Sirindhorn International Institute of Technology

Thammasat University at Rangsit

School of Information, Computer and Communication Technology

ECS 455: Problem Set 2

Semester/Year: 2/2011

Course Title: Mobile Communications

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Course Web Site: http://www2.siit.tu.ac.th/prapun/ecs455/

Due date: Feb 14, 2012 (Tuesday)

Instructions

1. ONE sub-question will be graded (5 pt). Of course, you do not know which part will be selected; so you should work carefully on all of them.
2. It is important that you try to solve all problems. (5 pt)
3. Late submission will be heavily penalized.
4. ***Write down all the steps*** that you have done to obtain your answers. You may not get full credit even when your answer is correct without showing how you get your answer.
5. You may use the MATLAB code from

   http://infohost.nmt.edu/~borchers/erlang.html

   to evaluate the Erlang B formula. Figure 3.6 from [Rappaport, 2002], which is included here in Appendix A, may give a rough approximation.

Please submit your solutions for the following questions.

1. Consider a cellular system with operating frequencies around fc = 900 MHz, cells of radius 100 m, and nondirectional antennas. Under the free-space path loss model, what transmit power is required at the access point such that all terminals within the cell receive a minimum power of 10 µW. How does this change if the system frequency is 2.4 GHz? [Example 2.1 in Goldsmith, 2005]

2. Consider the set of empirical measurements of Pr/Pt given in Table 1 below for a system operating around 900 MHz.

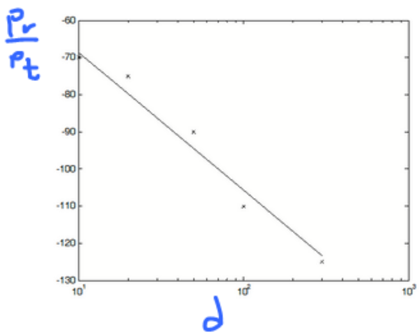
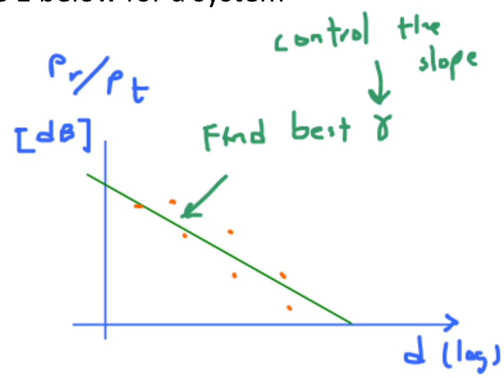


Table 1 Path Loss Measurements

Distance from Transmitter	P_r/P_t
10m	-70 dB
20m	-75 dB
50m	-90 dB
100m	-110 dB
300m	-125 dB



a. Find the path loss exponent γ that minimizes the MSE between the simplified model and the empirical dB power measurements, assuming that d_0 = 1 m and K is determined from the free space path gain formula at this d_0.

b. Find the received power at 150 m for the simplified path loss model with this path loss exponent and a transmit power of 1 mW (0 dBm).

[Example 2.3 in Goldsmith, 2005]

3. Let us take a look at the microwave ultra-wideband (UWB) impulse radio. UWB is a power-limited technology in the unlicensed band of 3.1–10.6 GHz. For the multiband OFDM (MB-OFDM) UWB systems, there are 5 band groups whose centers are provided in Table 2 below

Table 2: Relationship between center frequencies and coverage range for MB-OFDM UWB systems.

Band Group	Center frequency (MHz)	Range (meter)
1	3,960	10
2	5,544	?
3	7,128	?
4	8,712	?
5	10,032	?

According to the Friis equation, given the same transmitted power, propagation attenuation will be different for each band because they use different frequency. (This variation of received signal strength can be a bothering factor.) If band group 1 can cover 10 meters, estimate the coverage ranges for other band groups in Table 2.

4. Cellular communication in the USA is limited by the Federal Communication Commission (FCC) to one of three frequency bands, one around 0.9 GHz, one around 1.9 GHz, and one around 5.8 GHz. Find the corresponding wavelengths.

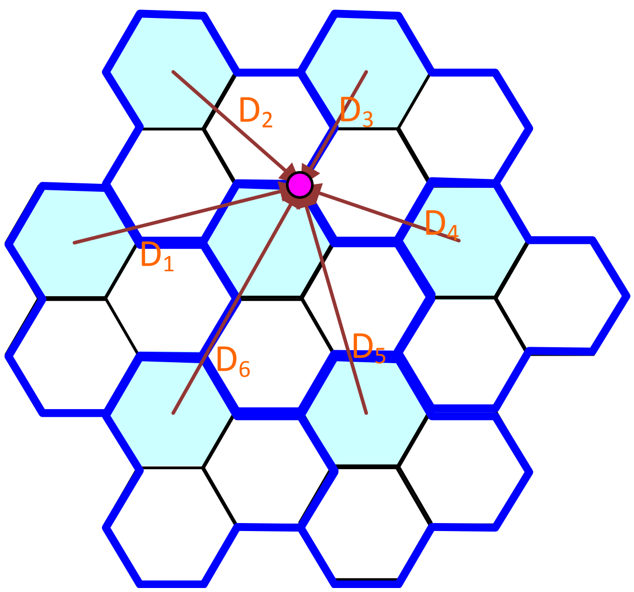
5. Some possible values of cluster size is N = 3, 4, or 7. Find the next fifteen lowest values of N.

6. If 20 MHz of total spectrum is allocated for a **duplex** wireless cellular system and each **simplex** channel has 25 kHz RF bandwidth, find:
   (a) the number of duplex channels.
   (b) the total number of channels per cell site, if N = 4 cell reuse is used.

7. In this question, we will find the unsectored (using omnidirectional antennas) SIR value when N = 3.
   (a) Recall that the SIR can be calculated from

$$\frac{S}{I} = \frac{kR^{-\gamma}}{\sum_{i=1}^{K} kD_i^{-\gamma}}$$

   where D_i is the distance from the *i*th interfering co-channel cell base station. Find all the distance D_i in the figure below.



   Express them as a function of *R* (the distance from the center of the hexagon to its vertex.) Hint: $D_1 = \sqrt{13}R$.

(b) Calculate the SIR (in dB) using the D_i values that you got from part (a). Assume a path loss exponent of $\gamma = 4$.

(c) Approximate all value of D_i by the **center-to-center** distance *D* between the nearest co-channel. Express *D* as a function of *R*. Recalculate the SIR (in dB) with all D_i replaced by D.

(d) Compare your answers from part (b) and part (c).

8. A cellular service provider decides to use a digital TDMA scheme which can tolerate a signal-to-interference ratio of 15 dB in the worst case. Find the optimal value of *N* for (a) omnidirectional antennas, (b) 120° sectoring, and (c) 60° sectoring. (Assume a path loss exponent of $\gamma = 4$.)

   Hint: Approximate the SIR value by

$$\frac{S}{I} = \frac{kR^{-\gamma}}{K \times \left(kD^{-\gamma}\right)} = \frac{1}{K}\left(\frac{D}{R}\right)^{\gamma} = \frac{1}{K}\left(\sqrt{3N}\right)^{\gamma}$$

   where *K* is the number of (first-tier) interfering (co-channel) base stations.

9. How many users can be supported for 0.5% blocking probability for the following number of trunked channels in a blocked calls cleared system?

   (a) 5

   (b) 15

   (c) 25

   Assume each user generates 0.1 Erlangs of traffic.

10. Assume each user of a single base station mobile radio system averages three calls per hour, each call lasting an average of 5 minutes.

    (a) What is the traffic intensity for each user?

    (b) Find the number of users that could use the system with 1% blocking if only one channel is available.

    (c) Find the number of users that could use the system with 1% blocking if five trunked channels are available.

    (d) If the number of users you found in (c) is suddenly doubled, what is the new blocking probability of the five channel trunked mobile radio system?

Appendix A

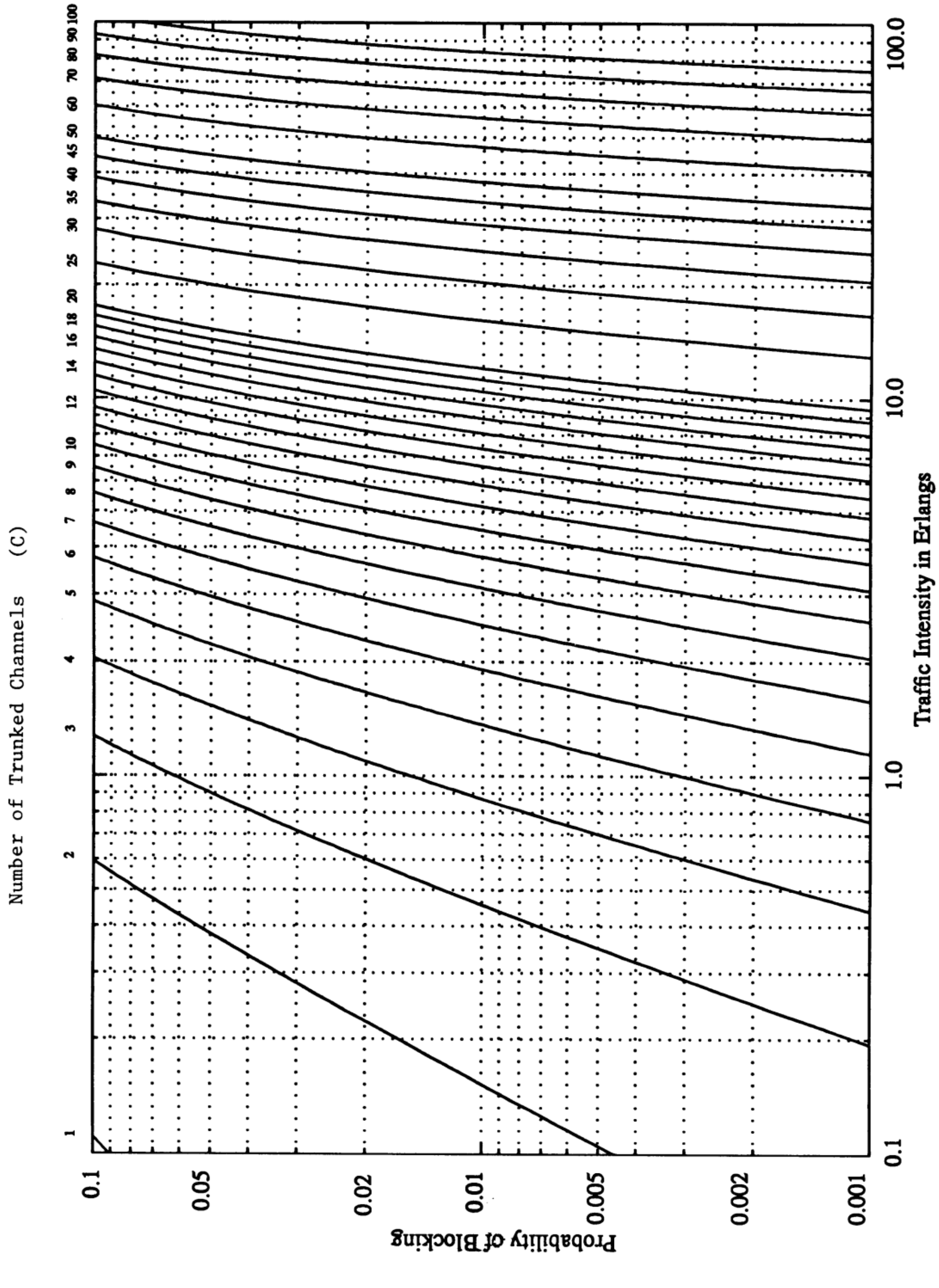


Figure 3.6 The Erlang B chart showing the probability of blocking as functions of the number of channels and traffic intensity in Erlangs.