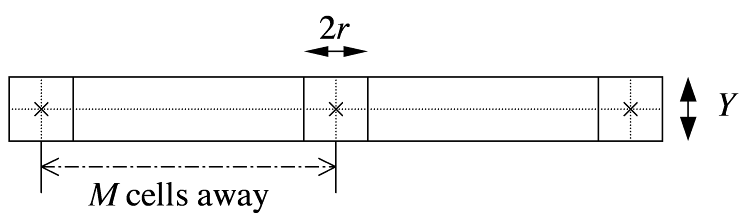
Wireless Communications
Lecture 19

[Frequency reuse: 1D case]

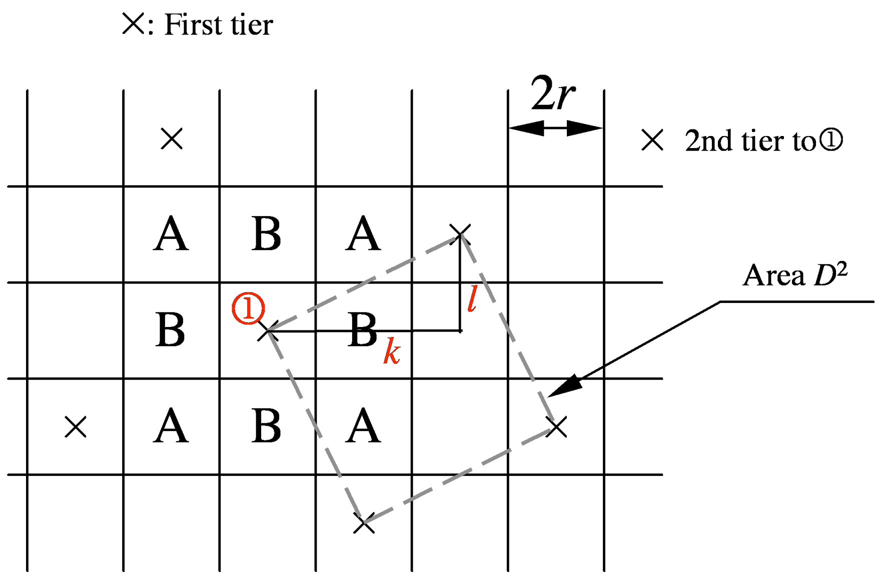
C_s	The number of cells without repeated frequency
M	Reuse distance
N_c	The number of channels per cell
W	Bandwidth of each channel

- ***Total frequency bandwidth*** $= C_s N_c W$.



$$
\begin{aligned}
C_s = M &= \frac{M2rY}{2rY} = \frac{\text{area covered by one complete set}}{\text{area of a cell}} \\
D &= \text{distance between co-channel cells} = 2rM
\end{aligned}
$$

[Frequency reuse: 2D case]



$$C_s = \frac{A_g}{A_{\text{cell}}} \quad A_g = \text{area covered by unique frequency}, A_{\text{cell}} = \text{area of a cell}$$

$$C_s = \frac{D^2}{(2r)^2} = \frac{(k^2+l^2)(2r)^2}{(2r)^2} = k^2 + l^2$$

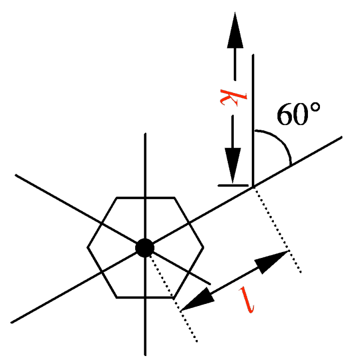
In the figure above $C_s = 5$.

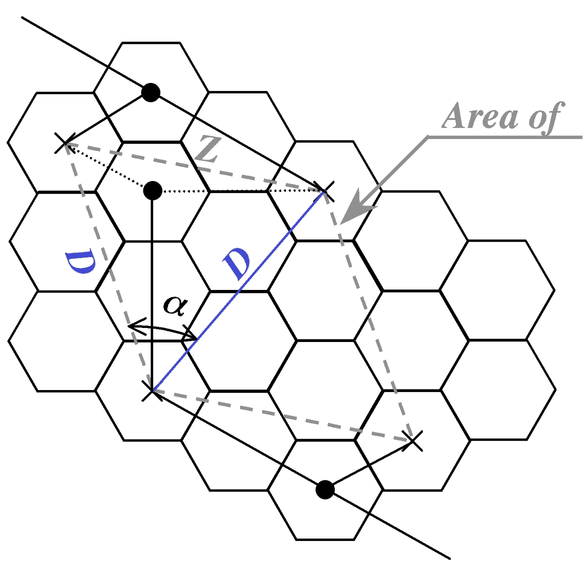
$$M = \text{reuse distance(Unitless)}$$
$$= \frac{D}{2r} = \sqrt{k^2+l^2} = \sqrt{C_s}$$

[Frequency reuse: hexagon cells]

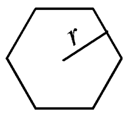
$$
\begin{aligned}
C_h &= k^2 + l^2 + kl \\
M &= \sqrt{C_h}
\end{aligned}
$$

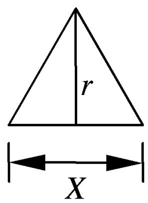
To identify co-channel cells: $k = 2, l = 1 \Rightarrow C_h = 7$ and $M = \sqrt{7} \Rightarrow$ North America AMPS standards





$$
\begin{aligned}
D &= \sqrt{k^2 + l^2 - 2kl\cos 120^\circ} \times 2r \\
&= \sqrt{k^2 + l^2 + kl} \times 2r \\
M &= \sqrt{k^2 + l^2 + kl} \\
\alpha &= 60^\circ \\
Z &= D
\end{aligned}
$$





all angles $= 60^\circ$

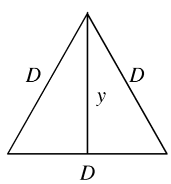
$$\left(\frac{X}{2}\right)^2 + r^2 = X^2$$

$$X\sqrt{\frac{3}{2}} = r$$

$$X = \frac{2r}{\sqrt{3}}$$

$$
\begin{aligned}
A_c &= 6\left(\frac{Xr}{2}\right) \\
&= 2\sqrt{3}r^2
\end{aligned}
$$

A_h is area of one complete set with no reuse

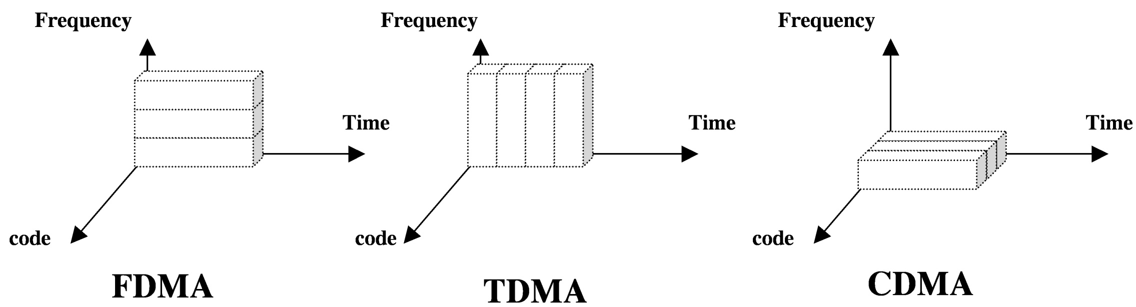


$$y^2 + \left(\frac{D^2}{4}\right) = D^2 \Rightarrow y = \frac{\sqrt{3}}{2}D$$

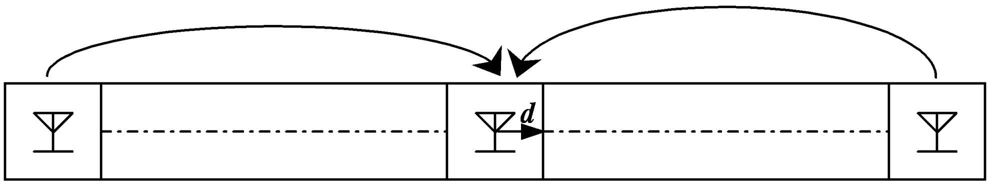
$$\Rightarrow A_h = \frac{\sqrt{3}}{2}D^2(2r)^2$$

$$
\begin{aligned}
C_h &= \frac{A_h}{A_c} = \frac{\sqrt{3}/2(4r^2)(k^2 + l^2 + kl)}{2\sqrt{3}r^2} \\
&= k^2 + l^2 + kl
\end{aligned}
$$

[Different Multiple Access Techniques]



[Example] Consider a 1D case. For path loss of $K/\text{distance}^3$ & $M = 2$ (reuse distance), how far to the right would the user move before the the downlink fails, if it fails for S/I of less than 10 dB?



$$S_p = k/d^3, \quad I = \frac{k}{(2Mr+d)^3} + \frac{k}{(2Mr-d)^3}$$

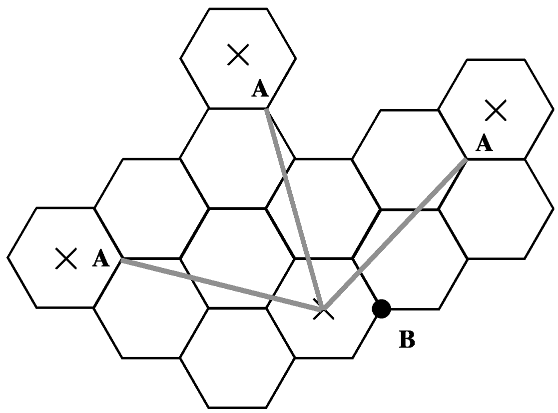
$$\begin{aligned} \text{SIR} &= \frac{1/d^3}{\frac{1}{(2Mr+d)^3} + \frac{1}{(2Mr-d)^3}} \\ &= \frac{1}{\frac{1}{(4r/d+1)^3} + \frac{1}{(4r/d-1)^3}} \geq 10 \end{aligned}$$

Solving $4r/d = x$,

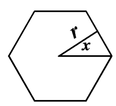
$$\frac{1}{(x+1)^3 + (x-1)^3} \leq 0.1$$

Solving numerically, $x = 3.2565$ then $d = 1.228r$.
When user moves out of cell & still uses the same base station.

[Example] For a cellular system with a 7-cell reuse pattern with hexagon cells, find the worse location for uplink SIR for the user & the interferences:

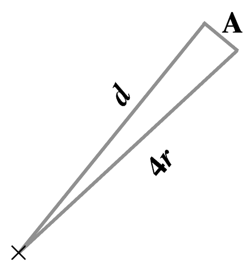


A: worse uplink interference, B:worse uplink signal strength



$$r^2 + x^2/4 = x^2 \rightarrow x = 2r/\sqrt{3}$$
$$S_p = \frac{k}{(2r/\sqrt{3})^n}$$

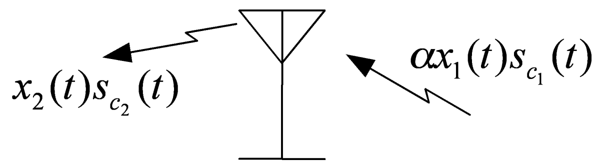
For interference:



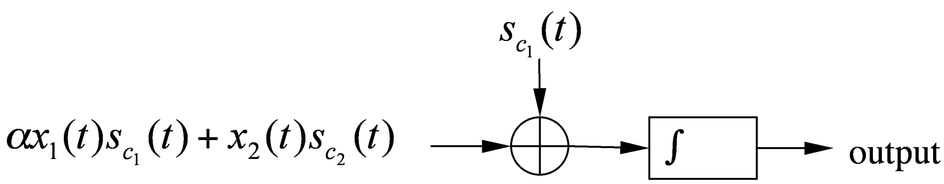
$$d^2 = (4r)^2 + (2r/\sqrt{3})^2 = 52r^2/3$$
$$\text{SIR} = \frac{(2r/\sqrt{3})^{-n}}{6\left(\frac{\sqrt{52}}{\sqrt{3}}r\right)^{-n}}$$

[Duplexing: separating uplink & downlink] Time Division Duplexing (TDD) or Frequency Division Duplexing (FDD).

- *Code Division Duplexing (CDD) is never used:*



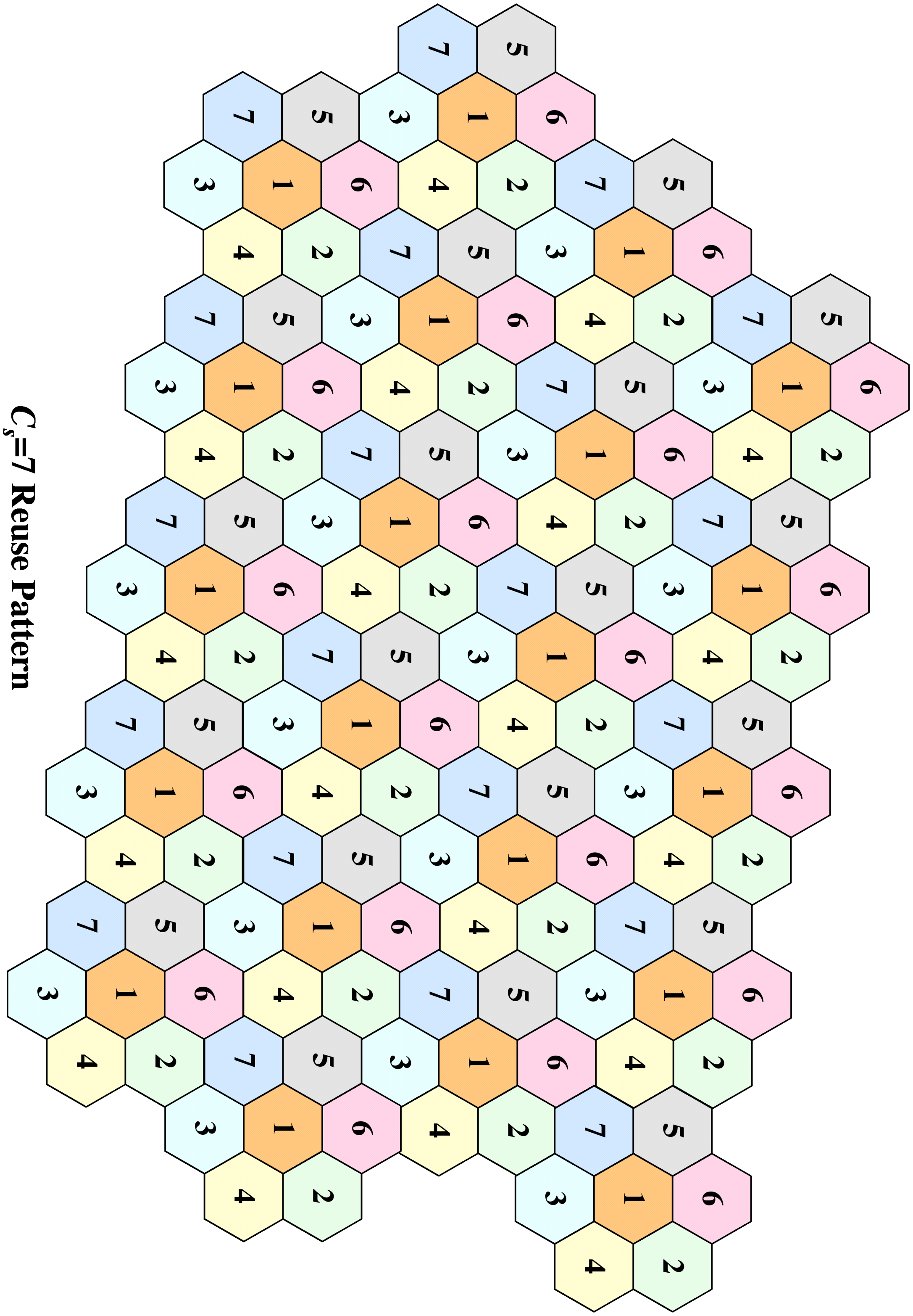
In the receiver:



$$\text{output} \quad = \quad \alpha x_1(t) + x_2(t)\rho_{12}(0) \quad \alpha \ll 1 \text{ if the user is far}$$

Similar to near-far problem but with the near user exactly on the base. *Never used*

- FDD: the easiest to implement but double BW usage.
- TDD: need good coordination, can estimate the channel from uplink and use it in downlink. Delay spread can hurt (better for indoor).



C_s=7 Reuse Pattern