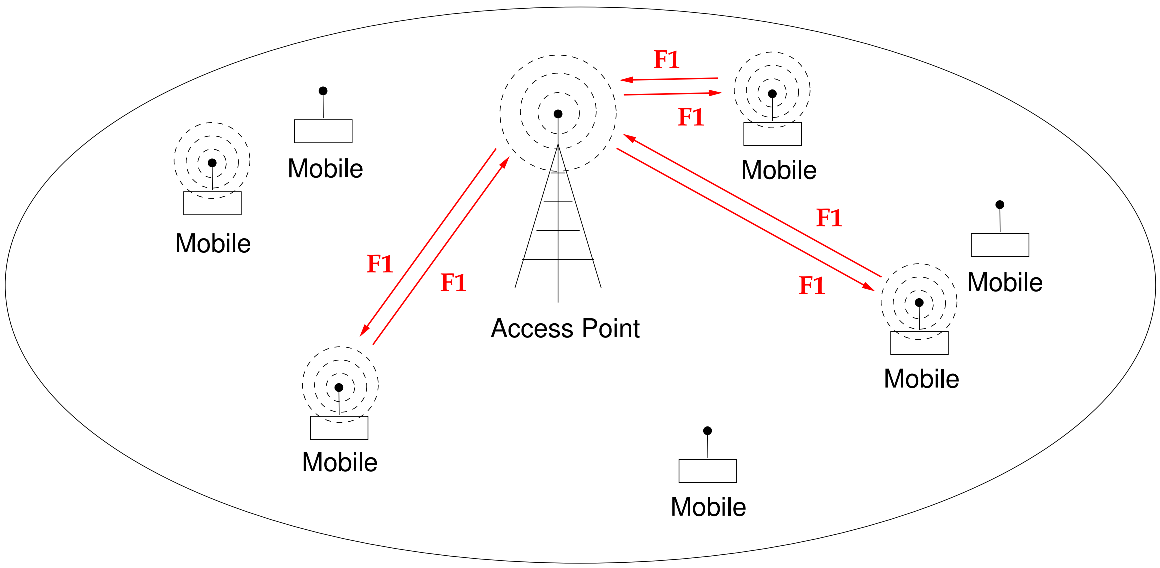
Wireless LAN (WLAN): infrastructure mode



WLAN: Infrastructure Network

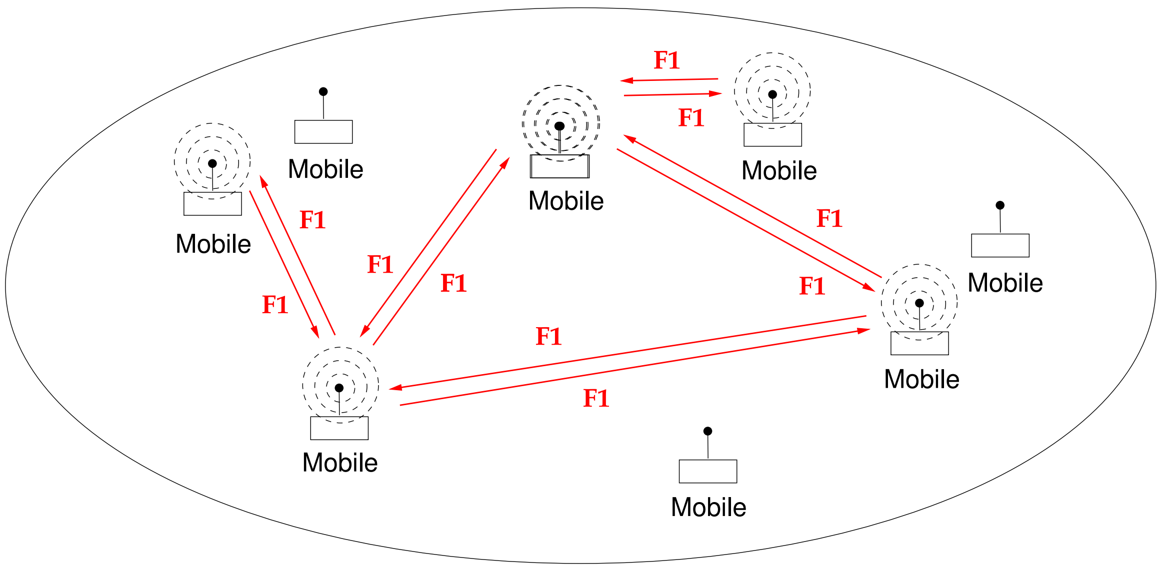
$\longrightarrow$ shared uplink & downlink channel $F1$

- basic service set (BSS)

  $\rightarrow$ "hot spot"

- 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

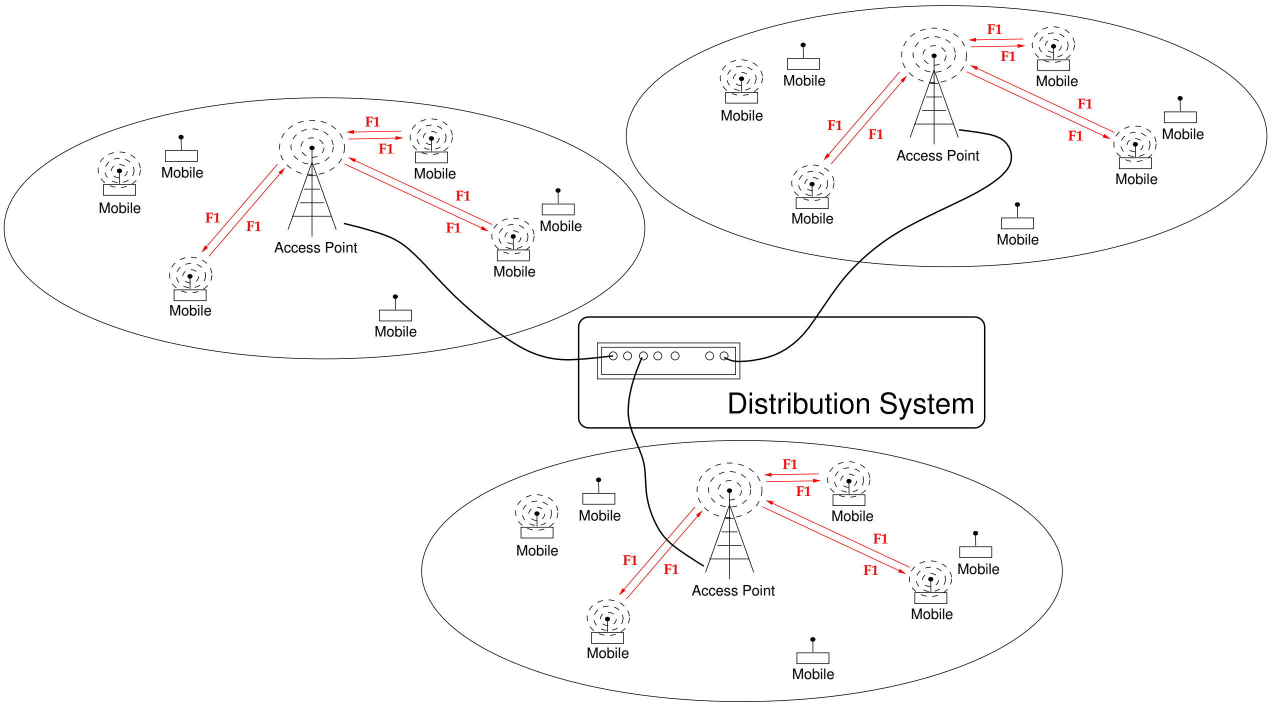
$\longrightarrow$ everyone is the same

$\longrightarrow$ 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

Source address discovery: learning bridge

→ at each interface monitor source MAC address of incoming frames

→ discover who is beyond

→ when unknown: flood (or broadcast)

→ simple form of routing

→ not scalable

Mobility and handoff:

$\longrightarrow$ mobiles roam

$\longrightarrow$ mobility management at link vs. network layer

$\longrightarrow$ link layer handoff dominant (vs. Mobile IP)

Mobility between BSS's in an ESS

- Association

  $\rightarrow$ AP sends out periodic beacon frame

  $\rightarrow$ mobile chooses AP and registers

- Disassociation

  $\rightarrow$ upon departure: notify AP

Handoff from old to new AP:

- reassociation

  → mobile initiated

  → e.g., switch to AP with stronger signal

  → go through association process

- handoff

  → inform new AP of old AP

  → forward buffered frames from old to new AP

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 (e.g., Japan)

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

→ UNNI (unlicensed National Information Infrastructure)

→ 23 non-overlapping channels

IEEE 802.11n: both 2.4 and 5 GHz

→ 40 MHz channel bandwidth

→ OFDM

→ 64-QAM

→ multiple antennae: MIMO (multiple input multiple output)

→ parallel transmission but single user (SU)-MIMO

IEEE 802.11ac: operates in 5 GHz only

→ WiFi 5

→ 80 and 160 MHz banwidth channels

→ 256-QAM

→ multi user (MU)-MIMO: transmit to multiple users using multiple antennae

IEEE 802.11ax: WiFi 6 and 6E

→ 1024 QAM

→ WiFi 6E uses 6 GHz band: 5.925-7.125 GHz

→ OFDMA

→ nominal speed: 9.6 Gbps

IEEE 802.11be: WiFi 7

→ 4096 QAM

→ bandwidth increased to 320 MHz

→ nominal speed: 46 Gbps

IEEE 802.11 medium access control (MAC):

$\longrightarrow$ CSMA/CA with exponential backoff

$\longrightarrow$ explicit positive ACK frame

$\longrightarrow$ optional feature: CA

Two modes of MAC operation:

- distributed coordination function (DCF)

  $\rightarrow$ CSMA

- point coordination function (PCF)

  $\rightarrow$ reservation

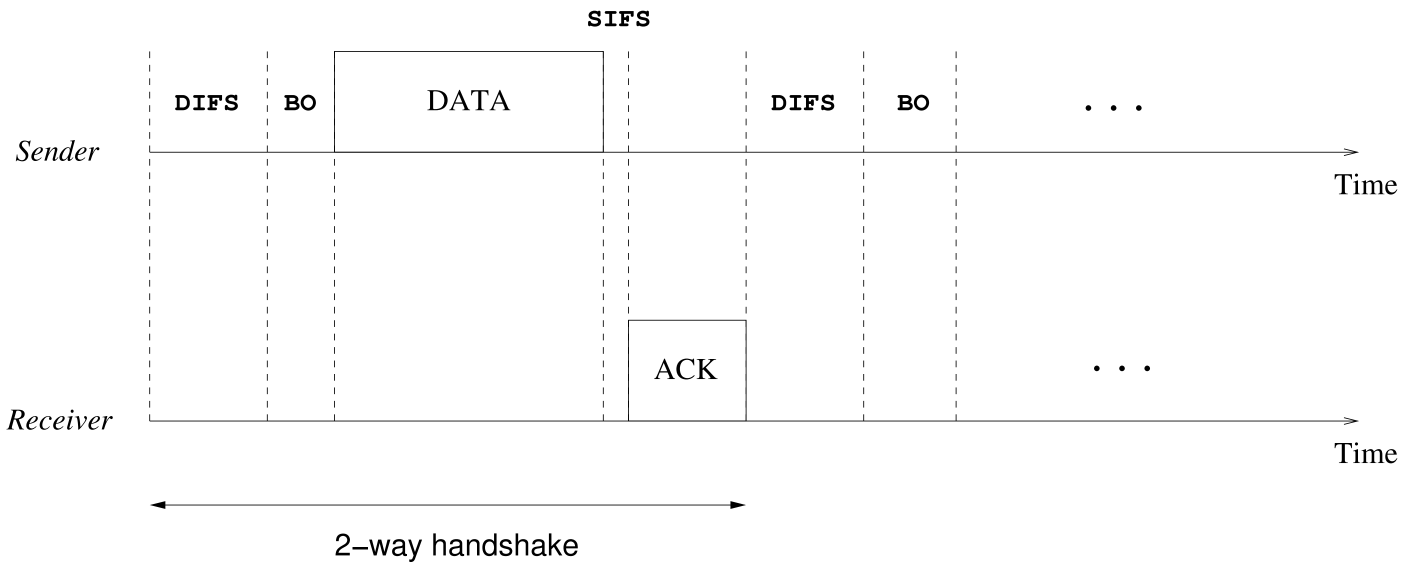
  $\rightarrow$ telephony support

  $\rightarrow$ not used in practice

- OFDMA resource reservation in WiFi 7

  $\rightarrow$ similar fate as PCF?

Timeline without collision:



- SIFS (short interframe space): 16 μs
- Slot Time: 9 μs
- DIFS (distributed interframe space): 34 μs

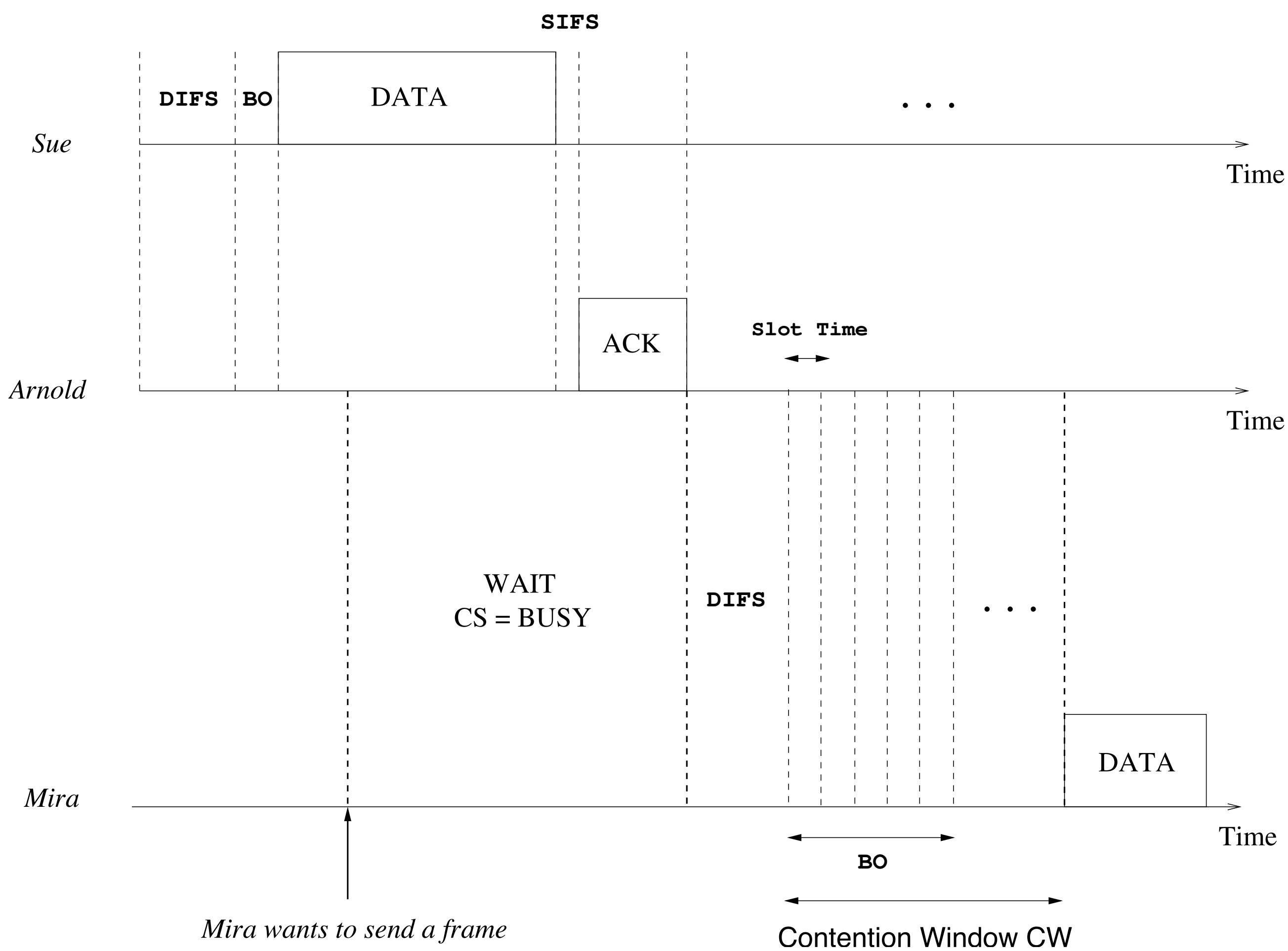
  $\rightarrow$ DIFS = SIFS + 2 $\times$ slot time
- BO: exponential back-off

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

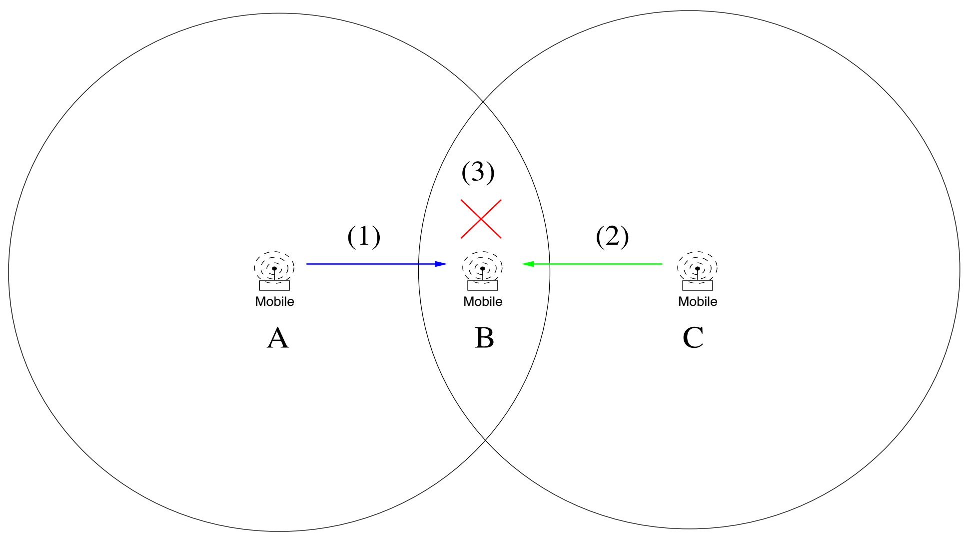
Time snapshot with Mira-come-lately:

→ Sue sends to Arnold

→ Mira joins competition later



Hidden station problem:



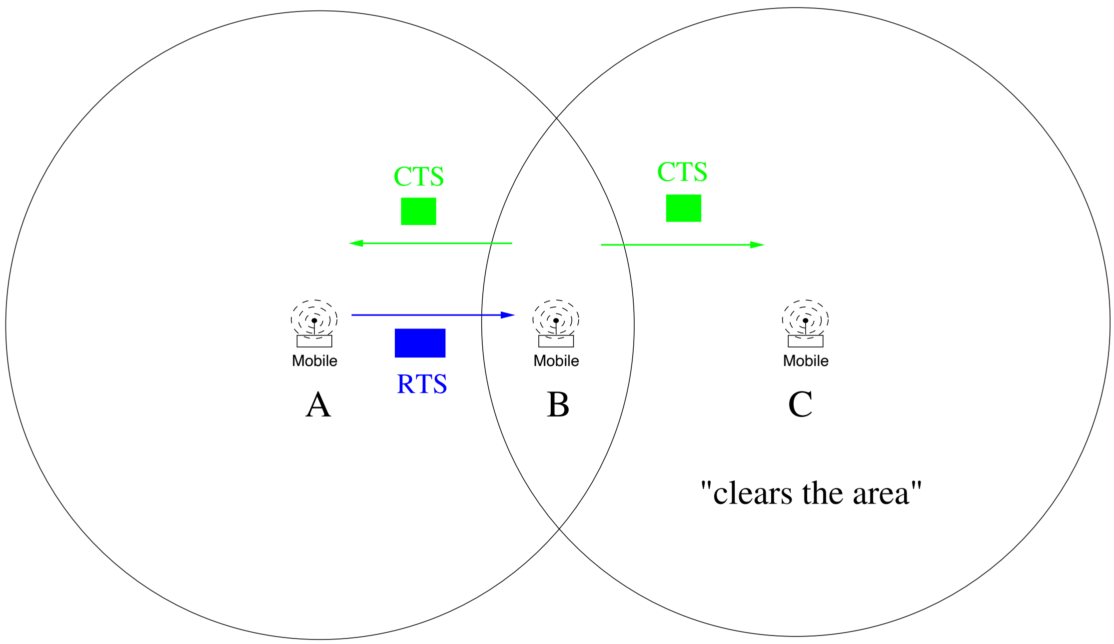
Hidden Station Problem

(1) A transmits to B

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

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

Hidden station problem: RTS/CTS handshake “clears” hidden area



`RTS/CTS Handshake`

RTS/CTS perform only if data > RTS threshold

→ why not for small data?

Not utilized in real-world deployments

→ repurposed OFDMA resource reservation in WiFi 7