Hamming Distance

- Hamming Distance between two sequences = Number of bits in which they disagree
- Example: 011011
  110001

  Difference 101010 ⇒ Distance = 3

Error Correction Example

- 2-bit words transmitted as 5-bit/word

Data	Codeword
00	00000
01	00111
10	11001
11	11110

Received = 00100 ⇒ Not one of the code words ⇒ Error

Distance (00100,00000) = 1 Distance (00100,00111) = 2

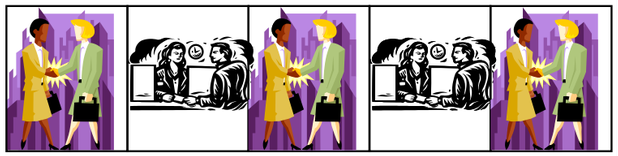
Distance (00100,11001) = 4 Distance (00100,11110) = 3

⇒ Most likely 00000 was sent. Corrected data = 00

b. Received = 01010 Distance(…,00000) = 2 = Distance(…,11110)
Error detected but cannot be corrected

c. Three-bit errors will not be detected. Sent 00000, Received 00111.

Multiple Access Methods

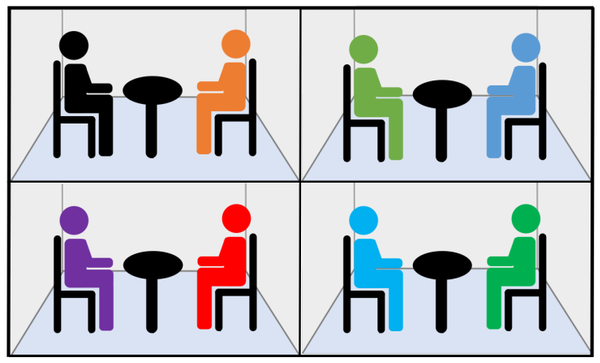


Time Division Multiple Access
(communicating groups are taking turns)

Code Division Multiple Access
(all communicating groups are talking at the same time)

Multiple Access

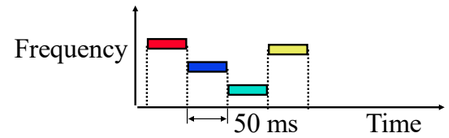
FDMA (frequency division multiple access)



CDMA

- Each communicating group is using a different "code"
- You can understand a conversation only if you know the code used in that conversation
- Much like a *multilingual party*, where people from different languages are all talking at the same time (code = language)
- Two popular coding methods for CDMA
  - Frequency hopping spread spectrum (FHSS)
  - Direct sequence spread spectrum (DSSS)

Frequency Hopping Spread Spectrum

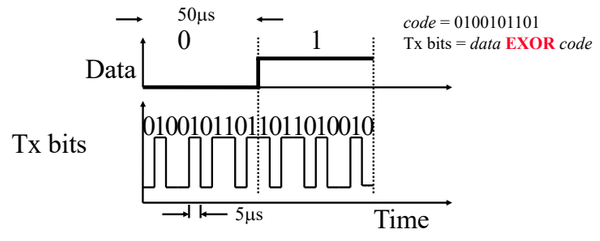


- Transmit over a narrowband, but continuously switch (hop) frequency over a wide spectrum
  - Spreads the transmission (power) over a wide spectrum ⇒ Spread Spectrum
- Pseudo-random frequency hopping (both transmitter and receiver use the same pseud-random number sequence = code)
  - Developed initially for military
  - Patented by actress Hedy Lamarr (idea came while playing a piano; tone changes continuously)

FHSS Advantages and Disadvantages

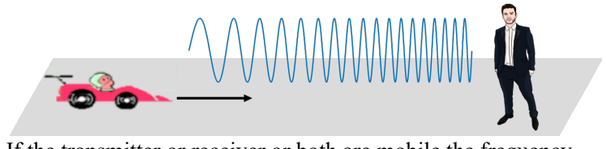
- Advantages
  - Difficult to intercept (appears as random 'blips')
  - Narrowband interference can't jam
- Disadvantages
  - Requires increased bandwidth (ability to randomly hop between 1000 frequencies → 1000 more bandwidth)
  - Both time and frequency synchronization

Direct-Sequence Spread Spectrum



- Many bits are transmitted for each data bit
- Spreading factor = Code bits/data bit, 10-100 commercial (Min 10 by FCC), 10,000 for military
- Signal bandwidth >10 × data bandwidth
- Code sequence synchronization
- Correlation between codes ⇒Interference (Orthogonal to avoid interference)

Doppler Shift



- If the transmitter or receiver or both are mobile the frequency of received signal changes
- Moving towards each other ⇒ Frequency increases
- Moving away from each other ⇒ Frequency decreases

Frequency difference = velocity/Wavelength = v/λ = vf/c

Example: 2.4 GHz ⇒ $\lambda = 3x10^8/2.4x10^9 = 0.125m$

v = 120km/hr = 120x1000/3600 = 33.3 m/s

Freq diff (Doppler shift) = 33.3/0.125 = 267 Hz