EECE 563 : WIRELESS COMMUNICATIONS
1999/2000 WINTER SESSION, TERM 2

Lecture 2

Computing Co-Channel Interference

- one co-channel cell every cluster (every N cells) causes co-channel interference

- consider the case where the mobile is at the cell boundary (worst case)

- for same-size cells with same transmitter powers, $S/I = \text{SIR}$ is determined by ratio $Q = D/R$ where D is the distance between centers of co-channel cells and R is the cell radius.

- if we use a smaller cluster size, N, we have smaller D and thus smaller Q

- system designer must choose N large enough to meet the SIR requirements

- for possible cluster sizes, it turns out that $Q = \sqrt{3N}$ (from cluster geometry)

- a simple model for the attenuation of the signal with distance is:

  $$P_r(d) = P_0 \left(\frac{d}{d_0}\right)^{-n}$$

  where d is the distance, P_0 is the power at distance d_0, and n is an value that depends on the environment but is typically around 3 for urban areas.

- if we consider only the first "ring" of i_0 interferers at distance D:

  $$\frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i} = \frac{R^{-n}}{\sum_{i=1}^{i_0} D_i^{-n}} = \frac{(D/R)^n}{i_0} = \frac{(\sqrt{3N})^n}{i_0}$$

- the assumption that Q is the same for all interferers is an approximation and more accurate results can be derived for specific cluster sizes.

- for small N we may need to include more than the first ring of interferers

Power Control

- base station can command mobile to reduce its power

- increases battery life

- reduces interference on reverse channel

Trunking Efficiency

- "trunks" are telephone lines linking telephone switches. "trunking" refers to sharing a fixed number of trunks by many telephone system subscribers

- in cellular radio the "trunks" are the radio channels which must be shared among the cellular system subscribers in a cell

- we need to install enough trunks (channels) in each cell to make the probability of all channels being busy (call blocking probability, "Grade of Service", GOS) acceptably low

- an Erlang is a (unitless) quantity: it is the amount of traffic that can be carried by one trunk (one voice channel)

- traffic intensity per user A_u, in Erlangs, is the fraction of time that a user requires use of a trunk and is the number of calls per unit time (λ) times the call holding time (duration) (H) specified in the same units:

  $$A_h = \lambda H$$

- for U users, the total traffic is:

  $$A = UA_u$$

- a system with C channels with $C \leq U$ there will be a finite probability that the all channels will be in use, the *blocking probability*.

- under various assumptions (infinite number of users, random call arrivals, exponentially-distributed call duration, blocked calls are not queued) the GOS of C trunks is given by the Erlang B formula:

$$Pr[blocking] = \frac{\frac{A^C}{C!}}{\sum_{k=0}^{C} \frac{A^k}{k!}}$$

  where A is the total offered traffic

- Exercise: 100 users in a cell generate 2 calls/hour, with average duration of 3 minutes. $A = 100 \cdot 2 \cdot 3/60 = 10$ Erlangs offered traffic. What GOS do the Erlang-B curves predict for 16 trunks (channels)?
- Exercise: Now we split the users into two cells each with 50 users and 8 trunks. What is the new GOS?
- combining trunks increases the "trunking efficiency" (Erlangs per trunk) at a certain GOS

Cell Splitting and Sectorization

- cell splitting maintains the same cluster size and re-use factor but reduces the cell radius.
- sectorization places directional antennas (typically 3) at base station
- the channels are split into 3 sets, one for each sector
- the use of directional antennas reduces the interference to (and from) cells in some of the other clusters (e.g. using 3 sectors eliminates 2/3 of the interferers)
- this reduces SIR and allows a smaller cluster size to be used
- unfortunately, it also reduces trunking efficiency

Log-Distance Path Loss Model

- already decribed: path loss is proportional to the n'th power of distance, or, in dB:

$$\overline{PL}(dB) = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right)$$

- n depends on environment
- 2 for free space, 3–5 in urban areas

Log-Normal Shadowing

- at any given distance from the base, the path loss will vary due to local factors
- this variation can be modelled as a random variable, X_σ, whose logarithm has a normal (Gaussian) distribution
- when X_σ is expressed in dB, is has zero mean and variance σ^2 dB
- the probability that a normal random variable, z, with mean m and standard deviation σ will exceed the value γ is:

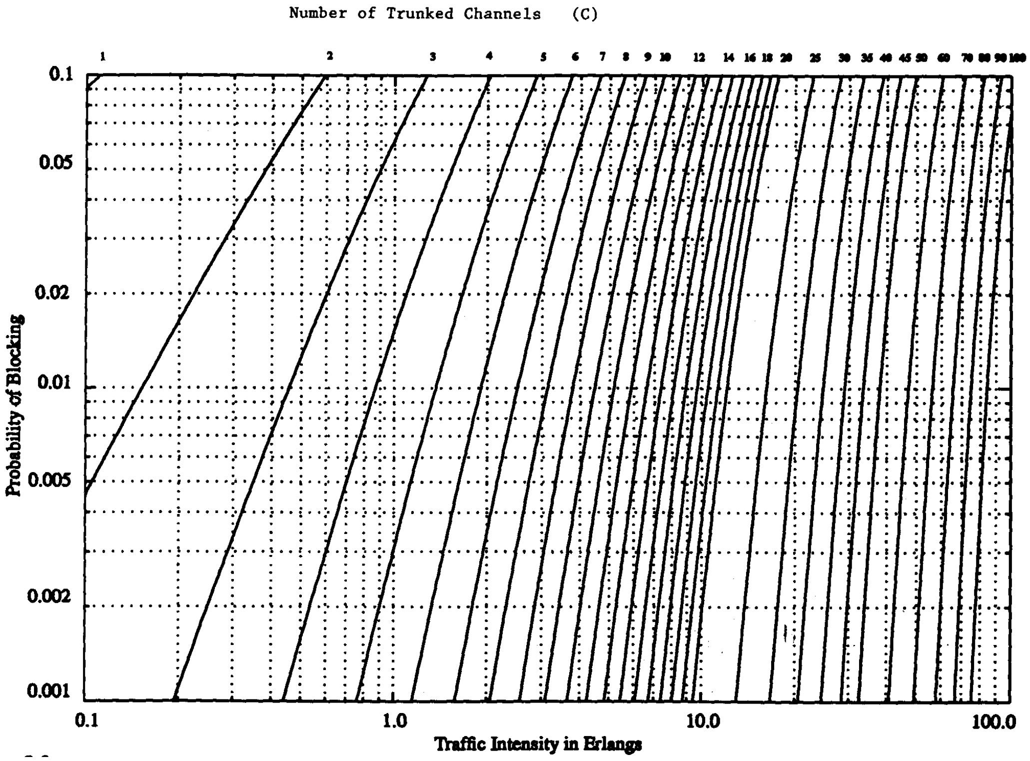
$$Pr[z > \gamma] = \frac{1}{2}\left(1 - \mathrm{erf}\left(\frac{z-\gamma}{\sqrt{2}\sigma}\right)\right)$$

Okumura Path-Loss Model

- a method for predicting median path loss for urban mobile radio
- based on extensive measurements in Japanese urban areas in the 60's
- can be used from 150 to 1900 MHz
- distances of 1 to 100 km (large cells)
- base heights 30 to 1000 m
- measurements were reduced to curves showing attenuation relative to free-space loss as function of frequency and distance
- correction factors are used for different antenna heights and type of terrain
- requires reading curves

Hata Equations

- fit equations to Okumura's curves
- valid from 150 to 1500 MHz



- equation gives estimated median path loss as function of frequency, distance and antenna heights:

  $$L_{50}(urban)(\text{dB}) = 69.55 + 26.16 \log f_c - 13.82 \log h_{te} - a(h_{re}) + (44.9 - 6.55 \log h_{te}) \log d$$

  where

  f_c is frequency (in MHz) from 1500 to 1500, h_{re} is effective receiver height (m) from 30 to 200, h_{te} is effective transmitter height (m) from 1 to 10, d is base-mobile distance (km), and $a(h_{re})$ is an equation for a correction factor (see text).