Problem solutions

Chapter 4: Cells and cellular traffic

Solution 2

From the problem text we know that:

Received signal power, $S = -97$ dBm $\Rightarrow 10^{-9.7}$ mW
Noise power, $N_0 = -117$ dBm $\Rightarrow 10^{-11.7}$ mW
CCI from each of the interfering signals, $\text{CCI}_i = -120$ dBm $\Rightarrow 10^{-12}$ mW
Number of interferers for a 7 cell cluster, $N_I = 6$

a) The overall signal to noise ratio is given by (4.5), thus

$$\begin{aligned}\frac{S}{N} &= \frac{S}{6 \times \text{CCI}_i + N_0} \\ &= \frac{10^{-9.7}}{6 \times 10^{-12} + 10^{-11.7}} \\ &\approx 24.96 \\ &\approx 14 \text{ dB.}\end{aligned}$$

b) The signal to CCI ratio (from page 142) becomes

$$\begin{aligned}\frac{S}{I} &= \frac{S}{6 \times \text{CCI}_i} \\ &= \frac{10^{-9.7}}{6 \times 10^{-12}} \\ &\approx 33.25 \\ &\approx 15.2 \text{ dB.}\end{aligned}$$

c) If we require $\frac{S}{I} = 20 \text{ dB} = 10^2 = 100$, the power from each of the interferers (CCI_i) should be

$$\begin{aligned}\frac{S}{I} &= \frac{S}{6 \times \text{CCI}_i} \\ \Rightarrow \text{CCI}_i &= \frac{S}{6 \times \frac{S}{I}}.\end{aligned}$$

Inserting the numerical values we get the result

$$\begin{aligned}\text{CCI}_i &= \frac{10^{-9.7}}{6 \times 100} \\ &\approx 3.33 \times 10^{-13} \text{ mW} \\ &\approx -124.8 \text{ dBm}\end{aligned}$$

Solution 7

The received signal power is proportional with $R^{-\nu}$, and the received power from an interferer is proportional with $D^{-\nu}$. For any cellular pattern $N_I = 6$, thus the signal to CCI ratio can be written as (from (4.8))

$$\begin{aligned}\frac{S}{I} &= \frac{R^{-\nu}}{6 \times D^{-\nu}} \\ &= \frac{1}{6}\left(\frac{D}{R}\right)^{\nu}\end{aligned}$$

$$\Rightarrow \frac{D}{R} = \left(6 \times \left(\frac{S}{I}\right)\right)^{1/\nu}.$$

Requiring $\frac{S}{I} = 20$ dB $= 10^2 = 100$, and when $\nu = 3$ we get

$$\begin{aligned}\frac{D}{R} &= (6 \times 100)^{1/3} \\ &\approx 8.43.\end{aligned}$$

I.e., if the distance to the interferers are 8.43 times the distance to the desired user, we get $\frac{S}{I} = 20$ dB.

Solution 8

We start by finding the average signal to noise ratio as

$$\begin{aligned}\left(\frac{S}{N}\right)_{\text{dB}} &= S_{\text{dB}} - N_{\text{dB}} \\ &= -96 \text{ dBm} - (-115 \text{ dBm}) \\ &= 19 \text{ dB} \\ &= 10^{1.9}.\end{aligned}$$

When the threshold is $\left(\frac{S}{N}\right)_{\text{thr}} = 15$ dB $= 10^{1.5}$, and the fading is Rayleigh distributed, we can find the outage probability from (2.40), as

$$\begin{aligned}p_{\text{out}} &= 1 - \exp\left(-\frac{(S/N)_{\text{thr}}}{S/N}\right) \\ &= 1 - \exp\left(-\frac{10^{1.5}}{10^{1.9}}\right) \\ &= 0.3284.\end{aligned}$$

If the acceptable outage probability is 2%, the corresponding average signal to noise ratio must be

$$\begin{aligned}p_{\text{out}} &= 1 - \exp\left(-\frac{(S/N)_{\text{thr}}}{S/N}\right) \\ \Rightarrow \frac{S}{N} &= -\frac{(S/N)_{\text{thr}}}{\ln(1 - p_{\text{out}})}.\end{aligned}$$

Inserting the numerical values gives

$$\begin{aligned}\frac{S}{N} &= -\frac{10^{1.5}}{\ln(1-0.02)} \\ &\approx 1565 \\ &\approx 32 \text{ dB}.\end{aligned}$$

The noise power can now be found by

$$\begin{aligned}N_{\text{dB}} &= S_{\text{dB}} - \left(\frac{S}{N}\right)_{\text{dB}} \\ &= -96 \text{ dBm} - 32 \text{ dB} \\ &= -128 \text{ dBm}.\end{aligned}$$

Solution 12

The traffic generated by one user is found by using (4.33),

$$\begin{aligned}A_I &= \lambda \times T_H \\ &= 2 \text{ calls/hour} \times \frac{3}{60} \text{ hour} \\ &= 0.1 \text{ Erl}.\end{aligned}$$

The calculations for each of the service providers are summarized in the tables below.

Service provider A	
Offered Traffic/cell (from Table 4.3), A	13.182 Erl
Carried Traffic/cell (4.37), $A_c = A[1 - p(B)]$	$13.182 \times [1 - 0.02] = 12.92$ Erl
Total Carried Traffic (4.34), $A_{\text{tot}} = K \times A_c$	$100 \times 12.92 = 1292$ Erl
Number of users that can be supported, A_{tot}/A_I	$1292/0.1 = 12920$

Service provider B	
Offered Traffic/cell (from Table 4.3), A	43.997 Erl
Carried Traffic/cell (4.37), $A_c = A[1 - p(B)]$	$43.997 \times [1 - 0.02] = 43.12$ Erl
Total Carried Traffic (4.34), $A_{\text{tot}} = K \times A_c$	$35 \times 43.12 = 1509$ Erl
Number of users that can be supported, A_{tot}/A_I	$1509/0.1 = 15090$

From the tables we see that service provider B can support $15090 - 12920 = 2170$ more users than service provider A.

Solution 20

From the problem we know that the power loss is approximately 0.7 dB/Km in the range of interest.

a) When only the long-term fading margin of 6 dB is factored in, the reduction in transmission distance compared to no fade margin is given by

$$\frac{6 \text{ dB}}{0.7 \text{ dB/Km}} \approx 8.6 \text{ Km}.$$

b) When only the short-term fading margin of 4 dB is factored in, the reduction in transmission distance compared to no fade margin is given by

$$\frac{4 \text{ dB}}{0.7 \text{ dB/Km}} \approx 5.7 \text{ Km}.$$

c) When both the long-term and the short-term fading margin are factored in, the reduction in transmission distance compared to no fade margin is given by

$$\frac{[6+4] \text{ dB}}{0.7 \text{ dB/Km}} \approx 14.3 \text{ Km}.$$