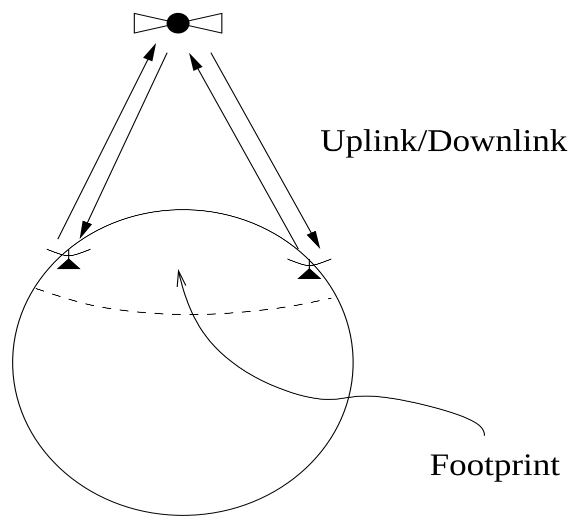
Long Distance Wireless Communication

Principally satellite communication:



- LOS (line of sight) communication

  → satellite base station is relay

- Effective for broadcast
- Limited bandwidth for multi-access

  → not scalable

Multi-access protocols:

- FDM + 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

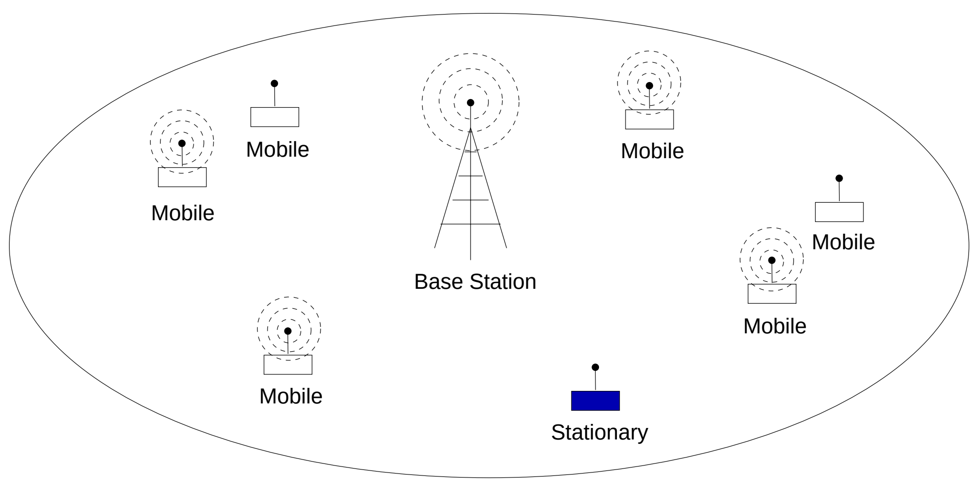
Long-distance wireless communication: effective when broadcasting

$\longrightarrow$ special applications

$\longrightarrow$ e.g., TV, GPS, digital radio, atomic clock

Short Distance Wireless Communication

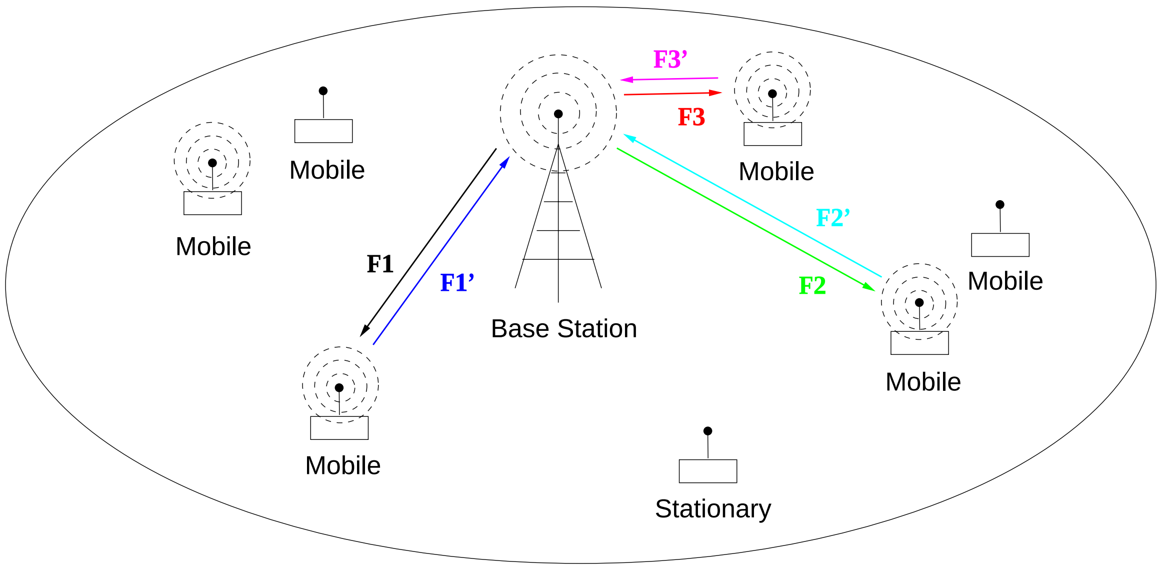
- very short: wireless PAN
- short: wireless LAN
- medium: wireless MAN



⟶ TDMA, FDMA, CDMA, polling

⟶ contention-based multiple access w/o priority

Cellular telephony: frequency & time division



FDD & TDMA

Ex.: GSM (U.S. IS-136) with 25 MHz frequency band

- uplink: 890–915 MHz
- downlink: 935–960 MHz
- 125 channels 200 kHz wide each ($= 25000 \div 200$)

  $\longrightarrow$ separation needed due to cross-carrier interference

  $\longrightarrow$ FDM portion

- 8 time slots within each channel

  → TDM portion
- total of 1000 possible user channels

  → 125×8 (124×8 realized)
- codec/vocoder: 13.4 kb/s
- compare with T1 standard

  → 24 users at 64 kb/s data rate each

Dedicated channels workable because data traffic is speech:

- Low bit rate & approximately CBR (constant bit rate)

  $\longrightarrow$ flat

  $\longrightarrow$ good/bad?

- Not so for:

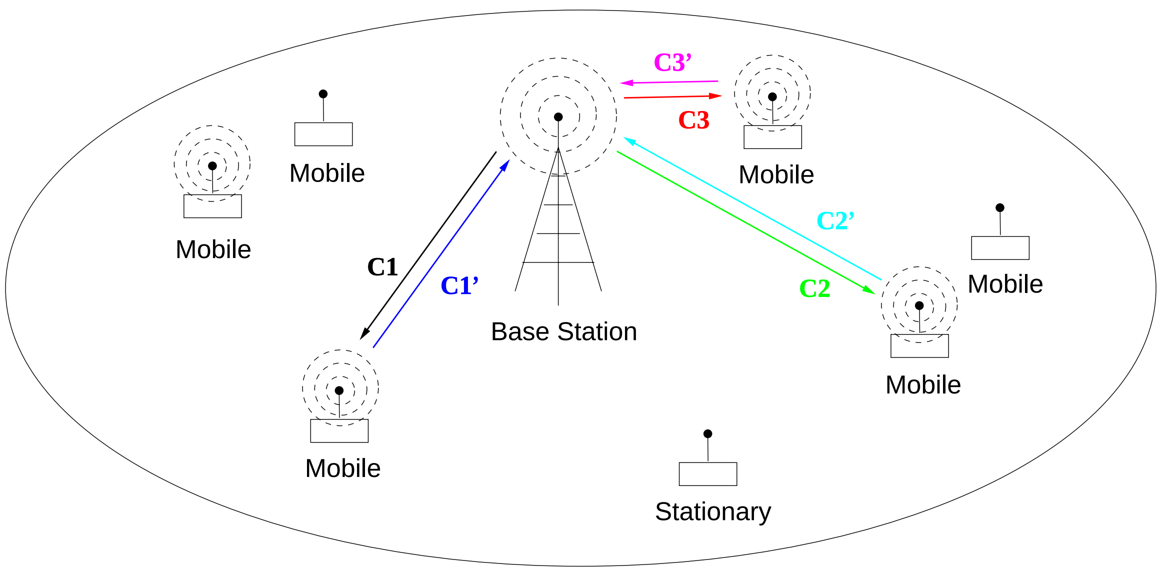
  $\longrightarrow$ different for compressed video (e.g., MPEG, H.261)

  $\longrightarrow$ cf. Terminator video

  $\longrightarrow$ VBR (variable bit rate)

  $\longrightarrow$ data files?

Cellular telephony: code division multiplexing



FDD & CDMA

$\longrightarrow$ same frequency band; different codes

Ex.: IS-95 CDMA with 25 MHz frequency band

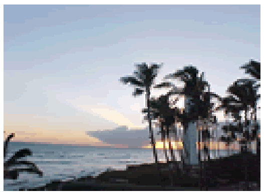
- uplink: 824–849 MHz; downlink: 869–894 MHz

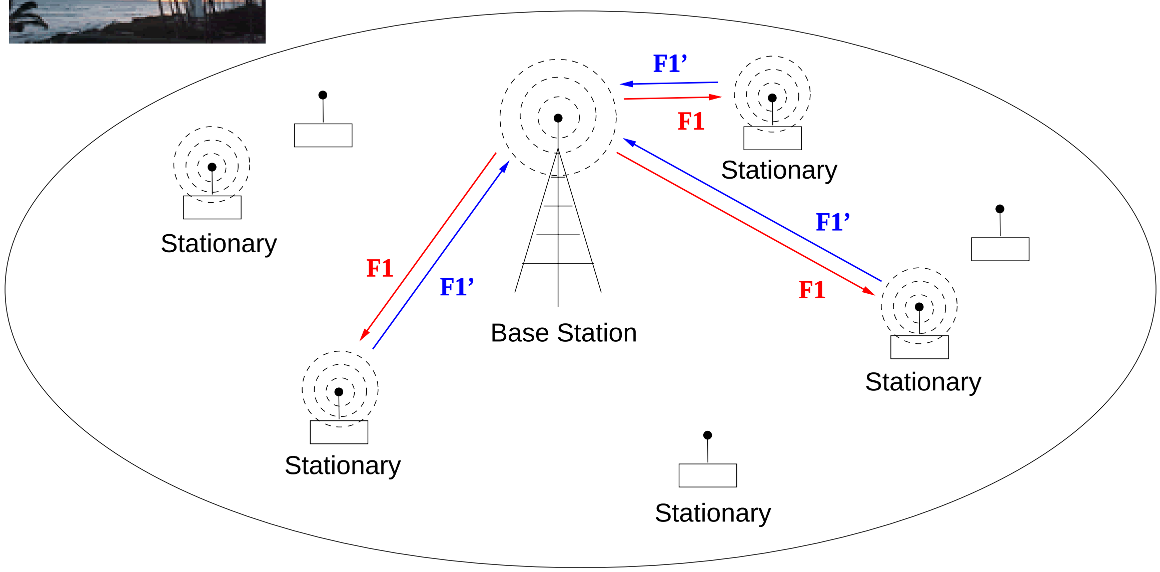
  $\rightarrow$ downlink: prepared; uplink: physical diversity

  $\rightarrow$ capture effect: closer station has advantage

- codec: 9.6 kb/s

Packet radio: ALOHA





ALOHA

$\longrightarrow$ downlink broadcast channel $F1$

$\longrightarrow$ shared uplink channel $F1'$

$\longrightarrow$ both baseband

Ex.: ALOHANET

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

- Norm Abramson

  → precursor to Ethernet (Bob Metcalfe)

  → pioneering Internet technology

  → parallel to packet switching technology

- FM radio carrier frequency

  → uplink: 407.35 MHz; downlink: 413.475 MHz

- bit rate: 9.6 kb/s

- contention-based multiple access: MA

  → plain and simple

  → needs explicit ACK frames

  → ALOHA

ALOHA protocol:

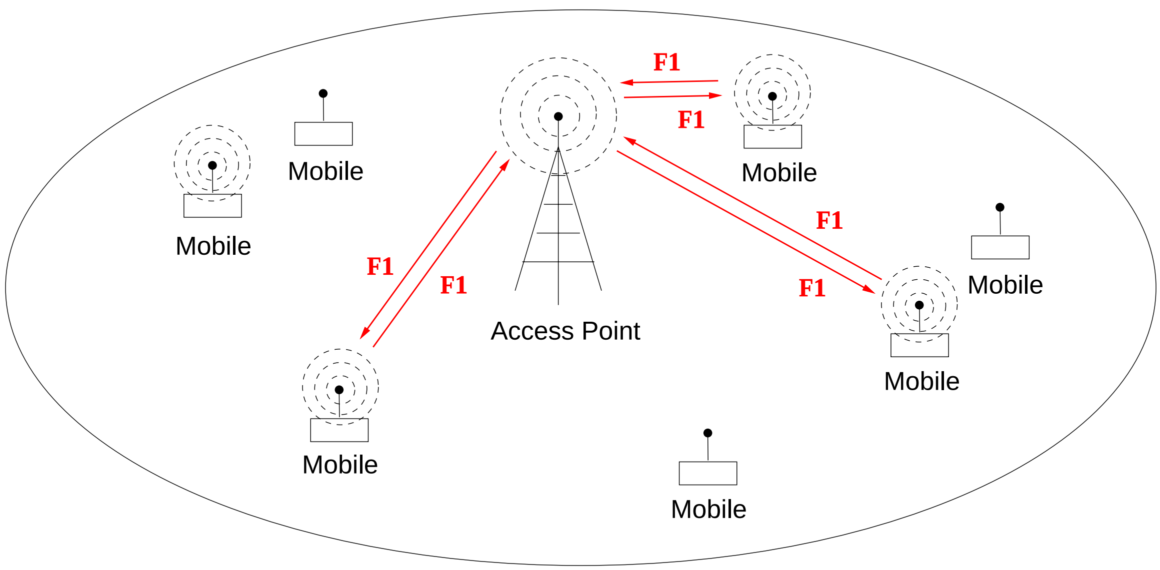
- send frame (no carrier sense)
- wait for ACK

  → collision detection through explicit ACK
- if timeout, retry with probability p

⟶ looks familiar. . .

⟶ pure vs. slotted ALOHA

Wireless LAN (WLAN): infrastructure mode



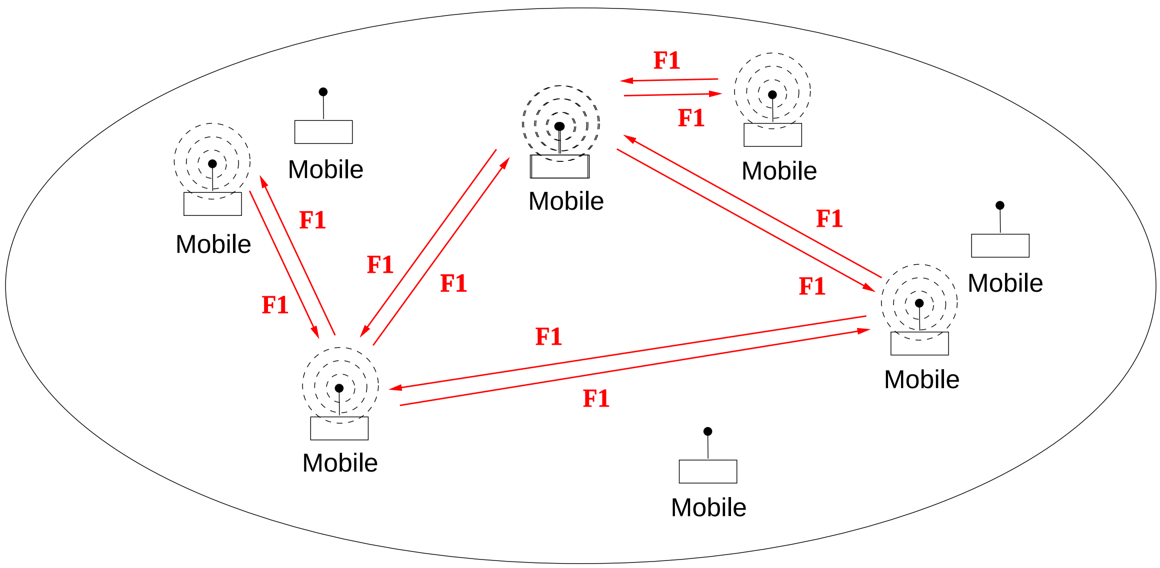
WLAN: Infrastructure Network

$\longrightarrow$ 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

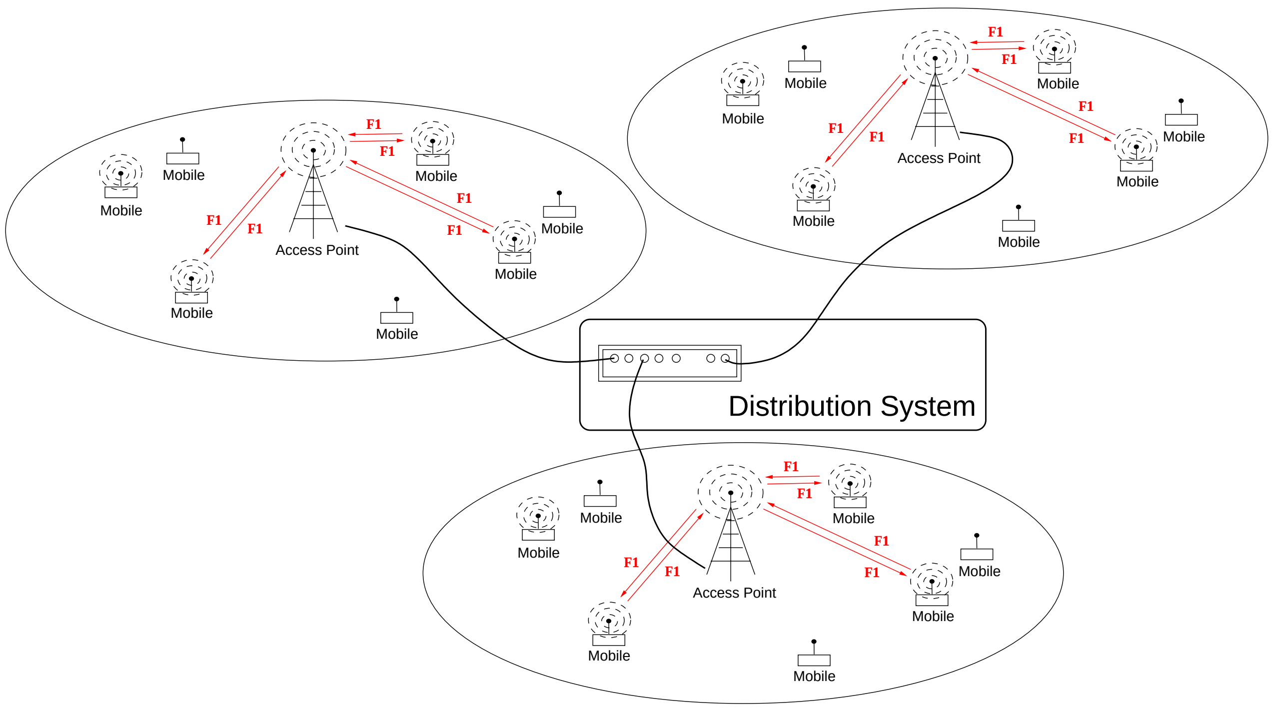
⟶ everyone is the same

⟶ 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)

- DS: wireline or wireless

  → common: Ethernet switch

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

  → bridge: link layer forwarding device

  → i.e., switch using MAC address relay

  → learning bridge: source address discovery

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

  → distributed ST & leader election

Additional headache: mobility

$\longrightarrow$ how to perform handoff

$\longrightarrow$ mobility management at MAC

$\longrightarrow$ mobility management at IP (Mobile IP)

Mobility between BSSes in an ESS

- association

  $\rightarrow$ registration process

  $\rightarrow$ 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

Association, disassociation, reassociation provides necessary information for distribution service within ESS

⟶ distribution service implemented in AP

Compatibility with non-802.11 devices in ESS:

⟶ integration service: portal abstraction

⟶ translation service

Complicated 802.11 frame format

⟶ 30-byte MAC header

⟶ four 48-bit address fields

⟶ 16-bit frame control field: 11 fields

⟶ e.g., version, type, subtype, to DS, from DS, ...

⟶ type (2-bit): mgt (00), control (01), data (10)

⟶ subtype (4-bit): association (mgt), ACK (ctl)

⟶ payload: 0–2313 bytes

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. . .

Examples:

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

⟶ PAL (Purdue Air Link)

⟶ partial mobility: MAC roaming (within ESS)

⟶ no mobile IP

⟶ but football scores at Ross-Ade through PDAs

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

⟶ full VoIP

⟶ free long distance

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

⟶ free Internet access

⟶ roof-top mesh networks

⟶ cable & DSL companies don't like it

Graffiti: warchalking

$\longrightarrow$ some cities

$\longrightarrow$ benevolent kids with lots of free time

Soon: integrated WLAN + cellular phones

$\longrightarrow$ use VoIP when near WLAN network

$\longrightarrow$ use cellular when outside WLAN coverage

$\longrightarrow$ automatic switch-over