# Solution 1

## a)

According to the path loss model $\alpha = 4$. The SINR at the corner is then

$$\gamma_t \approx \frac{1^{-4}}{\frac{6}{(3\,K)^{4/2}}\,\zeta(4-1) + \frac{1}{\gamma_0}} \Rightarrow 10^{1.3} \approx \frac{1}{\frac{2}{3\,K^2}\,1.2 + \frac{1}{10^4}} \Rightarrow K = 4$$

The capacity is then (♯ ch / cell)

$$\eta = \left\lfloor \frac{128}{4} \right\rfloor = 32$$

So if we need to support 5 users per km$^2$ then $5 = \eta\,/\,A_{\text{cell}} \Leftrightarrow A_{\text{cell}} = 6.4\,\text{km}^2$. The number of base stations is then

$$n = \left\lceil \frac{1000}{A_{\text{cell}}} \right\rceil = \left\lceil \frac{1000}{6.4} \right\rceil = 157$$

## b)

In dB the SINR is normal distributed so

$\Gamma_{\text{dB}} \in N(\gamma_0, 4)$

We want the availability to be 98 % which means that we want to calculate $\gamma_0$ so that

$$P(\Gamma_{\text{dB}} > \gamma_t) = 98\,\% \Leftrightarrow \text{cdf}(\gamma_t) = 2\,\% \Leftrightarrow \Phi\left(\frac{\gamma_t - \gamma_0}{4}\right) = 0.02 \Leftrightarrow \frac{\gamma_t - \gamma_0}{4} \approx -2.0537$$

$$\Rightarrow \gamma_0 \approx 13 + 8.2\,\text{dB} = 21.2\,\text{dB}$$

The new reuse factor is then found by

$$\gamma_0 \approx \frac{1^{-4}}{\frac{6}{(3\,K)^{4/2}}\,\zeta(4-1) + \frac{1}{\gamma_0}} \Rightarrow 10^{2.12} \approx \frac{1}{\frac{2}{3\,K^2}\,1.2 + \frac{1}{10^4}} \Rightarrow K \gtrsim 10.3 \Rightarrow K = 12 \text{ (next Loeschian)}$$

The new capacity is then (♯ ch / cell)

$$\eta = \left\lfloor \frac{128}{12} \right\rfloor = 10$$

and the number of base stations needed is

$$n = \left\lceil \frac{1000}{A_{\text{cell}}} \right\rceil = \left\lceil \frac{1000}{\eta\,/\,5} \right\rceil = 500$$

Solution 2:

(a). $P_t = P_r * d^4$.

$Pr(P_t \leq P) = Pr(P_r * d^4 \leq P) = Pr(d \leq \sqrt[4]{\frac{P}{P_r}}) = \frac{\pi\left(\sqrt[4]{\frac{P}{P_r}}\right)^2}{\pi R^2} = \frac{\sqrt[2]{\frac{P}{P_r}}}{R^2} = A\sqrt[2]{P}$,

where $A = \frac{\sqrt[2]{\frac{1}{P_r}}}{R^2} = \frac{\sqrt[2]{\frac{1}{15*10^{-13}}}}{100^2} = \sqrt[2]{\frac{1}{15*10^{-5}}} = 81.6$

(b). SNR= $P_r / N_o$=15e-10 */1e-10=15*.

R= $W log_2(1 + SNR) = 10 * 4$=40 kbit/s.

On average, in every 10 s, the user is in the active mode for t=10/40=0.25 s. It then stays in the sleep mode for 9.75 s. The average power consumption is given by

$\bar{P}$=(0.25*($P_t$/0.5+0.01)+9.75*0.001)/10= 0.05*$P_t$ + 0.001225.

Pr($\bar{P}$ ≤P)=Pr(0.05*$P_t$ + 0.001225≤P)= Pr($P_t$ ≤20*P-0.0245)=A$\sqrt[2]{20 * \mathrm{P} - 0.0245}$.

(c). The data rate requirement of each user is: 10 kbits/10=1kbit/s

The highest efficiency of Slotted ALOHA is 36.8%.

The maximum number of users≤ R*36.8%/1=40*36.8%=14.73.

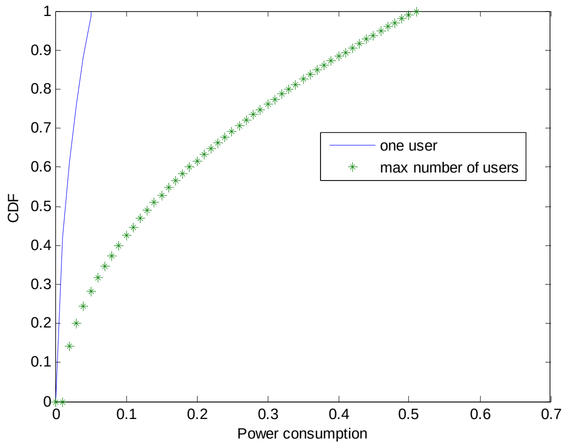
At most 14 users can be supported.

(d). Observe the efficiency formula, $\lambda \leq \max \gamma e^{\gamma} = e^{-1}$. The maximum number of users indicate that $\gamma = 1$. Therefore all users are always in the active mode for data transmission.

The average power consumption is:

$\bar{P}$=$P_t$/0.5+0.01.

Pr($\bar{P}$ ≤P)=Pr($P_t$/0.5+0.01≤P)= Pr($P_t$ ≤2*P-0.02)=A$\sqrt[2]{2 * \mathrm{P} - 0.02}$.



CDF
Power consumption
one user
max number of users
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Solution 3:

(a) In dB scale, link gain $=10\log_{10}\frac{1}{d^4}=-40\log_{10} d$.

$$G = -40 * \begin{pmatrix} \log_{10} 50 & \log_{10} 50 & \log_{10} 150 & \log_{10} 250 \\ \log_{10} 180 & \log_{10} 80 & \log_{10} 20 & \log_{10} 120 \end{pmatrix} \text{ dB.}$$

(b) It can be easily verified that A should be connected to the BS at 100 and B to 300.
Downlink:

A: $-40*\log_{10} 50-(-40*\log_{10} 150)=40\log_{10} 3=19.1$ dB.

B: $-40*\log_{10} 20-(-40*\log_{10} 180)= 40\log_{10} 9=38.2$ dB.

Uplink:

A: $-40*\log_{10} 50-(-40*\log_{10} 180)=40\log_{10} 3.6=22.3$ dB.

B: $-40*\log_{10} 20-(-40*\log_{10} 150)= 40\log_{10} 7.5=35.0$ dB.

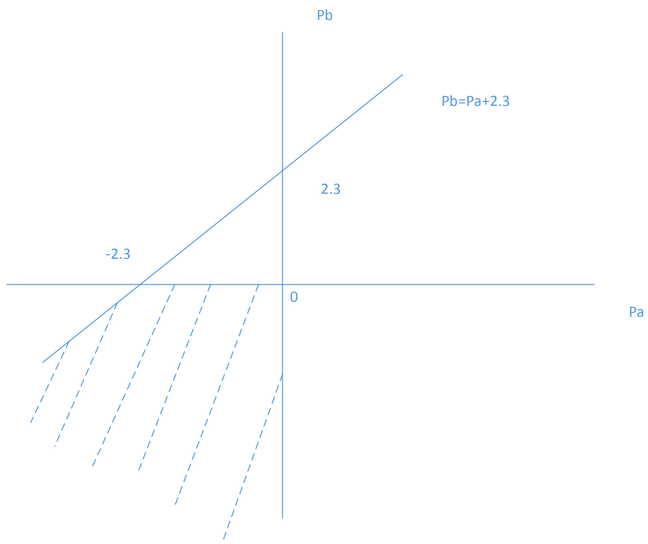
(c) Let $P_a$ and $P_b$ denote the power of the two terminals in dB.
$SIR_B= P_b -40*\log_{10} 20-( P_a -40*\log_{10} 150) = 35.0 + P_b - P_a$.

$SIR_A=P_a-40*\log_{10} 50-(P_b-40*\log_{10} 180) = 22.3 + P_a - P_b \geq 20 \Rightarrow P_a +2.3 \geq P_b$

Besides, $P_b \leq 0$dBW and $P_a \leq 0$dBW.

Evaluate the boundary conditions and we can see that to maximize $SIR_B$, $P_a$ and $P_b$ can be any value such that $P_a +2.3= P_b$ where $P_b \leq 0$.

The highest $SIR_B$ is 35+2.3=37.3 dB.



Solution 4

(a) $$\gamma(d) = \begin{cases} \dfrac{d^{-4}}{(2R-d)^{-4} + 0.5R^{-4}} & \text{if } d \le d_0 \\ \dfrac{d^{-4}}{0.5R^{-4}} & \text{if } d > d_0 \end{cases}$$

(b) Let's compare the sum rate of simultaneous transmission and resource division at the position $d = 0.5R$.

SINR of simultaneous transmission: $\gamma_{sim}(0.5R) = \dfrac{(0.5R)^{-4}}{(1.5R)^{-4} + 0.5R^{-4}} = 22.9381$

SINR of resource division: $\gamma_{div}(0.5R) = \dfrac{(0.5R)^{-4}}{0.5R^{-4}} = 32$

Sum rate of simultaneous transmission: $r_{sim}(0.5R) = 2B\log_2\left(1+\gamma_{sim}(0.5R)\right) = 91.625Mbps$

Sum rate of resource division: $r_{div}(0.5R) = 2\dfrac{B}{2}\log_2\left(1+\gamma_{div}(0.5R)\right) = 50.444Mbps$

Sum rate of simultaneous transmission is higher than that of resource division at $0.5R$. Therefore, the answer is YES. $d_0$ should be greater than $0.5R$.

(c) This means that noise power is now same as the power received from one AP at the cell border. This yields

$$\gamma(d) = \begin{cases} \dfrac{d^{-4}}{(2R-d)^{-4} + R^{-4}} & \text{if } d \le d_0 \\ \dfrac{d^{-4}}{R^{-4}} & \text{if } d > d_0 \end{cases}$$

By putting $d = R$, we get

Sum rate of simultaneous transmission: $r_{sim}(R) = 2B\log_2\left(1+\dfrac{1}{2}\right) = 11.699Mbps$

Sum rate of resource division: $r_{div}(R) = 2\dfrac{B}{2}\log_2\left(1+\dfrac{1}{1}\right) = 10Mbps$

Therefore, we can say the conclusion changes. Simultaneous transmission is better even at the cell border.

Solution 5:

a) Cell 1 is already in the active set at time \tau=0 and stays active until \tau_0. Hence, Cell 1 is the active set

Cell 2 is in the neighbor set at time \tau=0 and stays so until \tau_0. Hence Cell 2 is in the neighbor set

Cell 3 was in the active set at time \tau=0 but drops below T_DROP at \tau=4.5 and goes to the neighbor set at \tau=14.5 and stay so until \tau_0. Hence Cell 3 is in the neighbor set

Cell 4 was in the active set at time \tau=0 and drops below T_DROP at time \tau=14 where the drop timer starts. However, at time \tau=\tau_0, the timer is at 4 which is less than the timer time 10. Hence, Cell 4 is in the active set

Cell 5 is added to the active set at time \tau=9 and stays so until \tau=\tau_0. Hence, Cell 5 is in the active set

Cell 6 has been in the neighbor set since time 0 and stays so. Hence, Cell 6 is in the neighbor set.

b) The set of cells that are in the active set, obtained from a), are: Cell 1, Cell 4, and Cell 5