Mobilkommunikation - Mobile Communications

Exercise: Cellular Frequency Planning

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Task

An IEEE 802.11a network that covers a large hall has to be planned. The goal is to provide a minimum data rate of 24 Mb/s all over the place.

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Cellular network planning

- Maximum cell size $\Rightarrow$ minimal number of access points
- Minimum co-channel distance $\Rightarrow$ minimal number of channels

Signal power

The access points have a transmit power of 63 mW. Transmit antennas with a gain of 2 dB are used. The required received signal power to ensure a data rate of 24 Mb/s is -74 dBm. Assume a path loss coefficient of $\gamma = 2.5$

What is the maximum cell size?

Free-space path loss

The received power for free space propagation is

$$P_r = P_t \frac{G_t G_r}{L_p}$$

- P_r = received power
- P_t = transmitted power
- G_r = gain of the receiving antenna
- G_t = gain of the transmitting antenna
- L_p = free space path loss in distance d
- γ = path loss coefficient ($\gamma = 2$ for free space)

$$L_p = \left(\frac{4\pi d}{\lambda}\right)^{\gamma} \qquad \text{or} \qquad L_p = 10\gamma \log\left(\frac{4\pi d}{\lambda}\right) \text{ [dB]}$$

- λ = wave length $= c/f$
- c = speed of light, in free space $c = 3 \cdot 10^8$ m/s
- f = carrier frequency

Maximum path loss

Decibel and decibel milliwatt ($\log$ is $\log_{10}$)

- $10\log(X/Y)$ [dB]
- $10\log(X/1\text{mW})$ [dBm]

$$P_r = P_t \frac{G_t G_r}{L_p}$$

$$\Rightarrow 10\log\left(\frac{P_r}{1\text{mW}}\right) = 10\log\left(\frac{P_t}{1\text{mW}}\right) + 10\log G_t + 10\log G_r - 10\log L_p$$

- Transmit power: $10\log(63\text{mW}/1\text{mW}) = 18$ dBm
- Transmit antenna gain: 2 dB
- Minimum receive power: -74 dBm
- Allowed path loss: 94 dB

Maximum cell radius

$$L_p = 10\gamma \log\left(\frac{4\pi d}{\lambda}\right) \text{ dB} \leq 94 \text{ dB}$$

$$\Rightarrow \frac{4\pi d}{\lambda} \leq 10^{9.4/\gamma}$$

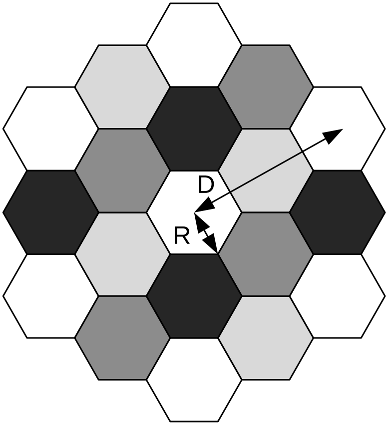
$$\Rightarrow d \leq \frac{\lambda}{4\pi} 10^{9.4/\gamma}$$

- $\lambda = c/f = (3 \cdot 10^8 \text{ m/s})/(5 \cdot 10^9) \text{ Hz} = 0.06 \text{ m}$
- $\gamma = 2.5$
- cell radius $R \leq 27,5$ m
- larger path loss $\gamma \Rightarrow$ smaller radius $R \Rightarrow$ more access points

Co-channel distance D

Some typical cluster sizes N and reuse ratios $D/R = \sqrt{3N}$

N	D/R	(u,v)
1	1.7	(1,0)
3	3.0	(1,1)
4	3.5	(2,0)
7	4.6	(2,1)
9	5.2	(3,0)
12	6.0	(2,2)
13	6.2	(3,1)
16	6.9	(4,0)
19	7.5	(3,2)



How many different channels N are required for $S/I \geq 13$ dB?

Co-channel interference

Considering the tier-1 interferers, the signal to interference ratio can be written as

$$\frac{S}{I} = \frac{S}{\sum_{k=1}^{6} I_k}$$

where

- $S =$ signal power
- $I_k =$ power of the k-th interferer

Inserting the path loss formula for signal and interference

$$\frac{S}{I} = \frac{\frac{\text{const.}}{R^\gamma}}{6\frac{\text{const.}}{D^\gamma}} = \frac{1}{6}\left(\frac{D}{R}\right)^\gamma$$

Cluster size

Inserting $D/R = \sqrt{3N}$ it follows that

$$N = \frac{1}{3}\left(6\,\frac{S}{I}\right)^{2/\gamma}$$

- $S/I \geq 13$ dB $\Rightarrow S/I \geq 10^{1.3}$
- $\gamma = 2.5$
- cluster size $N \geq 16$
- smaller path loss $\gamma \Rightarrow$ larger cluster size $N \Rightarrow$ more channels