Multiplexing Techniques in Mobile Communication

- Coordinate the successful operation of multiple terminals over a wireless channel
- Multiple simultaneous analog or digital signals are transmitted across a single data link.
- Originally for wired networks – Later adopted into wireless networks
- Assign a slot of time, a portion of frequency, a specific code → voice
Multiplexing Techniques in Mobile Communication (cont.)

• A communication system comprising three sources and destinations: (a) without multiplexing and (b) with multiplexing

Fixed-Assignment Access

• Voice-oriented networks
• Channel partitioning
• Predetermined basis
• Fixed allocation of channel resource
  – Frequency
  – Time
  – Code (spread spectrum code)
• FDMA, TDMA, CDMA, OFDMA
Fixed-Assignment Access (cont.)

- Forward channel or downlink
  - Base station to mobile station
- Reverse channel or uplink
  - Mobile station to base station
- FDD vs. TDD
  - TDD → open loop power control, synchronization between downlink and uplink, low power (because of interference control), low complexity

Frequency Division Multiple Access

- Transmit simultaneously
- Using separated frequency
- 1G
- Concern
  - Adjacent channel interference (ACI)
    - Forward link
    - Reverse link
FDMA (cont.)

Figure 4.1 (a) FDMA/FDD, (b) FDMA/TDD, (c) TDMA/FDD with multiple carriers, (d) TDMA/TDD with multiple carriers.


FDMA (cont.)

FDMA (cont.)

- Adjacent Channel Interference
  - Forward link
    - Adjust the sharpness of transmitter and receiver filters for separate carriers
  - Reverse link
    - Near-far problem
    - (BS) difficult to detect the weaker signal
    - In order to handle near-far problem
      - Frequency planning
      - Power control
      - Guard band
FDMA (cont.)

- **Advantages of FDM**
  - This concept is applicable on both analog signals as well as digital signals.
  - Simultaneous signal transmission feature.

- **Disadvantages of FDM**
  - Less Flexibility.
  - Bandwidth wastage is high and can be an issue.

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Time Division Multiple Access

- **Time Division** is used for a particular amount of time in which the whole spectrum is used.
- **Time frames** of same intervals are made such that the entire frequency spectrum can be accessed at that time frame.

Source: https://www.minigranth.com/mobile-computing/multiplexing-mobile-computing/
Time Division Multiple Access (cont.)

- Fully digital format
  - Format flexibility
- Buffering, multiplexing function, time-slot assignment
- Capable to provide different access rates
- Need synchronization at the receiver
- $2G \rightarrow GSM$
  - Improve voice quality, flexible to integrate data

Time Division Multiple Access (cont.)

- Advantages of TDM
  - Single user at a time
  - Less complex and more flexible architecture
- Disadvantages of TDM
  - Difficult to implement
- For Example: (Wired) ISDN (Integrated Service for Digital Network) telephonic service, (Mobile) GSM
TDMA (cont.)

- 8-slot TDMA scheme used in GSM
- FDD
- 124 carriers (FDMA) in each direction
- 13 kbps encoded digital speech
- Same as FDMA, TDMA uses power control for near-far problem

Figure 4.3 FDMA/TDMA/FDD in GSM.

Figure 4.4 FDMA/TDMA/TDD in DECT.
Synchronous vs. Asynchronous TDMA

- **Synchronous TDMA**

- **Asynchronous or Statistical TDMA**

Code Division Multiple Access

- Integration of various types of traffic
- Multiple users but no need for coordination
- Multiple users, same band, same time
  - Different codes
- Each user is a noise source to other users
  - Power control

Figure 4.6 Simple illustration of CDMA.

CDMA (cont.)

Figure 4.7 (a) CDMA/FDD and (b) CDMA/TDD.
CDMA (cont.)

- Also called spread-spectrum technique
- Advantages of CDM
  - Highly Efficient
  - Less Inference
- Disadvantages of CDM
  - Less data transmission rates
  - Complex in nature
- Example: Cell Phone Spectrum Technology (3G etc.)

Capacity of CDMA

- Processing gain $N$
- Information bandwidth $R$
- Transmission bandwidth $W$
- $M$ simultaneous users
- Received power from a terminal $P$ (equal, perfect power control)
- Received SNR for the target receiver $S_r$

\[
W = N \cdot R
\]

\[
S_r = \frac{NP}{(M-1)P} = \frac{N}{M-1}
\]

\[
M = \frac{W \cdot \frac{1}{S_r} + 1}{R \cdot S_r} \approx \frac{W}{R \cdot S_r}
\]
Practical Consideration

- Sectorization gain factor $G_A$ - Usually equal to the number of sectors in the cell
- Voice activity factor $G_V$ - Ratio of total connection time to active talk time
- Interference increase factor $H_0$ - Interference from users in other cells
- Hence

$$M = \frac{W}{R} \cdot \frac{1}{S_r} + 1 \approx \frac{W}{R} \cdot \frac{1}{S_r} \cdot \frac{G_A G_V}{H_0}$$

Performance Improvement Factor

Orthogonal Frequency Division Multiple Access (cont.)

- Multi-carrier modulation
- Efficient use of spectrum
- Data stream is distributed among multiple subcarriers separated closely and precisely
- In a simple OFDM-based system, the modulated signal are distributed over different subcarriers via Inverse Fast Fourier Transform (IFFT)
• Since the basis of the IFFT is unit vectors with equally angular separated in polar plane, the spectrum of OFDM signal is composed of $N$ shifted sinc functions

![Image: OFDM signal with four orthogonal subcarriers](https://www.intechopen.com/books/multiplexing/overview-of-multiplexing-techniques-in-wireless-networks)

• The subcarrier spacing is chosen such that the center frequency of each subcarrier is located on a null point of other subcarriers
  – No interference

• Example: IEEE WLAN standards, LTE/LTE-A

• Disadvantages
  – High peak-to-average power ratio (PAPR) impedes proper performance of amplifiers at OFDM transceivers
  – Sensitive to carrier frequency offset (CFO) -> cause inter-carrier interference (ICI).
OFDMA (cont.)

• Advantages
  – Resilience in frequency selective environments
  – Resilience in inter-symbol interference (ISI)
    • Lack of ISI also means simpler equalization mechanism and reduction in hardware cost of the OFDM receiver
  – Little affects by narrow-band interference
    • Narrow-band interference blurs the reference signals for synchronization or corrupts the data
    • Error correction codes and interleaving aid
  – Spectral efficiency: closely separated frequency sub-channels yields higher spectral efficiency
  – Low-computational complexity: FFT&IFFT modules are simple

Question & Discussion

Assignment

Resources

• https://www.minigranth.com/mobile-computing/multiplexing-mobile-computing/