4.4 Wireless Communication Systems

- **Providing mobility to network users**
- **At any time, from anywhere**

Cellular Structure

- a key for wide coverage area and large capacity
- using many transmitters and receivers (base stations), each covering only a small portion of the service area (cell) and allocated with a number of channels
- each cell is a hexagon
- base station can be either at the center of the cell (omni-directional) or at three of the six vertices (sectored-directional)

  See Fig. 1.5, p. 15 of Rappaport

- **Frequency Reuse**
  - a cluster of N cells collectively using the complete set of available frequencies

    See Fig. 2.1, p. 27 of Rappaport

  - moving alone one direction by i cells, turning 60° and moving by another j cells to find a co-channel cell

    $$N = i^2 + i\,j + j^2$$

    See Fig. 2.2, p. 29 of Rappaport

Cellular Structure

- **Handoff/Mobility Management**
  - automatically switched to a new channel belonging to a new base station when a mobile user moving from one cell to another during the conversation

    See Fig. 2.3, p. 31 of Rappaport

- **Capacity Increase due to Congestion of Users**
  - cell splitting : subdividing a cell into smaller cells each with its own base station with lower transmitter power
  - sectoring : replacing an omni-directional base station by several directional base stations each serving a specific sector

    See Figs. 2.8, 2.10, pp. 55, 59 of Rappaport

- **Mixed Cell Architecture**
  - smaller cell provides higher capacity
  - larger cell provides wider coverage
  - larger cell reduces the necessary handoffs for users moving at higher speed
  - umbrella cell, macrocell, microcell, picocell, etc.

Multi-path Fading

- **complicated propagation geometry**
  See Fig. 3.25, p. 121 of Rappaport
- **a simplified model**
  - transmitted signal : s(t)

    received signal

    $x(t) = \sum_{k} a_k s(t-\tau_k)$

    a_k , τ_k random variables, time-varying
- **an example : Rayleigh Fading**
  See Fig. 4.15, p. 173 of Rappaport

  $P_r(r) = \frac{r}{\sigma^2} e^{-r^2/2\sigma^2}$, probability density function of Rayleigh distribution

  See Fig. 4.16, p. 174 of Rappaport

Multiple Access

- **Time-Division Multiple Access (TDMA)**
  - a channel is a time slot reoccurring every time frame cyclically
  - the available bandwidth is divided into repeating time frames each including a number of time slots
  - data transmission is not continuous, but occurs in bursts
  - the idle time helps in handoffs
  - high synchronization overhead is required
  - possible to allocate different number of time slots per time frame to different users bandwidth can be supplied on demand

  See Figs. 8.3, 8.4, pp. 401, 402 of Rappaport

Multiple Access

- Frequency-Devision Multiple Access (FDMA) and CDMA

  See Figs. 8.2, 8.5, pp. 400, 406 of Rappaport

Characteristics of Wireless Communications

- **User terminals are Mobile**
  - connection is much less reliable in general
  - time-varying channel distortion and noise characteristics
- **Multi-path Fading**
  - many reflected and refracted waves in the air
  - signal amplitude/phase seriously corrupted
  - time-varying and location dependent
- **Bandwidth Constraints**
  - radio transmission bandwidth always very limited
  - frequencies carefully re-used by cellular structures
  - transmission speed (bits/sec) stringently restricted
- **Handset Limitations**
  - size, weight, power
  - computation/memory resources
- **Related Network Problems**
  - network congestion/routing
  - packet loss/delay
  - transmission errors and error control
  - mobility management
  - protocols

Ref : 2.1, 2.2, 2.4, 4.6, 8.3 of Rappaport