Lec10

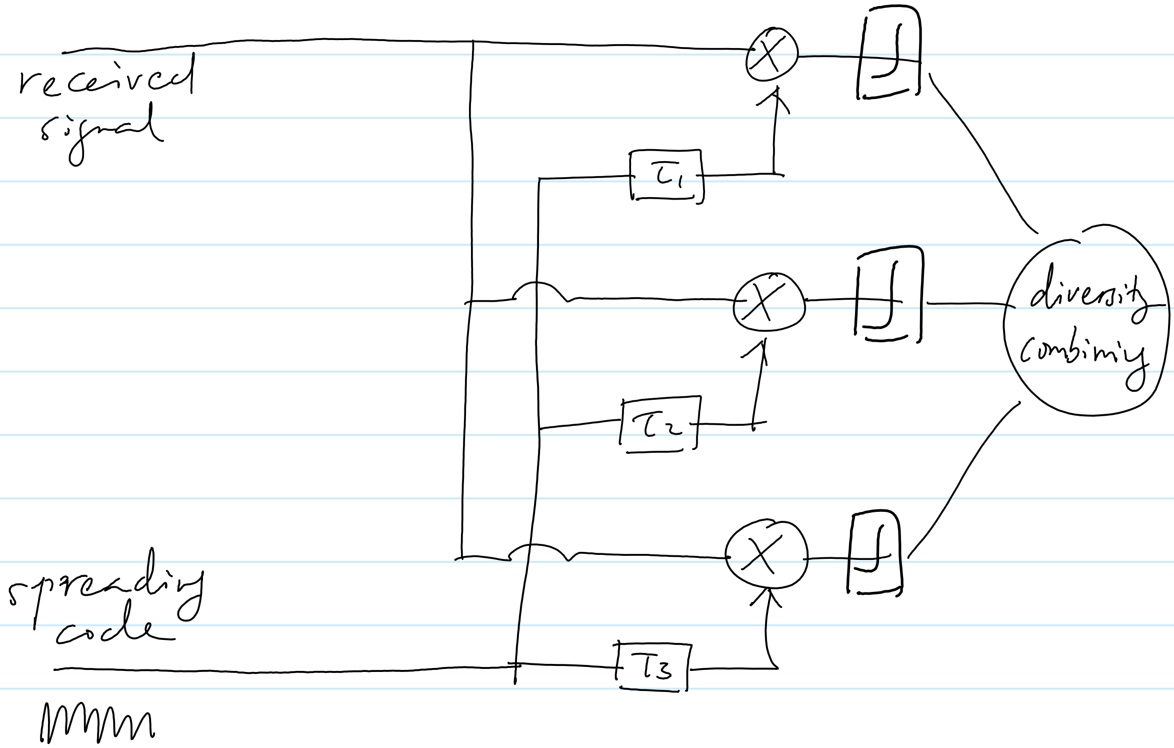
Thursday, February 6, 2020 8:43 AM

HW2 is assigned.
Bring CDMA handout

Rake receiver - 10min

Wednesday, January 16, 2008 3:42 PM

In CDMA, when bandwidth of the signal is much larger than the coherent bw, different paths can be seperately detected.
Multiple detected path can be combined to achieve higher SINR



Each individually resolvable path of the signal will have maximum correlation with the spreading code at a particular delay.

Diversity combining can pick either the max path, or some weighted sum. that maximizes the SINR.

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Single cell - 15min

Saturday, March 15, 2008 10:42 AM

Given a particular modulation scheme (before spreading), a certain SINR for the received signal $\tilde{s}(t)$ is required for correct detection.

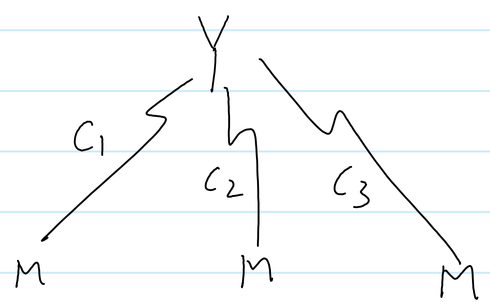
$$\frac{E_b}{I_0}$$

E_b — energy of signal

I_0 — energy of noise/interference

7 dB (= 5) typical.

Single Cell, No fading



Assumptions:

- There are K users in one cell.
- Focus on the uplink of the cell.
- All users in the cell has power control, so that the same received power P_R is received at BS

— No noise. no fading

In order to decode the signal from a particular receiver:

Energy: $E_b = P_R \cdot T_s$

Interference due to $(k-1)$ interfering users

$$I_0 = \frac{P_R}{W} \cdot (k-1) \cdot T_s$$

$$\therefore \quad \frac{E_b}{I_0} = \frac{P_R \cdot T_s}{\frac{P_R}{W}(k-1) \cdot T_s} = \frac{W}{K-1}$$

The requirement on $\frac{E_b}{I_0}$ limits the maximum number of users the cell can support:

$$K = \frac{W}{E_b/I_0} + 1.$$

Example: IS-95

- Information bit rate $1/T_s = 9.6k$ bps
- Transmission bandwidth $1/T_C = 1.2288$ Mbps

$$W = T_s/T_C = 128$$

- $E_b/I_0 = 5$ (or 7dB)

$\therefore$ $K = 26$ users/cell for 1.25MHz

For a 25MHz band, we have

$$\frac{25\,\text{MHz}}{1.25\,\text{MHz}} \times 13 = 520 \text{ users/cell}$$

compared to 248 users/cell in the GSM example. (4-reuse)

$$\frac{25M}{200} \times \frac{8}{4} = 250$$

Caveates:

- We have not taken into account the interference from other cells
- Fading

Note: In the above derivation, we have assumed perfect power control.

Power control is critical to CDMA systems.

Consider the case w/o power control

- If users transmit at the same Power

- If users transmit at the same Power
- The received power P_i at the BS will be different
  - closed-in users have a larger received power than far-away users

$$\text{SNR for user } i = \frac{P_i}{\sum_{j \neq i} \frac{P_j}{W}}$$

$\Rightarrow$ The close-in users would have a higher SNR than far-away users, making the signal of far-away users difficult to decode.

- We will discuss power-control techniques later.

(60)

Multi-cell - 5min

Saturday, March 15, 2008 11:03 AM

Multicell case with shadow fading

Assumptions:

- Focus again on uplink
- Power control is executed in each cell, such that the same average receiving power P_R is received from the mobiles in the cell.
- The channel gain changes slowly due to shadow fading.

Due to power control, the transmitted power of the mobile must be adjusted according to the fading gain, in order to maintain the same received power.

X

We assume that power control is fast enough to compensate the changes in channel gain due to shadow fading.

- Assume that shadow fading & path-loss parameters are the same across cells.

$$P_R = P_T \cdot r^{-n} \, 10^{\xi/10} \quad , \; \xi \sim N(0, \sigma^2)$$

To model the distance r:

- Mobiles are uniformly distributed in each cell. The average # of users in each cell is K.

- Hard-handoff: a mobile communicates with the BS in the geometric cell only.

  (This is versus the <u>soft</u>-handoff we will discuss later: a mobile communicates with the BS with the smallest propagation loss.)

- Ignore multipath fading: Assume it is taken into account in the SINR threshold.

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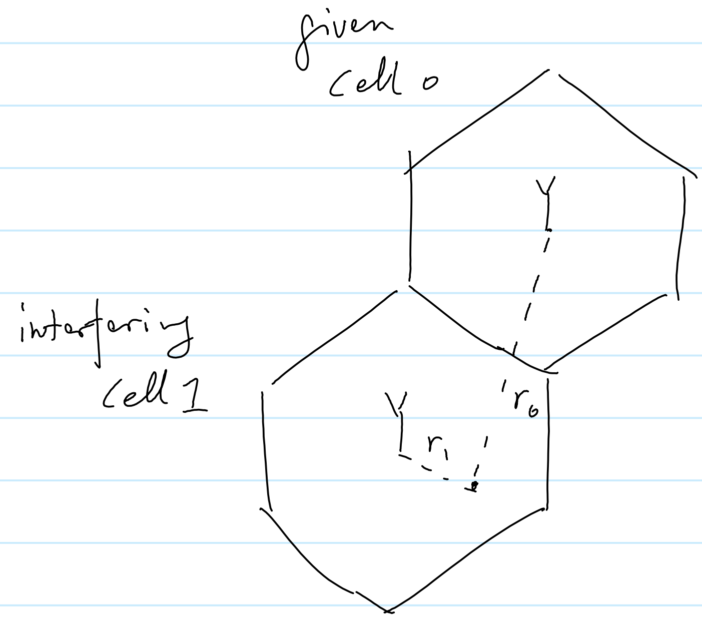
Interfering cells - 15min

Saturday, March 15, 2008 11:16 AM

We need to derive the interference from other cells.



Consider a given mobile in interfering cell 1.

Let r_1 be its distance to its own BS,
let r_0 be its distance to the BS in the cell of interest (cell 0).

Let us calculate the interference caused by this mobile at the BS of cell 0.

At the interfering cell, since we assume perfect power control:

$$P_R = P_{T_1} \cdot r_1^{-n} 10^{\xi_1/10}$$

$\Rightarrow$ Transmission power

$$P_{T_1} = P_R \cdot r_1^{\,n}\, 10^{-\zeta_1/10}$$

At cell 0, interference created by this mobile is given by

$$P_{T_1} \cdot r_0^{-n} \cdot 10^{\zeta_0/10}$$

$$= P_R \cdot \left(\frac{r_1}{r_0}\right)^n 10^{(\zeta_0 - \zeta_1)/10}$$

Note that the density of the mobile is

$$\rho = \frac{2K}{3\sqrt{3}\, R^2}$$

$\uparrow$ radius of cell.

Hence, the total average interference power at BS_0 from mobiles outside S_0 is given by

$$I_{S_0^*} = \frac{2K}{3\sqrt{3}\, R^2} P_R \cdot E\left\{ \iint_{S_0^*} \left[\left(\frac{r_1}{r_0}\right)^n \cdot 10^{(\zeta_1-\zeta_0)/10} \right] dA \right\}$$

Why is expected value enough?

$\uparrow$ areas outside cell 0.

Assume that shadow fading is independent of the location.

$$I_{S_0^*} = \frac{2k}{3\sqrt{3}\,R^2} \cdot P_R \cdot \underbrace{E\left[10^{(\xi_1-\xi_0)/10}\right]}_{\text{due to shadow fading}} \cdot \underbrace{\iint_{S_0^*} \left(\frac{r_1}{r_0}\right)^n dA}_{\text{due to mobile location}}$$

- When there is no fading $\Rightarrow 1$

- With fading > 1!

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Interfering cells - handout

Saturday, March 15, 2008 11:16 AM

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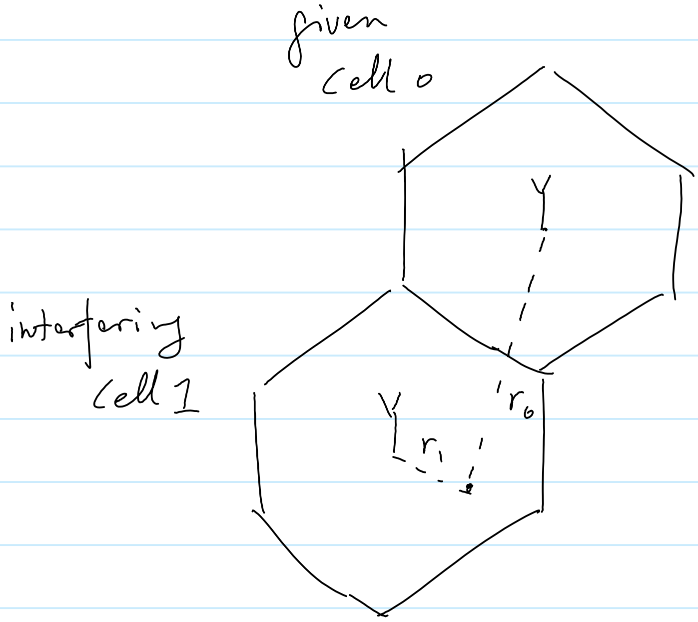

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$I_{S_0}^{*} = .$

Effect of shadow fading - 10min

Saturday, March 15, 2008 11:30 AM

Let us first derive

$$E\left[10^{(z_1 - z_0)/10}\right]$$

$$z_1, z_0 \sim N(0, \sigma^2)$$

In general, z_1 & z_0 may be correlated because BS_0 & BS_1 are close to each other.

Assume in addition that

$$z_i = ah + bh_i, \quad i = 1, 2$$

where

h, h_i's are Gaussian r.v.'s $N(0, \sigma^2)$

h represents the fading term common to z_1 & z_0

h_i's represent the independent fading terms.

a, b are coefficients, $a^2 + b^2 = 1$

Then

$$y \triangleq z_1 - z_0 = b(h_1 - h_0)$$

is a Gaussian r.v. with variance $2b^2\sigma^2 \triangleq \sigma_y^2$

Knowing σ_y^2, we can then calculate

$$E\left[10^{(z_1 - z_0)/10}\right] \triangleq E\left[10^{y/10}\right]$$

$$E\left[10^{(\cdots)}\right] = E\left[10^{Y/10}\right]$$

$$= \int e^{y \cdot \frac{\ln 10}{10}} \cdot \frac{1}{\sqrt{2\pi}\,\sigma_y} e^{-y^2/2\sigma_y^2}\, dy$$

$$= \frac{1}{\sqrt{2\pi}\,\sigma_y} \int e^{-\frac{1}{2\sigma_y^2}\left(y - \sigma_y^2 \frac{\ln 10}{10}\right)^2} \cdot e^{\frac{1}{2}\sigma_y^2 \left(\frac{\ln 10}{10}\right)^2} dy$$

$$= e^{\frac{1}{2}\sigma_y^2 \left(\frac{\ln 10}{10}\right)^2}$$

30

$= 1$ if $\sigma_y = 0$

> 1 in general

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