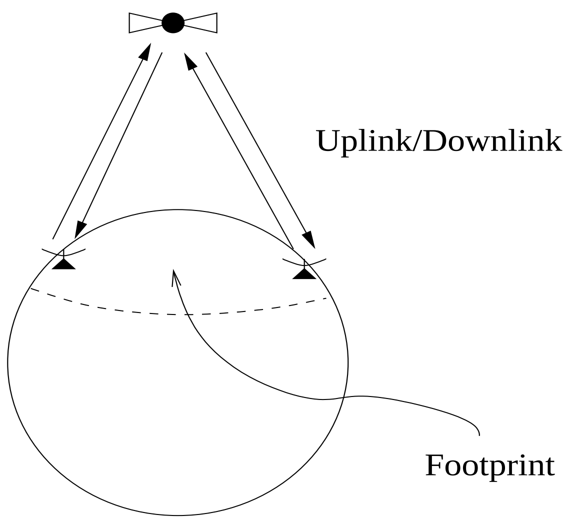
Long Distance Wireless Communication

Principally satellite communication:



- LOS (line of sight) communication

  → satellite base station is relay
- Effective for broadcast
- Limited bandwidth

MAC protocols:

- FDMA + TDMA: dominant

  → broadband

  → GSM cellular

  → recently: OFDM

- CDMA: e.g., GPS and defense related systems
- CSMA: viable?

Long-distance wireless communication: useful for broadcast service

⟶ subset of killer applications

⟶ e.g., TV, GPS, digital radio, atomic clock

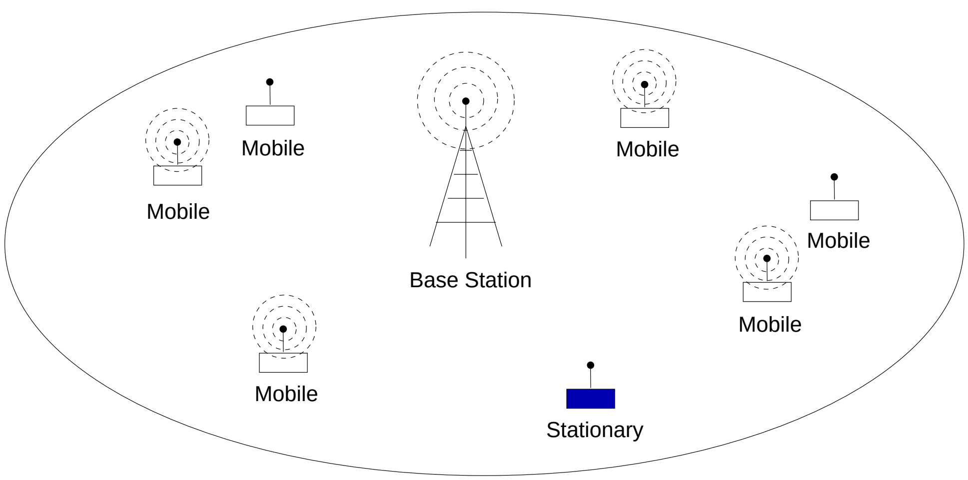
⟶ not suited for Internet access service!

Short Distance Wireless Communication

- medium: wireless MAN (IEEE 802.16)
- short: wireless LAN (IEEE 802.11)
- very short: wireless PAN (IEEE 802.15)

  → home area networks

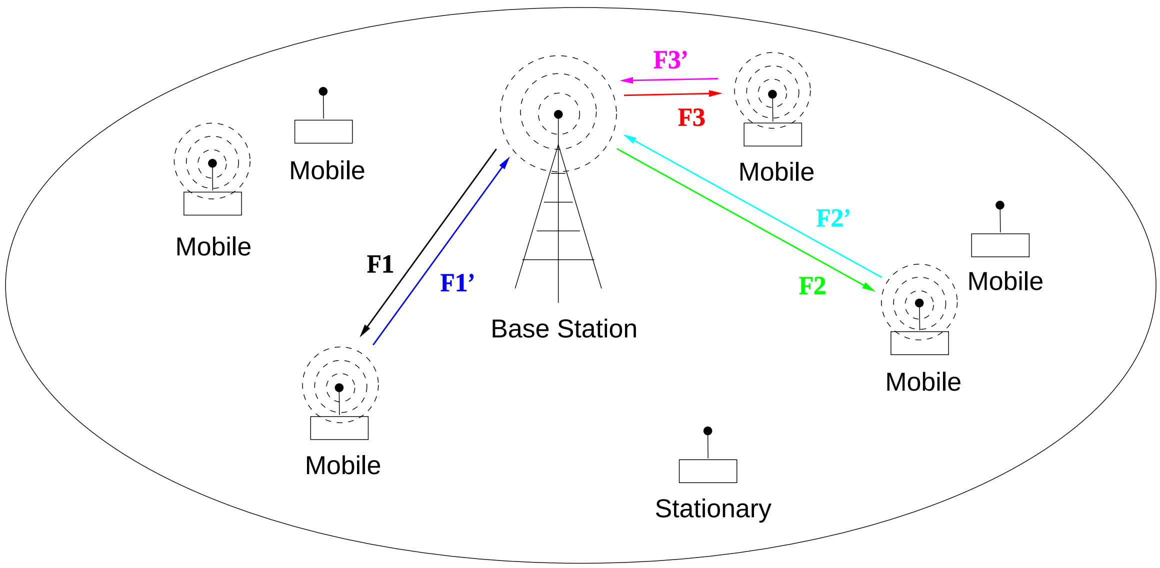
  → near field communication (e.g., RFID)



⟶ OFDM, FDMA, TDMA, CDMA, SDM/MIMO

⟶ contention-based multiple access (CSMA)

Cellular telephony: TDMA (frequency and 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

  $\longrightarrow$ FDMA; higher spectral efficiency with OFDMA

- 8 time slots within each channel (i.e., carrier frequency)

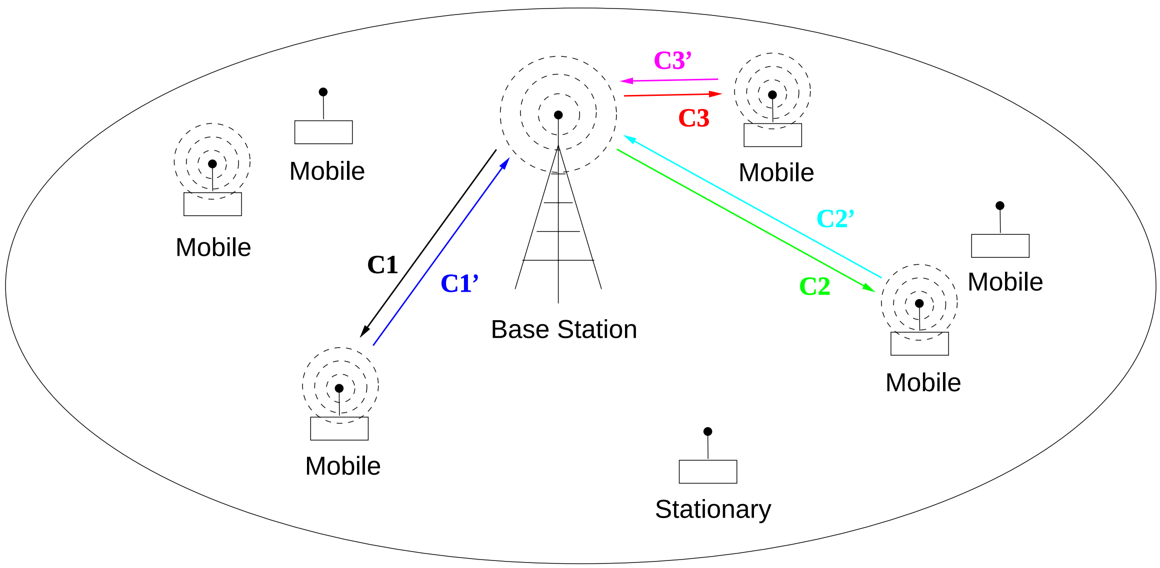
  $\rightarrow$ TDM component
- total of 1000 possible user channels

  $\rightarrow 125 \times 8$ (124×8 realized)
- codec/vocoder (i.e., compression): 13.4 kbps
- compare with T1 standard

  $\rightarrow$ 24 users at 64 kbps data rate each

  $\rightarrow$ 64 kbps vs. 13.4 kbps: landline has clearer sound

Cellular telephony: CDMA



FDD & CDMA

⟶ different code (i.e., basis vector) per user

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

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

  → no separate carrier frequencies

  → everyone shares same 25 MHz band

- codec: 9.6 kb/s

Recall: in CDMA each user gets a code vector

→ code vectors between users are orthogonal

→ pseudo-random

→ called pseudonoise (PN) sequence or chipping code

Moreover: a single data bit is encoded using $r > 1$ code bits

→ apply FEC

→ r is called code rate

In single-user CDMA:

- data bits $x = x_1 x_2 \ldots x_n$
- chipping sequence (i.e., code vector) $y = y_1 y_2 \ldots y_{rn}$

  $\rightarrow$ code rate r

  $\rightarrow$ pseudo-random

  $\rightarrow$ orthogonal if multi-user
- code rate r expanded data bits

  $\rightarrow$ $x' = x_{11} x_{12} \ldots x_{1r} x_{21} x_{22} \ldots x_{2r} \ldots x_{n1} x_{n2} \ldots x_{nr}$

  $\rightarrow$ total length: rn bits

  $\rightarrow$ r-fold replication of each data bit x_i
- transmitted bits $z = z_1 z_2 \ldots z_{rn}$: send $x' \oplus y$

  $\rightarrow$ bit-wise XOR of x' and y

Ex.: Suppose $r = 5$. To send single bit, say $x = 1$,

- "expand" x to $x' = 11111$ (r-fold replication)
- if $y = 01001$ then send $z = x' \oplus y = 11111 \oplus 01001 = 10110$

To decode: apply XOR again

$\rightarrow z \oplus y = 10110 \oplus 01001 = 11111$

Called DSSS (direct sequence spread spectrum) CDMA

$\rightarrow$ used in IEEE 802.11b WLAN: 11-bit chip sequence

$\rightarrow$ note: since single-user CDMA (DSSS), 802.11b uses CSMA for multi-user communication

Frequency hopping spread spectrum (FHSS) CDMA:

Use pseudorandom number sequence as key to index a set of carrier frequencies $f_1, f_2, \ldots, f_m$.

→ frequency spreading

→ send first bit on f_1, second bit on f_2, etc.

Receiver with access to pseudorandom sequence can decode transmitted signal.

→ receiver's tuner must jump around

→ code input as wideband output

→ spread data across carrier frequencies: spread spectrum

→ conceived in the 1950s for military applications

→ why is DSSS CDMA called "spread spectrum"?

Benefits of CDMA:

- more secure against eavesdropping

  → confidentiality

- resistant to jamming

  → must jam a wider spectrum: more difficult

- noise resistance

  → code rate r

- graceful degradation compared to FDMA/TDMA

  → code vectors don't need to be perfectly orthogonal for successful decoding

- resistance to multi-path fading

  → recall: fading varies across carrier frequencies

  → don't put all eggs in one basket

Deployment and usage:

→ old 802.11 wireless LAN (WLAN): DSSS and FHSS

→ e.g.: 802.11 Bluetooth—79 frequency hopping sequence

→ cellular (e.g., Sprint PCS, Verizon): DSSS CDMA

→ GPS

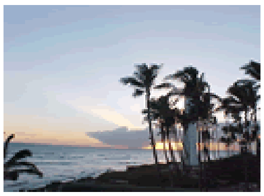
Today: OFDM aims at best of both worlds

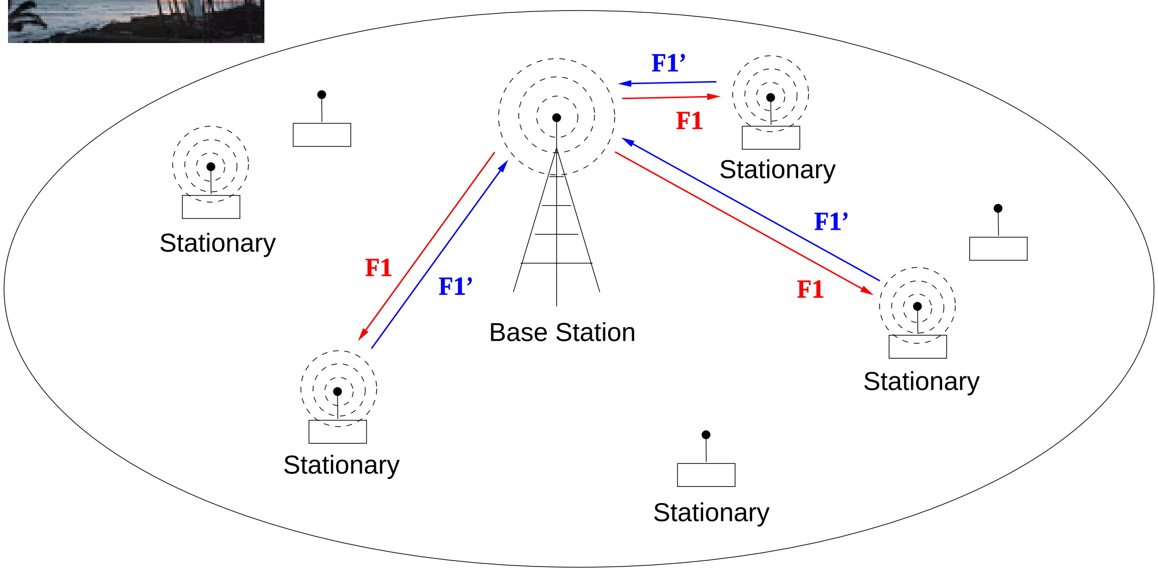
→ FDMA: simplicity

→ CDMA: spread spectrum

→ simple, spectrally efficient, spread spectrum communication

Packet radio: ALOHA





ALOHA

$\longrightarrow$ downlink broadcast channel $F1$

$\longrightarrow$ shared uplink channel $F1'$

Ex.: ALOHANET

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

- Norm Abramson

  → precursor to Ethernet (Bob Metcalfe)

  → pioneering Internet technology

  → parallel to wired packet switching technology

- FM 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