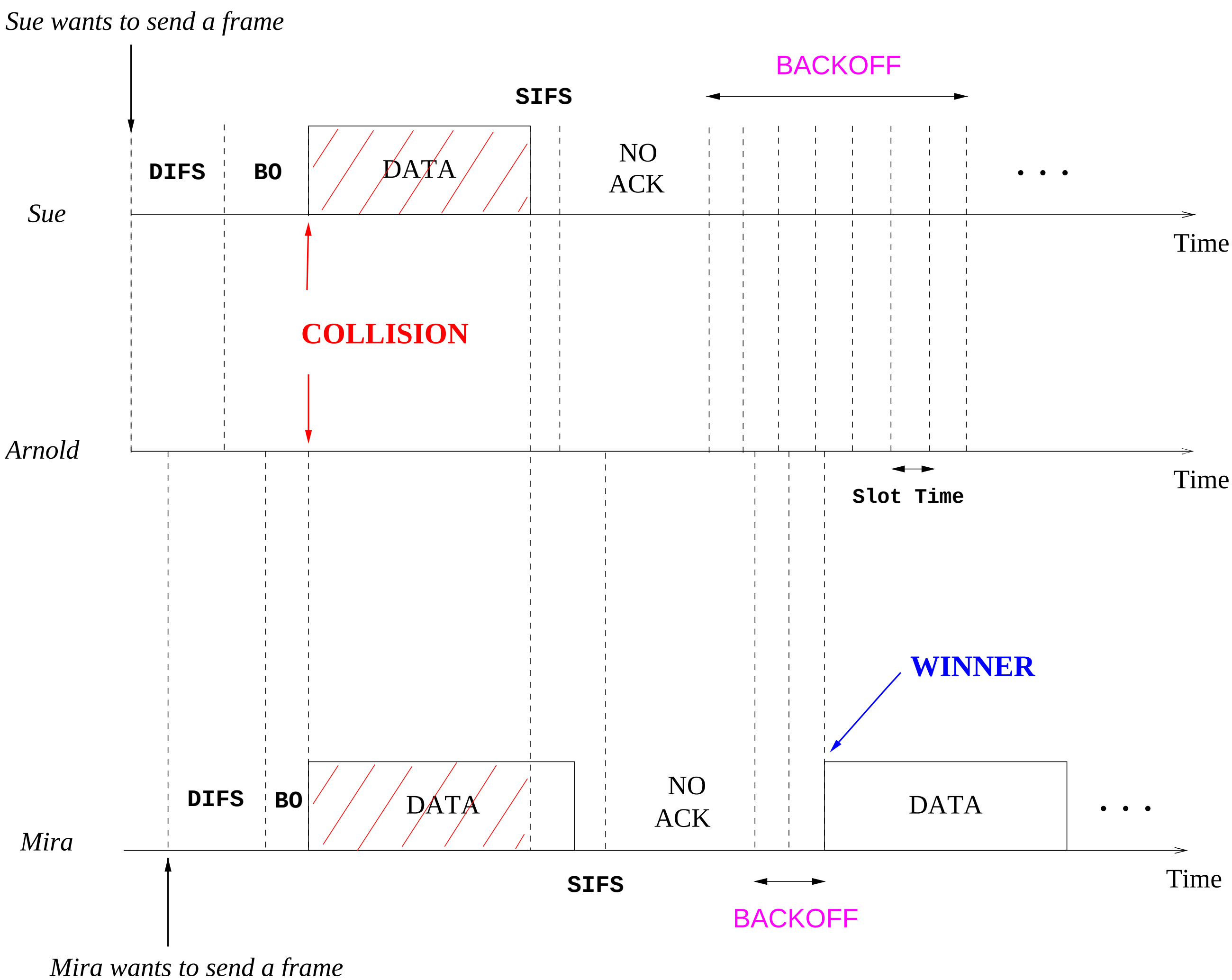
  → `CW` is in units of slot time
- Decrement `CW` when channel is idle
- Transmit when $\texttt{CW} = 0$

Time snapshot with Mira-come-lately:

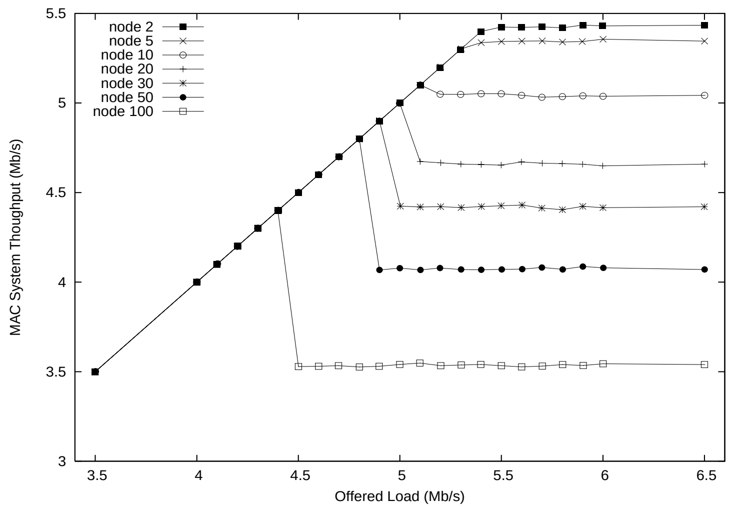
⟶ Sue sends to Arnold

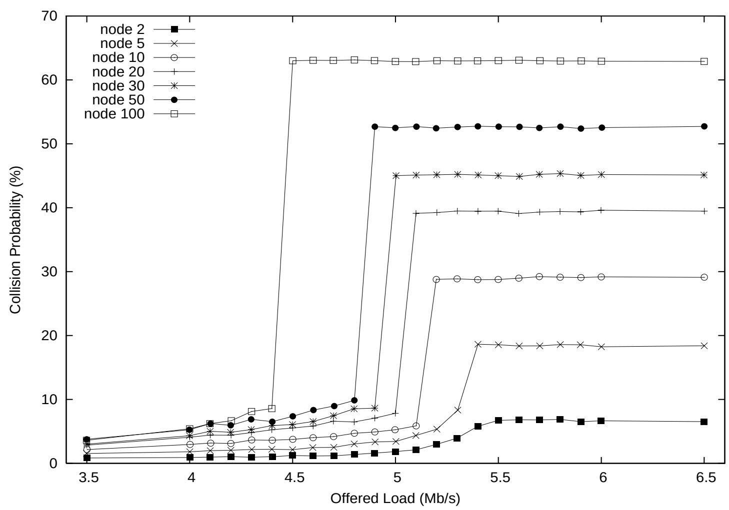


Time snapshot with collision (Sue & Mira):



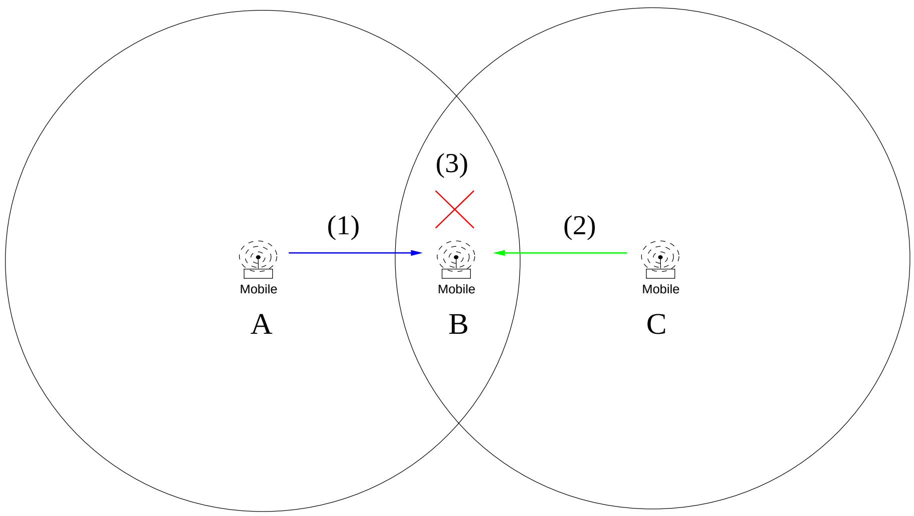
Throughput and collision:





Additional issues with multiple access in wireless media:

Hidden station problem:



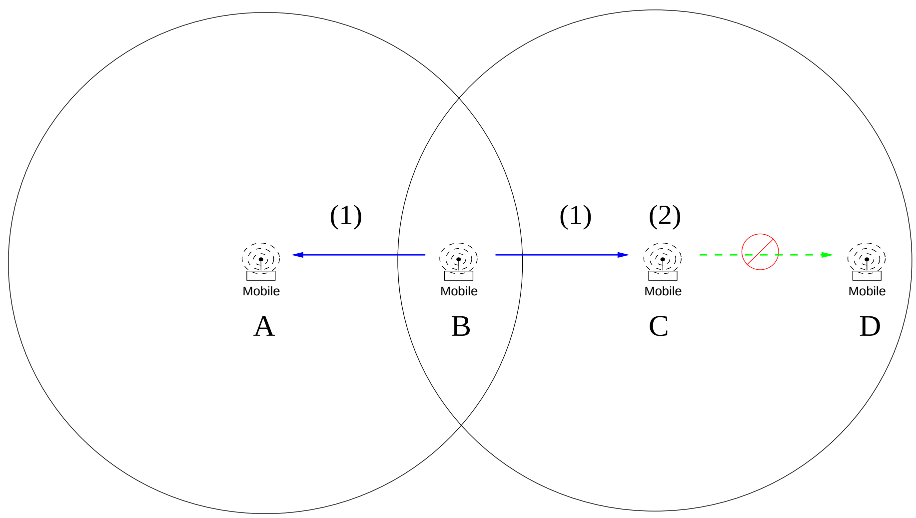
Hidden Station Problem

(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

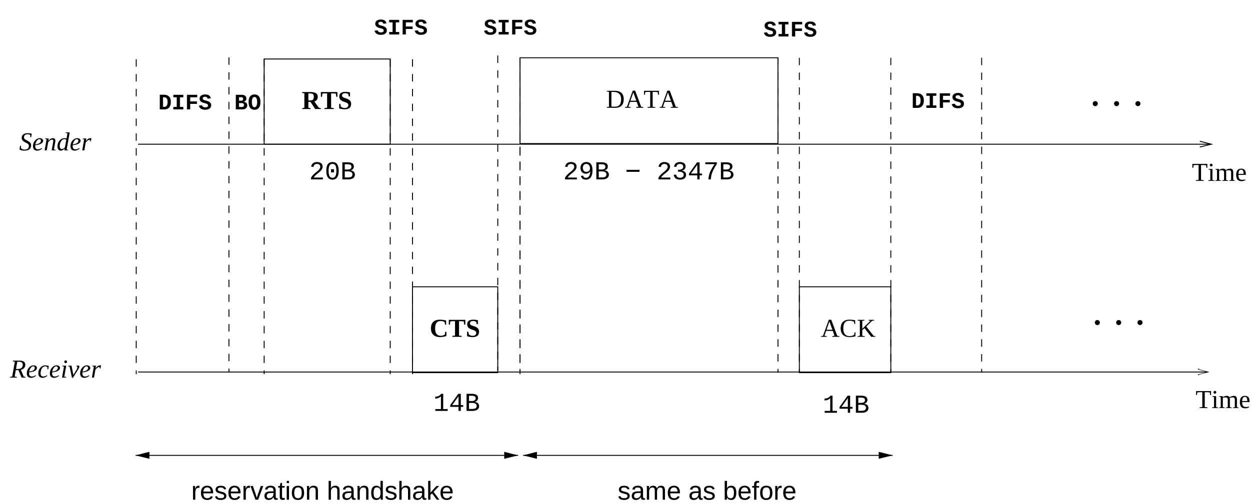
$\longrightarrow$ C refrains from transmitting to D

$\longrightarrow$ omni-directional antenna

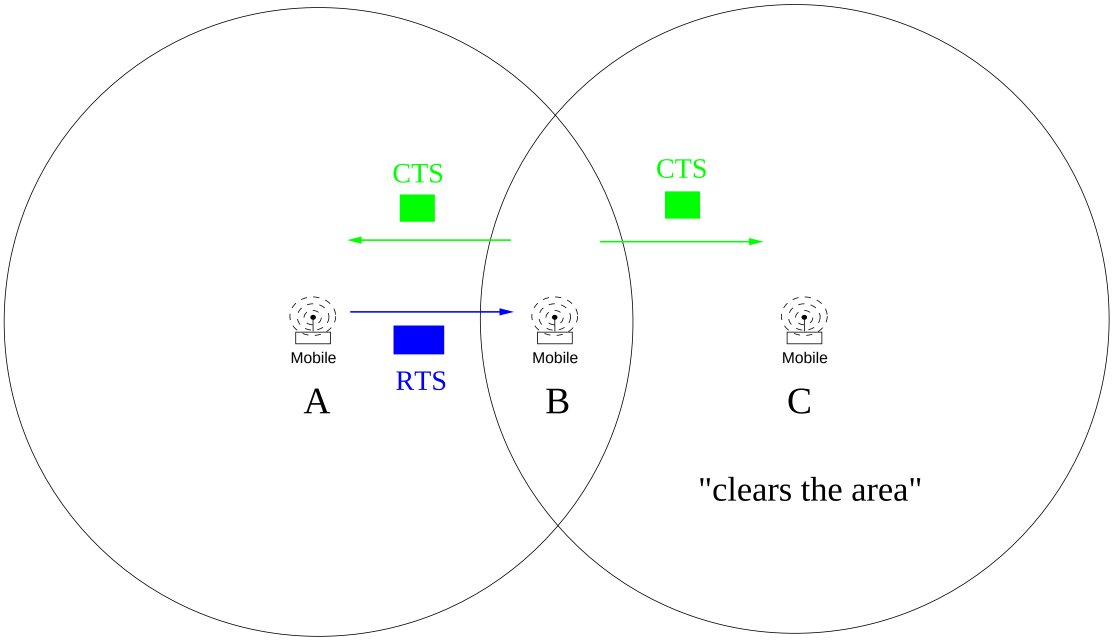
Solution: CA (congestion avoidance)

$\longrightarrow$ 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?

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

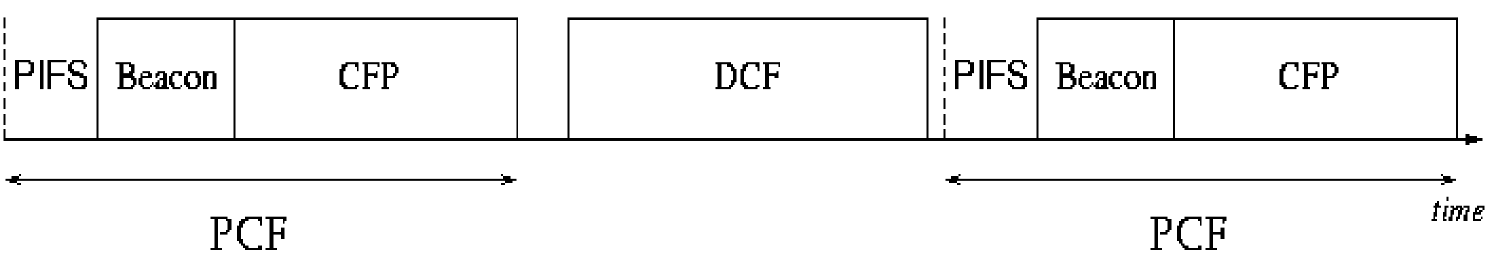
PCF (point coordination function):

$\longrightarrow$ 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 or 2 Mbps using either DSSS or FHSS
- 11 bit chip sequence
- uses IEEE 802 address format along with LLC
- uses 2.4–2.4835 GHz ISM band in radio spectrum
- IEEE 802.11b (High Rate) ratified: 5.5 or 11 Mbps using DSSS only
- others: e.g., IEEE 802.11a at 54 Mbps

  → 5.725–5.85 GHz band

Bluetooth, 802.16, . . .