Cochannel and Adjacent Channel Interference

- base station capacity: handle the services of many mobile users
- interference from transmission of other mobiles in the same cell, background noise, and interference from transmissions by mobiles in neighboring cells
- time domain or frequency domain separation between uplink and downlink transmission, interference from transmissions in the other link can be neglected
- interference from other mobiles at the cell-site receiver in the same cell is intracell interference
- interference from other cells is intercell interference
- intercell interference in the downlink affects the reception at the individual mobile hosts, may be more problem, than uplink interference at the base station (cell-site receiver)

- tradeoff: use of different sets of frequencies intercell interference is minimum, system capacity limited
- frequency reuse, system capacity increased
- cochannel interference should be at an acceptable level
- intercell interference dominated by cochannel interference
- Cochannel Interference
  - S power of the desired signal and I power of the cochannel interference at the output of the receiver demodulator
  - N_I number of cochannel interfering cells and I_i interference power caused by transmission from the ith interfering cochannel cell base station

- signal-to-cochannel interference ratio S/I at the desired mobile receiver

$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{N_I} I_i}$$

- average received received signal strength at any point decays as a power law of the distance between the transmitter and receiver
- D_i distance between the ith interferer and the mobile
- received interference, I_i at a given mobile due to the ith interfering cell is proportional to $(D_i)^{-\kappa}$, κ is the path loss exponent (determined by measurement, $2 \le \kappa \le 5$)
- desired received signal power S is proportional to $r^{-\kappa}$, r distance between the mobile and the serving base station

- if transmit powers from all base stations are equal and the path loss exponent is the same throughout the geographical coverage area, the cochannel interference the ith cochannel cell I_i ($\forall i$), depends on D_i and κ

$$\frac{S}{I} = \frac{r^{-\kappa}}{\sum_{i=1}^{N_I} D_i^{-\kappa}}$$

- with hexagon shaped cellular system, 6 cochannel interfering cells in the first tier
- $N_I = 6$ neglecting second and higher tiers
- $r = R$ if mobile is located at the cell boundary and $D_i = D$

$$\frac{(D/R)^{\kappa}}{N_I} = \frac{q^{\kappa}}{N_I} = \frac{(\sqrt{3N})^{\kappa}}{N_I}$$

$$q = \left(N_I \times \frac{S}{I}\right)^{1/\kappa} = \left(6 \times \frac{S}{I}\right)^{1/\kappa}$$

- $S/I = 18$ dB, $\kappa = 4$, then

$$q = (6 \times 10^{1.8})^{1/4} \simeq 4.41 \text{ and } N = q^2/3 = 6.49 \simeq 7$$

- $S/I = 20$ dB, $\kappa = 4$, $q = (6 \times 100)^{1/4} = 4.9492 \rightarrow N = 8.165 \simeq 9$
- with $q = D/R$, given R; D can be determined and vice versa
- worst case - mobile at the cell boundary

$$\frac{S}{I} = \frac{R^{-\kappa}}{2(D-R)^{-\kappa} + 2D^{-\kappa} + 2(D+R)^{-\kappa}}$$

- $D/R = q, \kappa = 4$

$$\frac{S}{I} = \frac{1}{2(q-1)^{-4} + 2q^{-4} + 2(q+1)^{-4}}$$

- For a cellular system that requires S/I 18 dB
- $N = 7$ $q = \sqrt{3N} = 4.6$ $\kappa = 4$ worst case $\frac{S}{I} = 17.3$ dB
- to increase S/I, decrease I, can be achieved by increasing the frequency reuse factor N
- $N = 9$ $q = 5.20$ and $S/I = 19.8$ dB
- increase in N result into decrease in system capacity (9-cell reuse offers a spectrum utilization of 1/9 within each cell)
- Adjacent Channel Interference (ACI)
  - due to imperfect receiver filter; allows nearby frequencies to leak into the passband
  - near-far effect significantly increase ACI

- to reduce ACI
  - use modulation schemes which have low out-of-band radiation
  - carefully design the bandpass filter at the receiver front end
  - use proper channel interleaving by assigning adjacent channels to different cells
  - avoid using adjacent channels in adjacent cells
  - separate the uplink and downlink by TDD or FDD
- Signal-to-interference ratio determines the transmission bit error rate
- for a user: QoS is more than an acceptable transmission accuracy

Call Blocking

- two aspects
  - how successfully can a new user get a connection established?
  - After connection establishment, how successfully will the connection be maintained as the user moves from one cell to another?
- First aspect refers to the admission of new calls
- Second aspect refers to the admission of handoff calls
- performance measure is the probability that a call (new or handoff) is blocked
- to find probability of call blocking, say radio cell has been allocated J channels having large population size of mobile users in the cell
- during connection time each user occupies one channel
- if number of active user during any epoch equals J, all channels will be occupied then with probability 1, a call will be blocked (denied)

- if number of ongoing calls is fewer than J, a call will be blocked with probability smaller than 1, *i.e.*, to condition that the trunk traffic load in Erlangs is less than J
- One Erlang represents the amount of traffic load carried by a channel that is completely occupied, one call-hour per hour
- if channel is busy for 30 minutes during a one hour period, then the channel is said to carry 0.5 Erlangs of traffic
- Offered traffic refers to the amount of traffic sent by the users and carried traffic refers to the amount of traffic served
- say, base station (cell-site) bufferless system, no buffer, blocked calls are lost
- L users in the system

- aggregate arrival traffic is Poisson distributed with rate λ
- duration of a call is exponentially distributed with parameter μ_1
- residence time of each user in a cell is exponentially distributed with parameter μ_2
- exponential random variable is memoryless
- the channel holding time is minimum of the call duration and the cell residence time, is also exponentially distributed with parameter $\mu = \mu_1 + \mu_2$ (mean channel holding time of call)
- it is corresponding to a mean service rate of μ for the call
- the service time of each of the servers is also exponentially distributed
- with Poisson arrival and exponential service times, the underlying queueing process is Markovian

- base station (cell-site) receiver modeled as J-server system and each server serves traffic at a mean rate μ
- J-server system for a population of size L and aggregate arrival rate λ
- when system is in state j $(j = 0, 1, \ldots, J)$, there are j ongoing calls and j servers, each with mean service rate μ are being engaged
- if system is in state $j = J$, all J servers are engaged and new requests will be blocked
- if $L \leq J$ than no blocking