Signal Propagation and Power

Free space loss:

- transmitting antenna: signal power P_{snd}
- receiving antenna: signal power P_{rcv}
- distance: d
- frequency: f

$$P_{\text{rcv}} \propto P_{\text{snd}} \frac{1}{d^2 f^2}$$

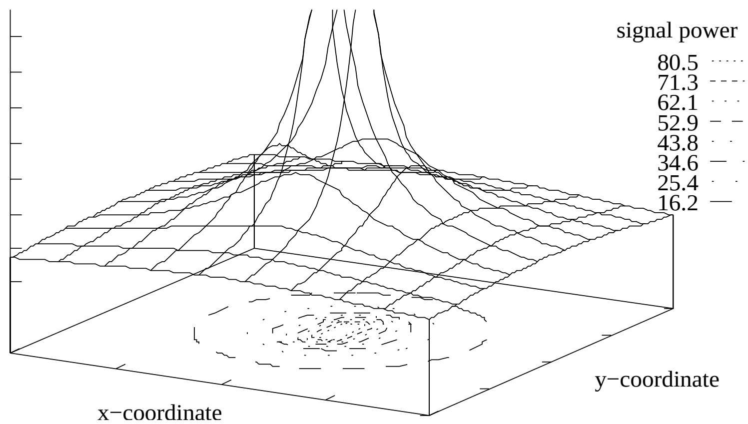
$\longrightarrow$ quadratic decrease in distance

$\longrightarrow$ quadratic decrease in frequency

$\longrightarrow$ idealized case: free space

$\longrightarrow$ in-doors and mobility: much more complicated

Power profile in 2-D space:



In real-world:

www.cs.purdue.edu/∼park/cs422-wireless-pic

Design implications:

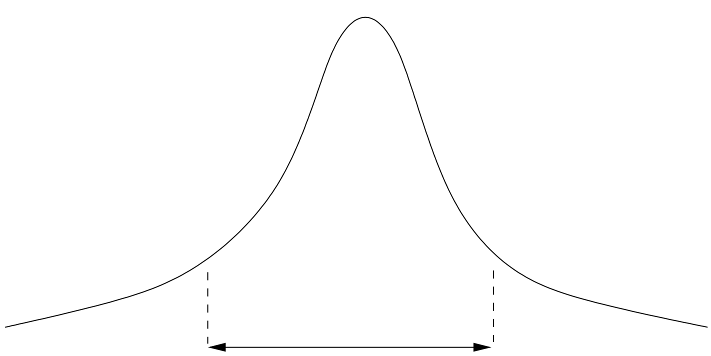
- coverage limited primarily by distance

  $\longrightarrow$ impacts SNR (signal-to-noise ratio)

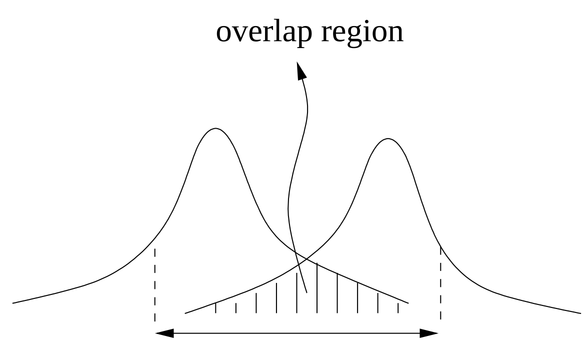
  $\longrightarrow$ the farther away, the weaker the signal

  $\longrightarrow$ in CSMA: SIR (signal-to-interference ratio)

- choice: single high-power antenna or multiple low-power antennae

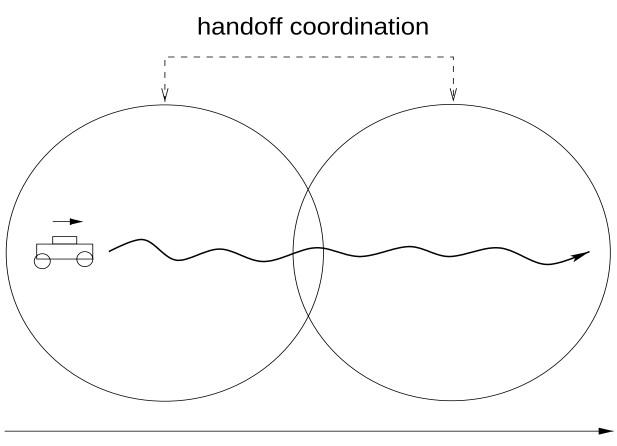


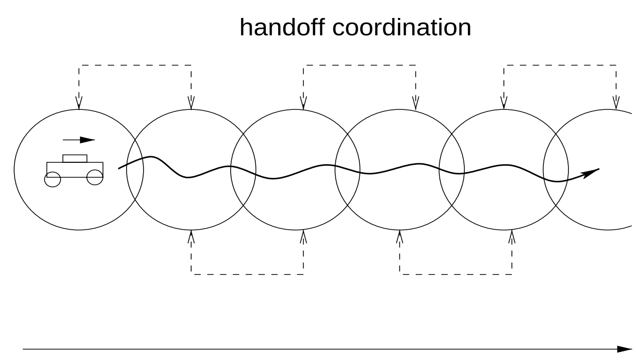
spatial coverage by one high−power antenna



spatial coverage by two low−power antennas

- low-power:
  - ⟶ decreases cell size: bad for coverage
  - ⟶ but good because enables frequency reuse
  - ⟶ think of radio stations
  - ⟶ good: increased battery life
  - ⟶ bad: more antennae required
  - ⟶ creates handoff coordination overhead (e.g., I65)





<u>Cellular Networks</u>

$\longrightarrow$ network of wireless base stations

Can view as:

$\longrightarrow$ both affect tiling of the plane

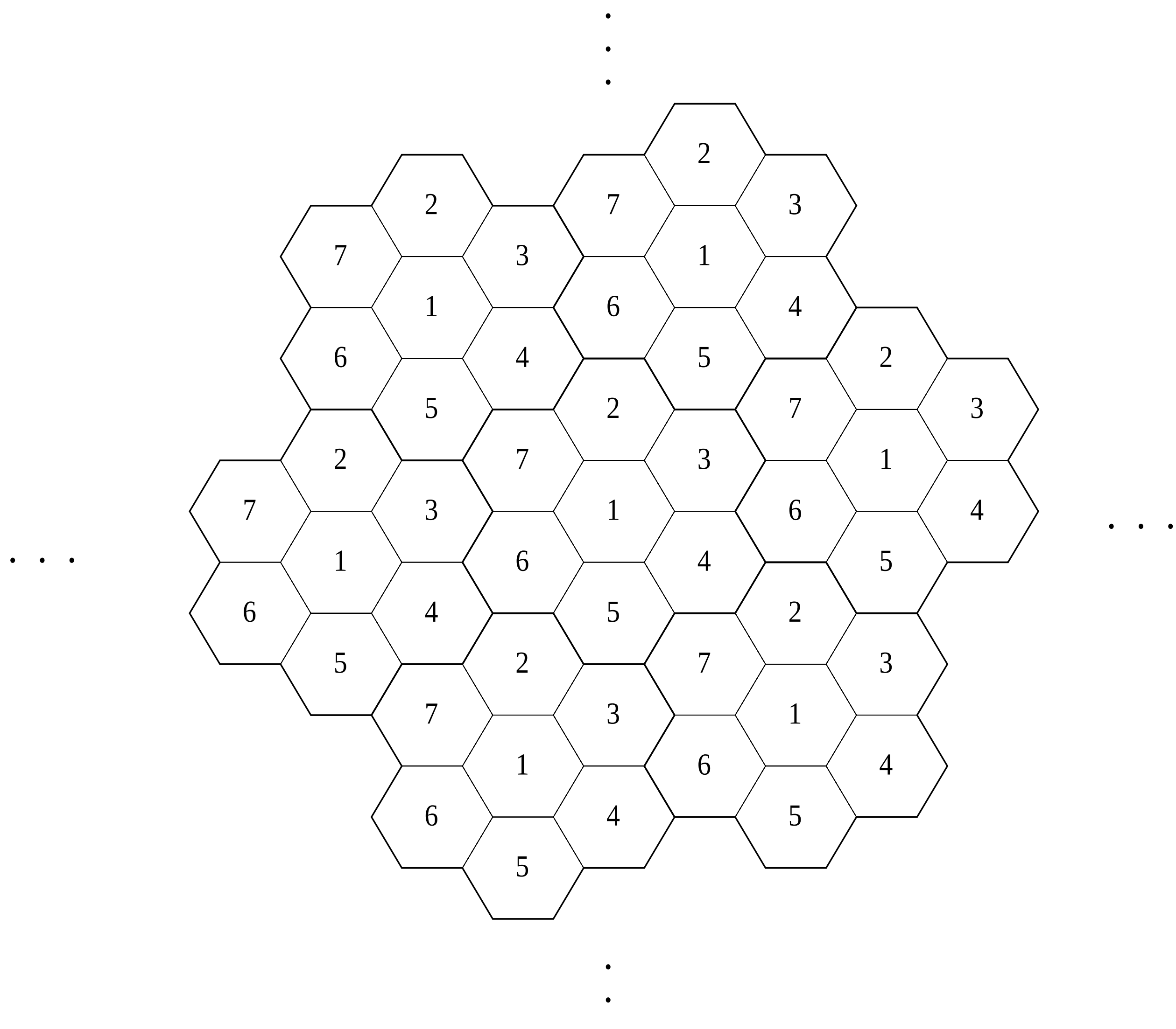
$\longrightarrow$ why hexagonal?

Frequency reuse: assume adjacent cells do not use common carrier frequency

$\longrightarrow$ avoid interference

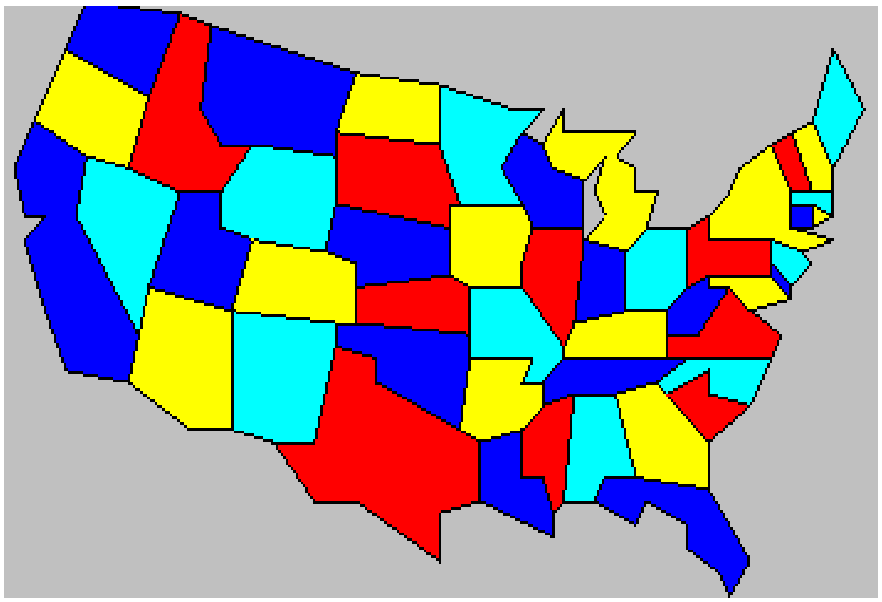
$\longrightarrow$ how many frequencies are required?

For example, using seven frequencies:



$\longrightarrow$ in general, coloring problem

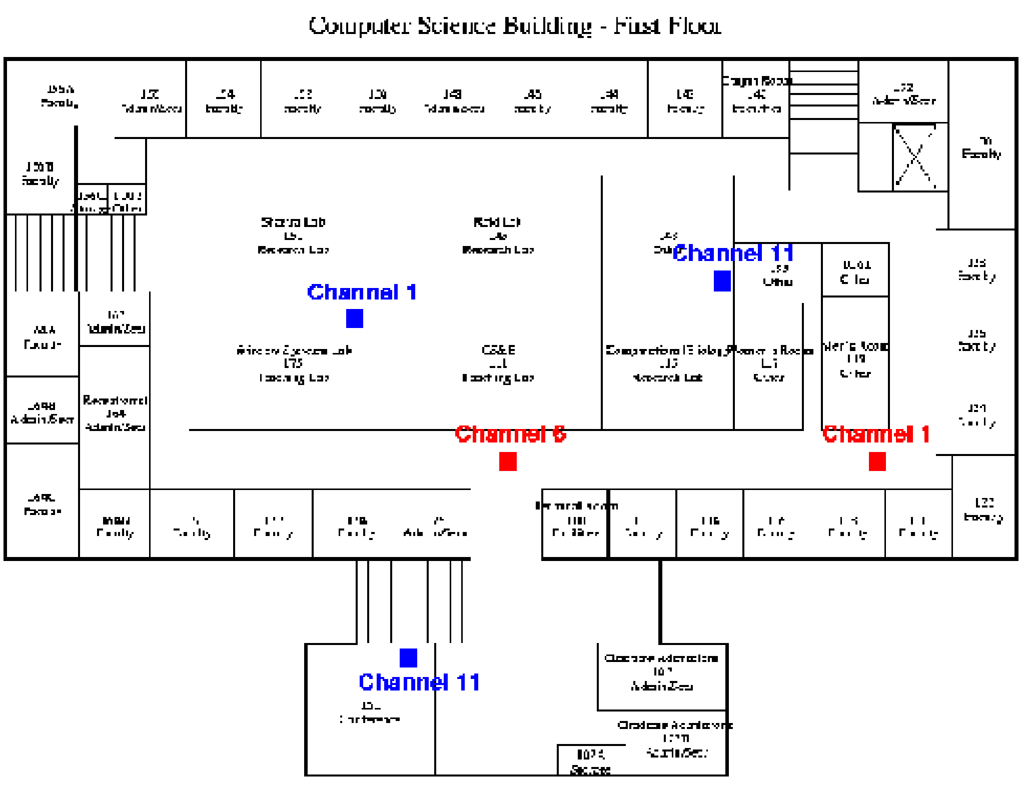
4-coloring of U.S. map:



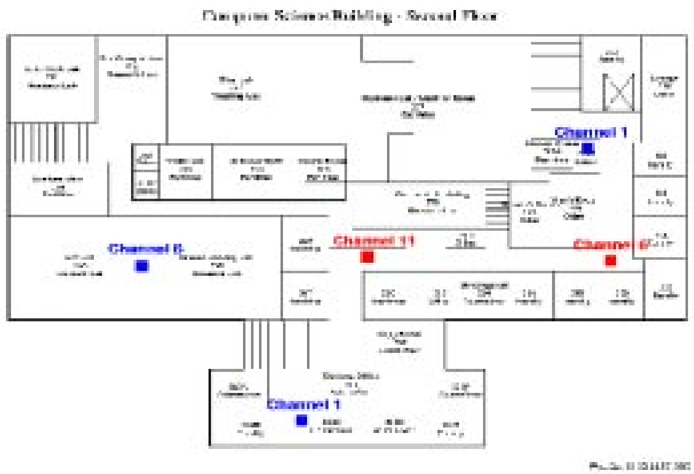
⟶ Y. Kanada, Y. Sato; Univ. of Tokyo

Old CS Building (aka HAAS):

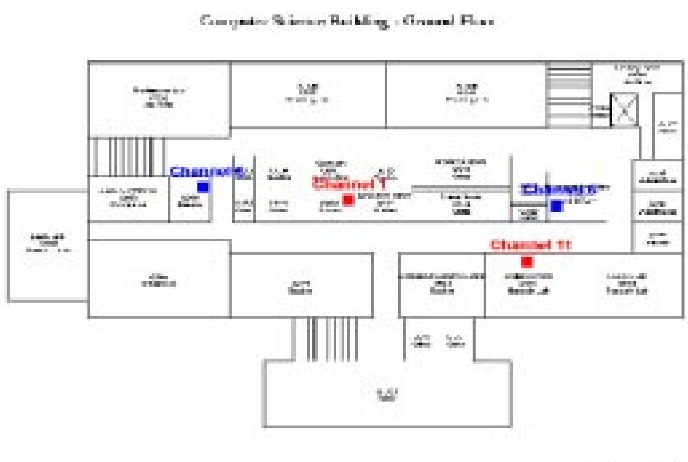
First floor frequency reuse:



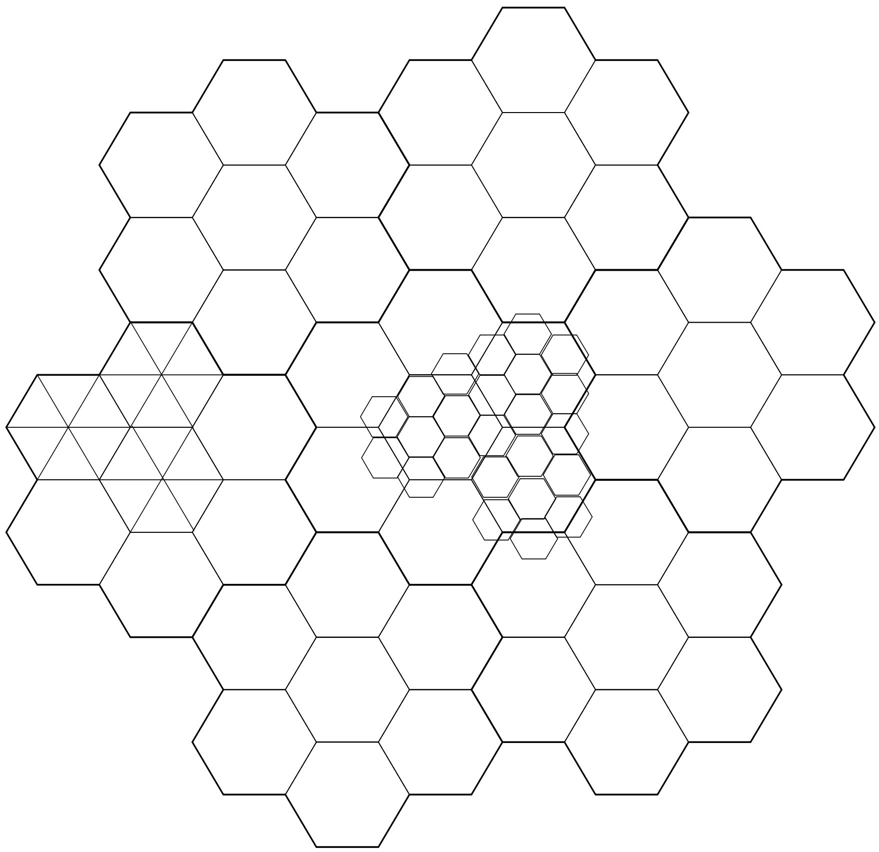
Second floor frequency reuse:



Ground floor frequency reuse:



Non-uniform covering:

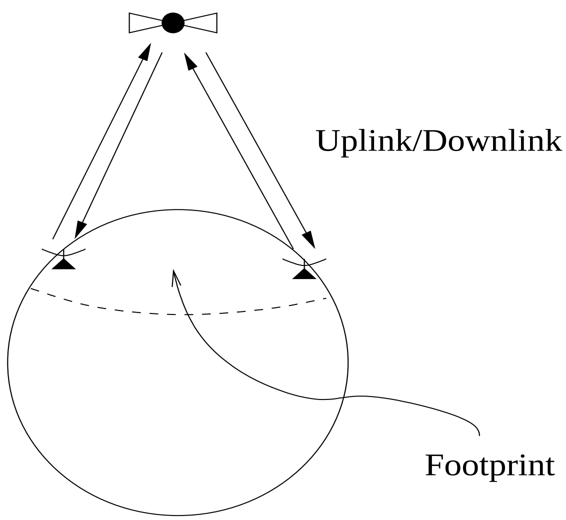


⟶ directional antenna: triangular shape (like cone)

⟶ non-uniform density (e.g., city center, stadium)

Long Distance Wireless Communication

Principally satellite communication:



- LOS (line of sight) communication

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

MAC protocols:

- FDM + TDMA: dominant

  → broadband

  → GSM cellular

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

Long-distance wireless communication: useful for broadcast service

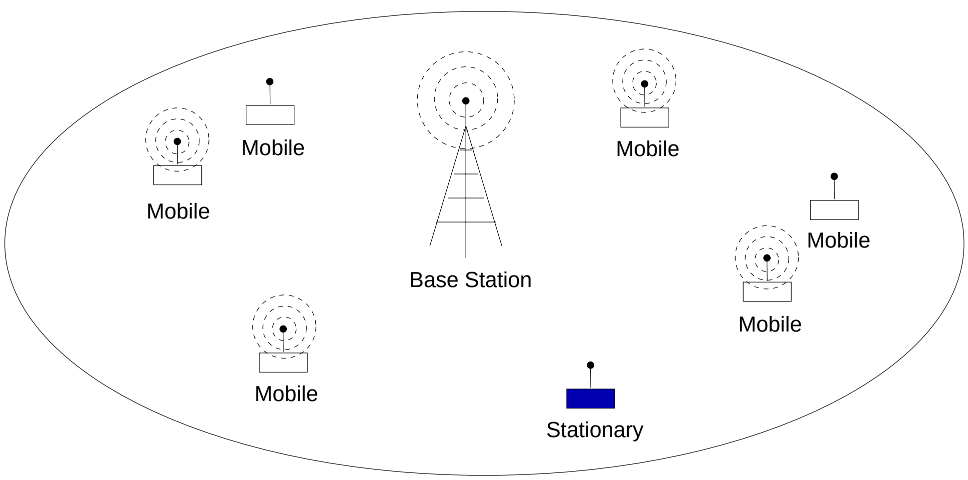
⟶ subset of killer applications

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

⟶ not suited for Internet access service!

Short Distance Wireless Communication

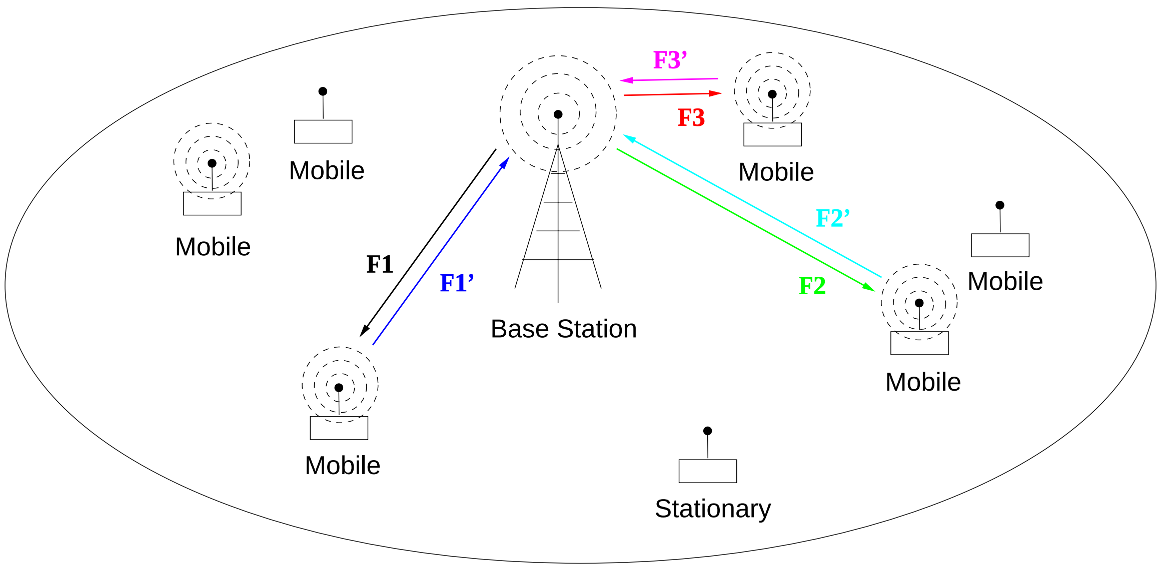
- very short: wireless PAN (IEEE 802.15)
- short: wireless LAN (IEEE 802.11)
- medium: wireless MAN (IEEE 802.16)



$\longrightarrow$ FDM, TDM, TDMA, CDMA

$\longrightarrow$ 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

  $\longrightarrow$ FDM component

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

  → TDM component

- total of 1000 possible user channels

  → 125×8 (124×8 realized)

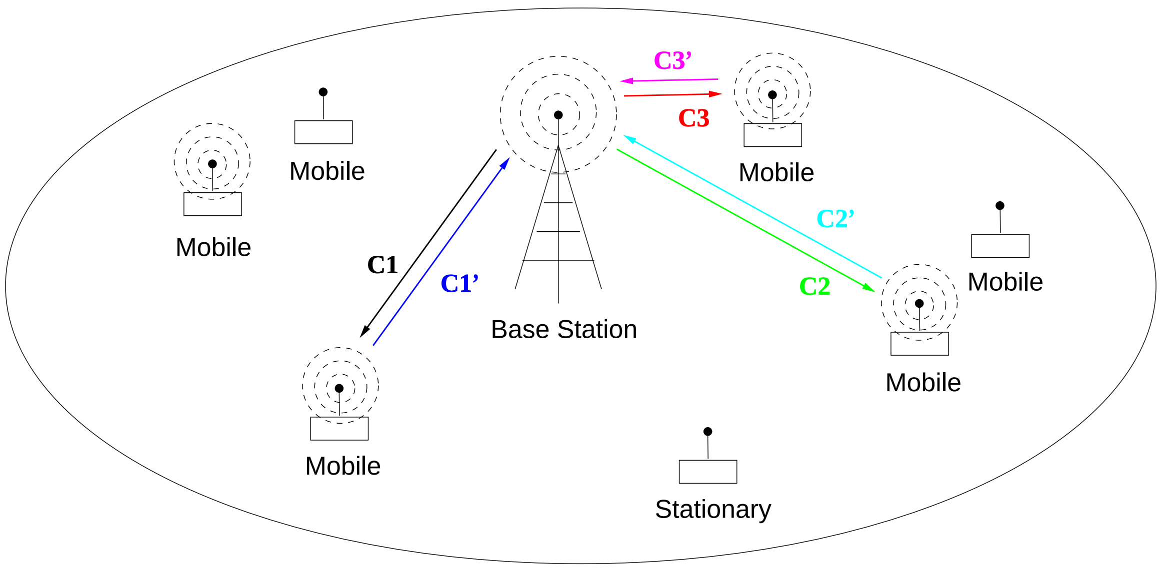
- codec/vocoder (i.e., compression): 13.4 kbps

- compare with T1 standard

  → 24 users at 64 kbps data rate each

  → 64 kbps vs. 13.4 kbps: landline has clearer sound

Cellular telephony: CDMA



FDD & CDMA

$\longrightarrow$ different code (i.e., basis vector) per user

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

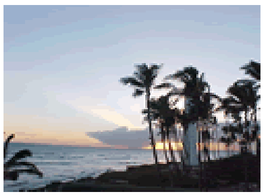
- uplink: 824–849 MHz; downlink: 869–894 MHz

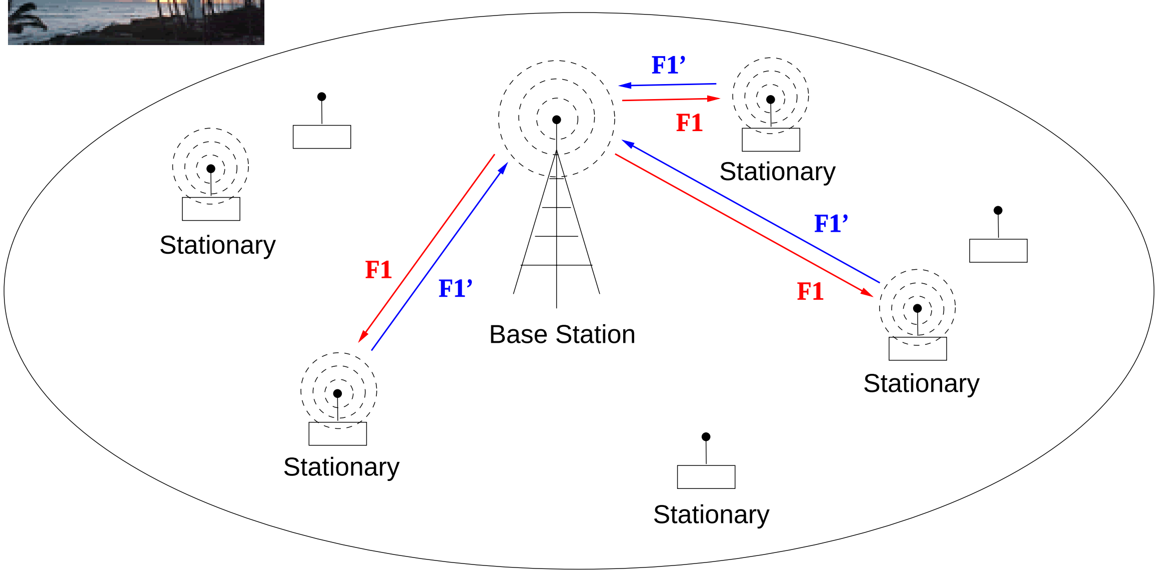
  $\rightarrow$ no separate carrier frequencies

  $\rightarrow$ everyone shares same 25 MHz band

- codec: 9.6 kb/s

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