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On the Capacity of a Cellular CDMA System

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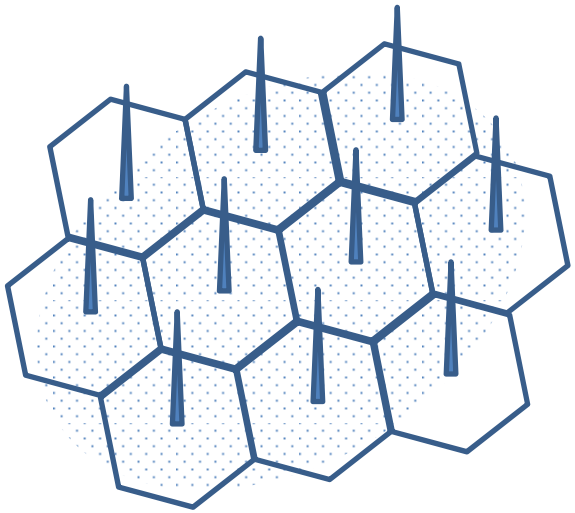
EE360 Presentation

Capacity of Cellular CDMA

- Number of users per Cell
- BER or SINR requirement (10^{-3} or 7dB)
- Cellular systems



- Comparison with other systems
  - 6x Improvement compared to FDMA/TDMA
  - 18x Improvement compared to Analog

FDMA/TDMA – BW Limited

- Users don't interfere with each other
- Eb/No can be increased by increasing transmit power

$$E_b/N_0 = \frac{S/R}{N_0}$$

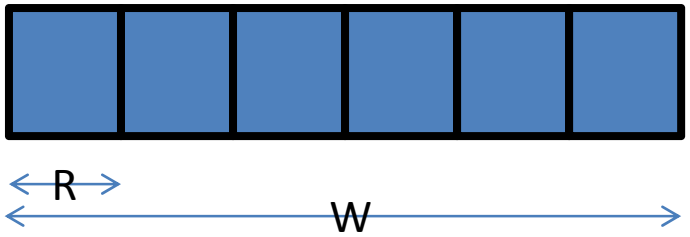
S: Received Power from one user, same for users

W: Total BW

R: Bit Rate

- Number of users are BW limited (hard Limit)

$$N \leq W/R$$



CDMA – Interference Limited

- Use of Non-Orthogonal Codes
- Every users interfere with every other user
- Gradual increase in interference

$$E_b/N_0 = \frac{S(W/R)}{(N-1)S+\eta} \approx \frac{W/R}{N-1}$$

S: Received Power from one user, same for users

W: Total BW

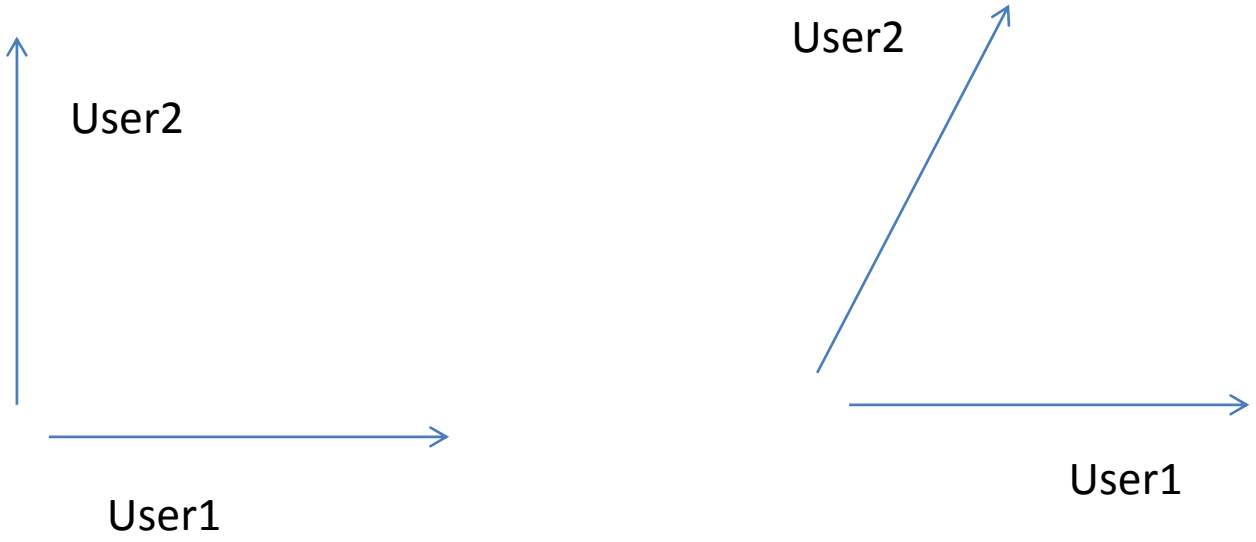
R: Bit Rate

- Number of users are interference limited (soft limit)

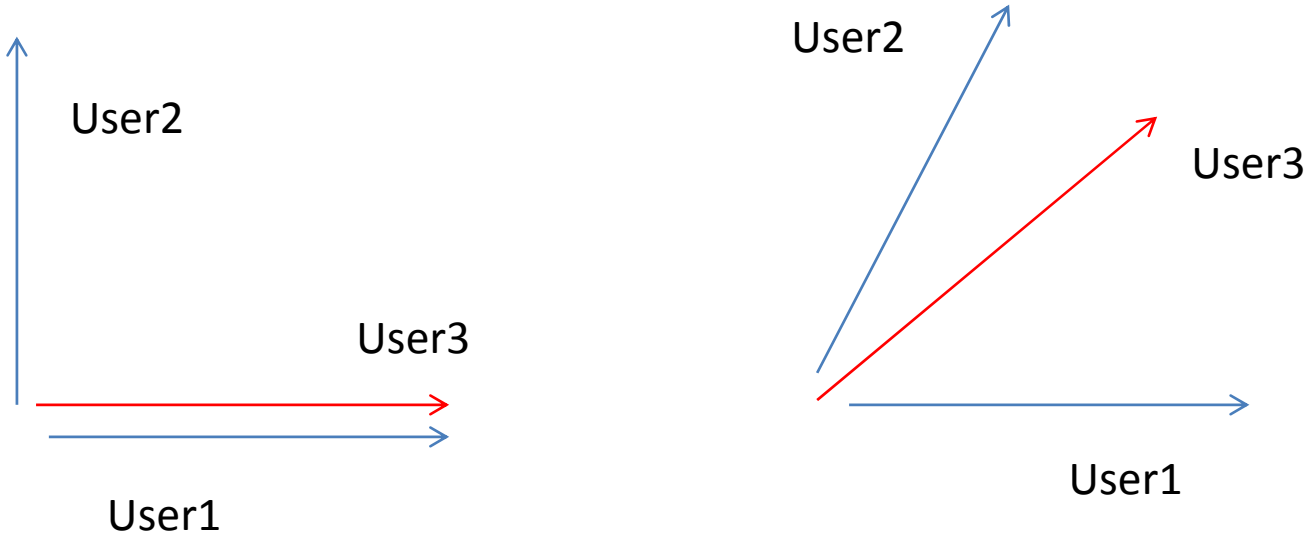
$$N \leq 1 + \frac{W/R}{E_b/N_0} - \frac{\eta}{S}$$

CDMA vs FDMA

CDMA vs FDMA



CDMA vs FDMA



Single Cell

- BER=10^{-3} => Eb/No=7dB ~ 5

$$N_{FDMA} \leq W/R \qquad N_{CDMA} \leq 1 + \frac{W/R}{E_b/N_0} - \frac{\eta}{S}$$

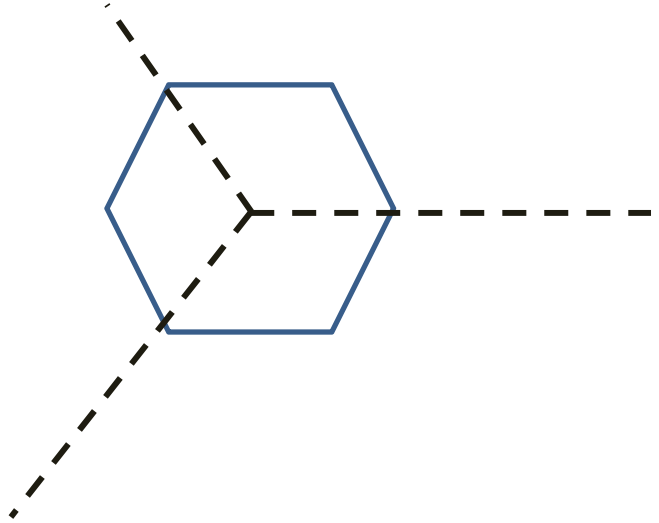
- CDMA capacity short by 5x ?

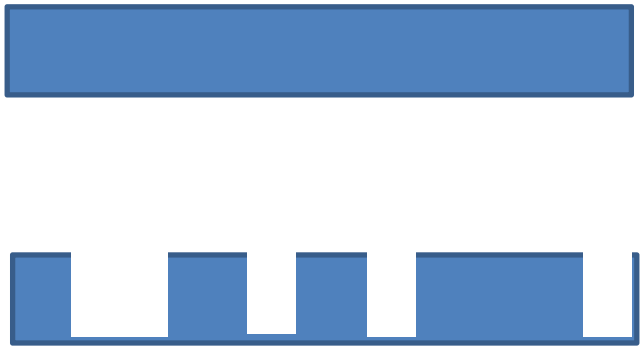
Single Cell

- N can be increased
  - Sectorize (cell can be subdivided into 3 sectors)
  - Voice Activity Factor (Silent 3/8 fraction of times)

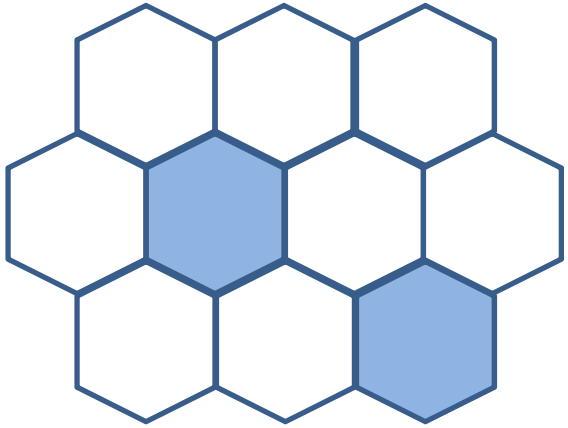
$$E_b/N_0 = \frac{(W/R)}{(N_s - 1)\alpha} \qquad N = 3N_s$$

- For single cell: CDMA ~ FDMA (BER of 10^{-3})



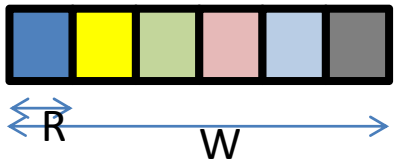


Multiple Cell

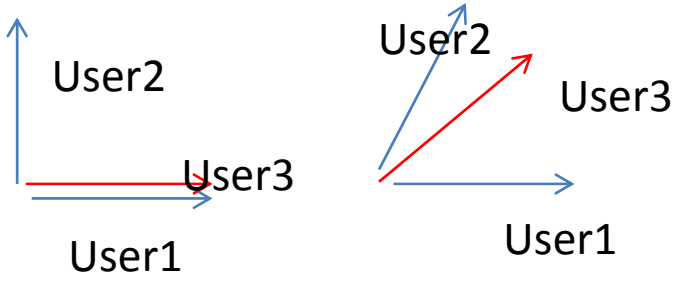


- Inter-Cell interference
- No two adjacent cell use same frequency
- FDMA: Frequency reuse 1/7

$$N = \frac{1}{7}(W/R)$$



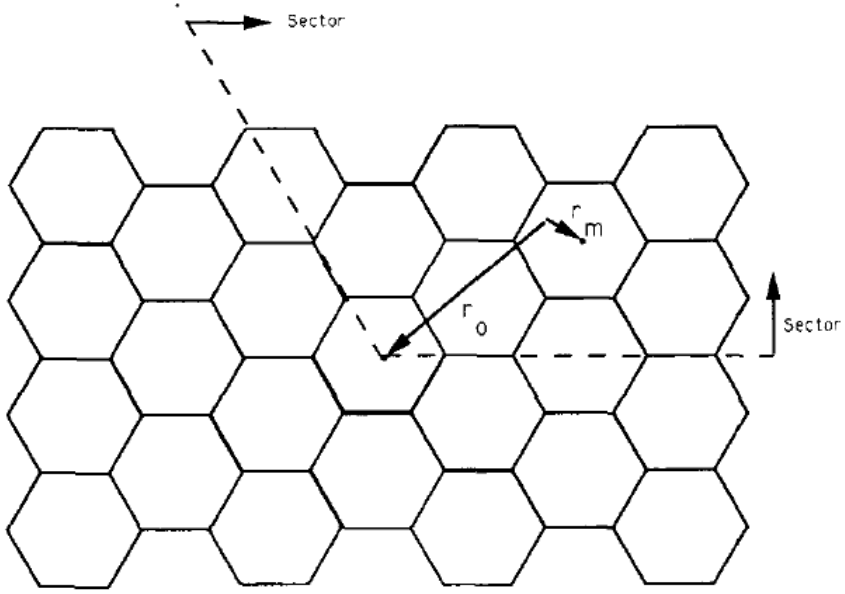
- CDMA: Higher frequency reuse possible
  - Power Control
  - Uplink and Downlink



CDMA Uplink

- User selects BS with max channel gain.
- Power Control: Received Power (at BS) from each user is same (~ single cell)
- BS suffers interference from other user

$$I = \frac{S}{\left(\frac{10^{z_m/10}}{r_m^4}\right)} \left(\frac{10^{z_0/10}}{r_0^4}\right)$$

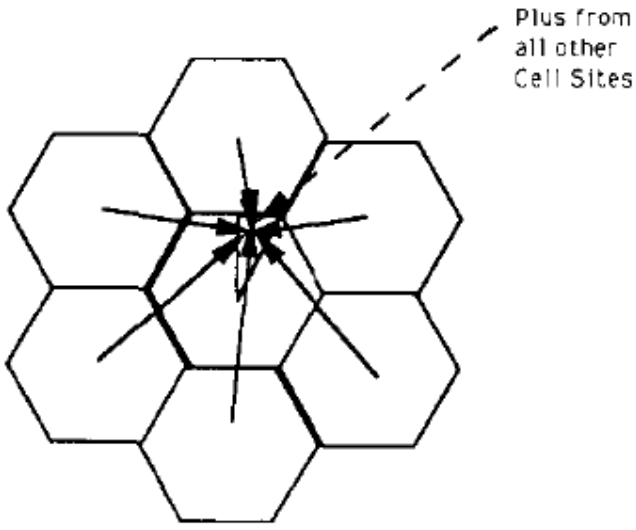


CDMA Downlink

- Power Control: Depends on users interference from other cells.
- User suffer interference from other BS

$$\left(\frac{E_b}{N_0}\right)_i \geq \frac{\beta \varnothing_i S_{T_1} / R}{\left[\left(\sum_{j=1}^{K} S_{T_j}\right)_i + \eta\right] / W}$$

- 1-β = Fraction of power for pilot signal
- $\varnothing_i$ = Fraction of power for user i



CDMA Capacity Result

- R = 8 kb/s W=1.25MHz
- W/R = 160
- (1/7)x ~ 23 users / cell

- N ~ 36 user/sector
- N ~ 108 user / cell
- Frequency Reuse ~ 0.67

- 6x improvement from FDMA (1/7 ~ 0.15)

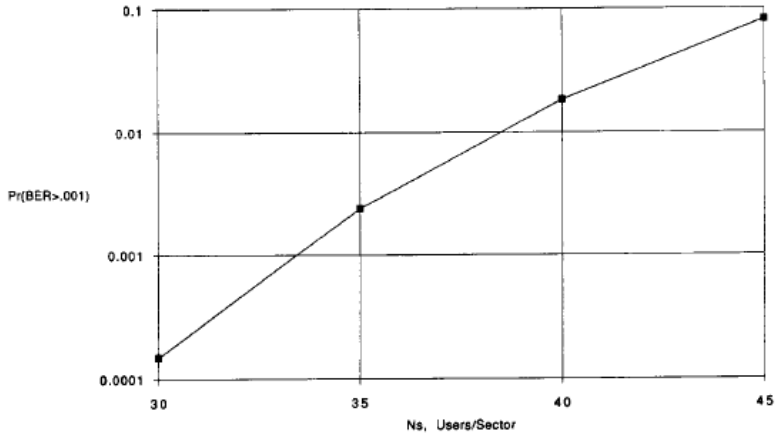


Fig. 5. Forward link capacity/sector. (W = 1.25 MHz, R = 8 kb/s, voice activity = 3/8, pilot power = 20 %).

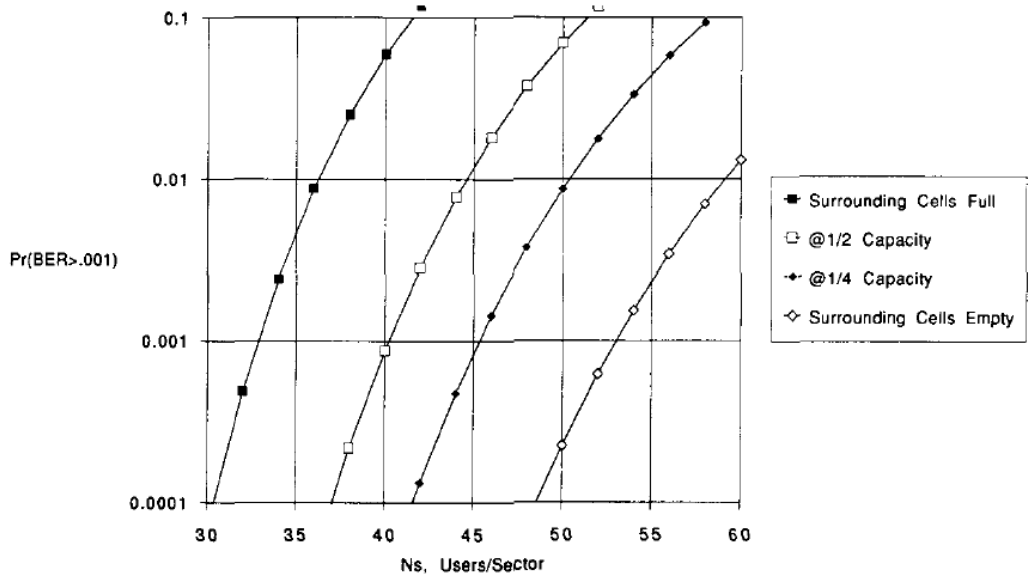


Fig. 3. Reverse link capacity/sector. (W = 1.25 MHz, R = 8 kb/s, voice activity = 3/8).

Main Ideas

- CDMA leads to increase in capacity (users per cell)
  - Sectorize
  - Voice Activity Factor
  - Power Control
  - Soft Limit on number of users
  - Frequency Reuse
- Today, are these factor limited to CDMA?
- The work lead to CDMA standard (and Qualcomm Inc.)