College of Engineering

Capacity Allocation in Multi-cell UMTS Networks for Different Spreading Factors with Perfect and Imperfect Power Control

Robert Akl, D.Sc.

Son Nguyen, M.S.

Department of Computer Science and Engineering

Outline

- User and Interference Model
- WCDMA Capacity with Perfect Power Control
- WCDMA Capacity with Imperfect Power Control
- Spreading Factors
- Numerical Results
- Conclusions

CDMA with One Class of Users

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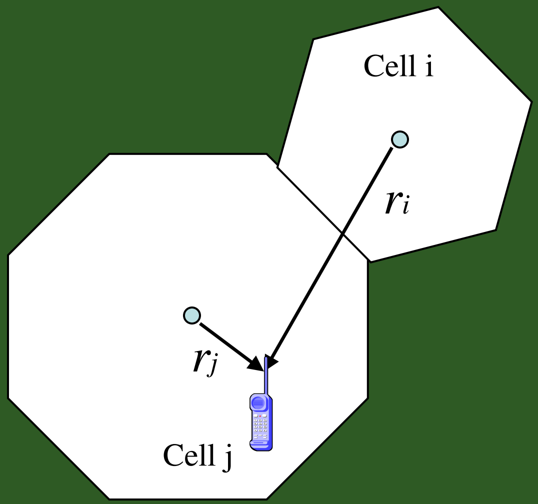
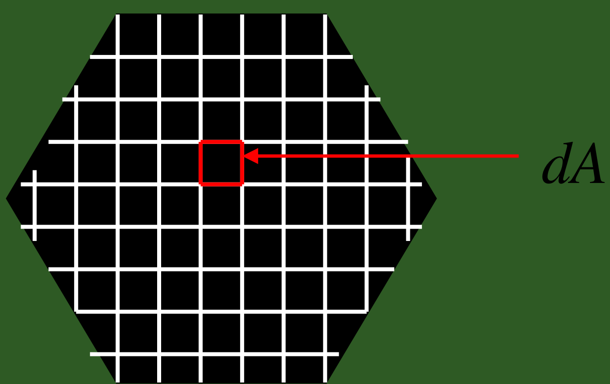
I_{ji} = Relative average interference at cell i caused by n_j users in cell j



$$I_{ji} = \mathrm{E}\left[\iint_{Cj} \frac{r_j^m(x,y)10^{\zeta_j/10}}{r_i^m(x,y)/\chi_i^2}\,\frac{nj}{Aj}\,dA(x,y)\right]$$

$$I_{ji} = e^{(\gamma\sigma_s)^2}\,\frac{nj}{Aj}\iint_{C_j}\frac{r_j^m(x,y)}{r_i^m(x,y)}\,dA(x,\ y)$$



where $\gamma = \frac{\ln(10)}{10}$

σ_s is the standard deviation of the attenuation for the shadow fading

m is the path loss exponent

WCDMA with Multiple Classes of Users

- **Inter-cell Interference at cell *i* caused by n_j users in cell *j* of class *g***

$$I_{ji,g} = S_g v_g n_{j,g} \frac{e^{(\gamma\sigma_s)^2}}{A_j} \iint_{C_j} \frac{r_j^{\,m}(x,y)}{r_i^{\,m}(x,y)} w(x,y)\,dA(x,y)$$

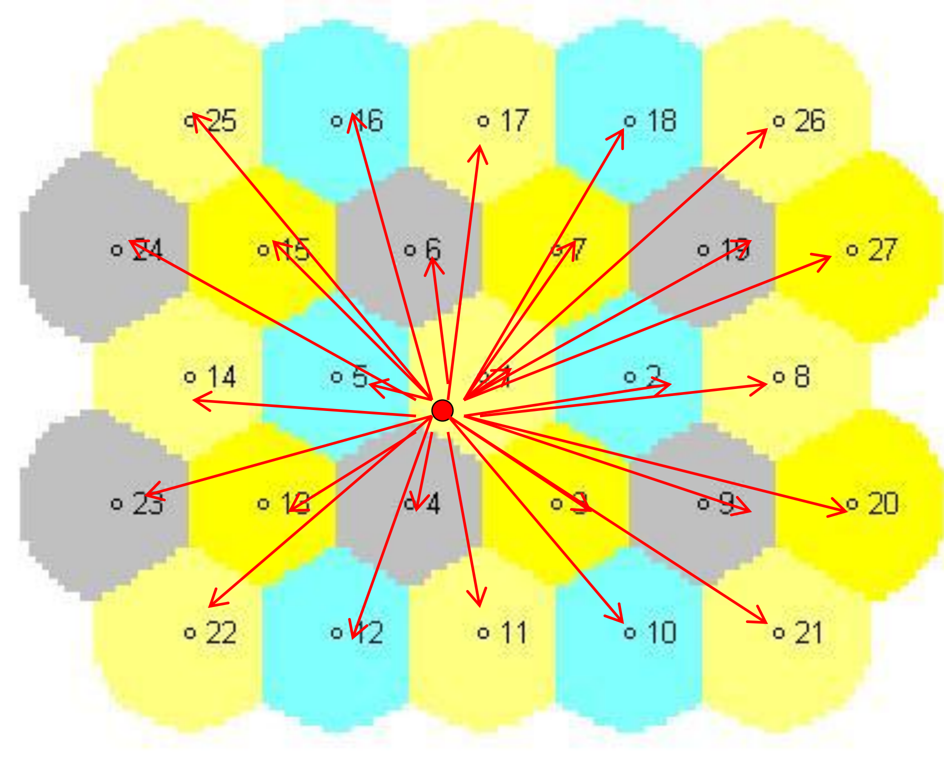
$$\kappa_{ji,g} = \frac{e^{(\gamma\sigma_s)^2}}{A_j} \iint_{C_j} \frac{r_j^{\,m}(x,y)}{r_i^{\,m}(x,y)} w(x,y)\,dA(x,y).$$

$w(x,y)$	is the user distribution density at (x,y)
$\kappa_{ji,g}$	is per-user (with service *g*) relative inter-cell interference factor from cell *j* to BS *i*

Total Inter-cell Interference Density in WCDMA

$$I_g^{\text{inter}} = \frac{1}{W} \sum_{j=1, j \neq i}^{M} \sum_{g=1}^{G} S_g \nu_g n_{j,g} \kappa_{ji,g}$$

M	is the total number of cells in the network
G	total number of services
W	is the bandwidth of the system



Model User Density with 2D Gaussian Distribution

$$w(x, y) = \frac{\eta}{2\pi\sigma_1\sigma_2} e^{-\frac{1}{2}\left(\frac{x-\mu_1}{\sigma_1}\right)^2} e^{-\frac{1}{2}\left(\frac{y-\mu_2}{\sigma_2}\right)^2}$$

- "means" is a user density normalizing parameter
- "variances" of the distribution for every cell

$$I_g^{\text{own}} = \frac{1}{W}\sum_{g=1}^{G} S_g \nu_g n_{i,g}$$

is the total intra-cell interference density caused by all users in cell *i*

Signal-to-Noise Density in WCDMA

$$\left(\frac{E_b}{I_0}\right)_{i,g} = \frac{\dfrac{S_g}{R_g}}{N_0 + I_i^{\text{own}} + I_i^{\text{inter}} - \dfrac{S_g \nu_g}{W}}$$

$$\tau_g \le \frac{\dfrac{S_g^*}{R_g}}{N_0 + \dfrac{S_g^*}{W}\left[\sum_{g=1}^{G} n_{i,g}\nu_g + \sum_{j=1, j\neq i}^{M}\sum_{g=1}^{G} n_{j,g}\nu_g \kappa_{ji,g} - \nu_g\right]}$$

where N_0 is the thermal noise density,

R_g is the bit rate for service g

τ_g is the minimum signal-to-noise ratio required

Simultaneous Users in WCDMA Must Satisfy the Following Inequality Constraints

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$$\sum_{g=1}^{G} n_{i,g} v_g + \sum_{j=1, j\neq i}^{M} \sum_{g=1}^{G} n_{j,g} v_g \kappa_{ji,g} - v_g \leq c_{eff}^{(g)}$$

where $c_{eff}^{(g)} = \frac{W}{R_g}\left[\frac{1}{\tau_g} - \frac{R_g}{S_g^* / N_0}\right]$

τ_g is the minimum signal-to-noise ratio

S_g^* is the maximum signal power

$n_{i,g}$ the number of users in BS i for given service g

The capacity in a WCDMA network is defined as the maximum number of simultaneous users $(n_{1,g}, n_{2,g}, \ldots, n_{M,G})$ for all services $g = 1, \ldots, G$. This is for perfect power control (PPC).

Imperfect Power Control

- **Transmitted signals between BSs and MSs are subject to multi-path propagation conditions**
- **The received signals** $\left(\frac{E_b}{I_0}\right)_{i,g}$ **vary according to a log-normal distribution with a standard deviation on the order of 1.5 to 2.5 dB. Thus** $(E_b)_{i,b}$ **in each cell** i **for every user with service** g **needs to be replaced**

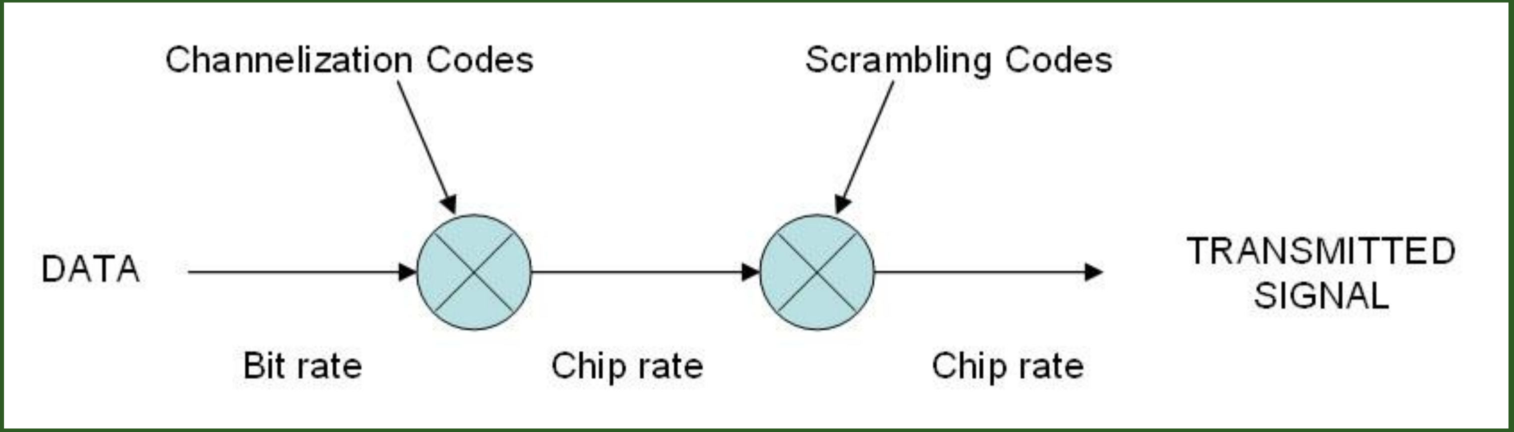
$$(E_b)_{i,b} \cong \varepsilon_{i,g}(E_b)_{o,b}$$

$$E\left[\frac{(E_b)_{o,b}}{I_0}\varepsilon_{i,g}\right] = \frac{(E_b)_{i,b}}{I_0}e^{(\beta\sigma_c)^2}$$

$$c_{eff\_IPC}^{(g)} \Rightarrow \frac{c_{eff}^{(g)}}{e^{\frac{(\beta\sigma_c)^2}{2}}}$$

Relationship between Spreading and Scrambling

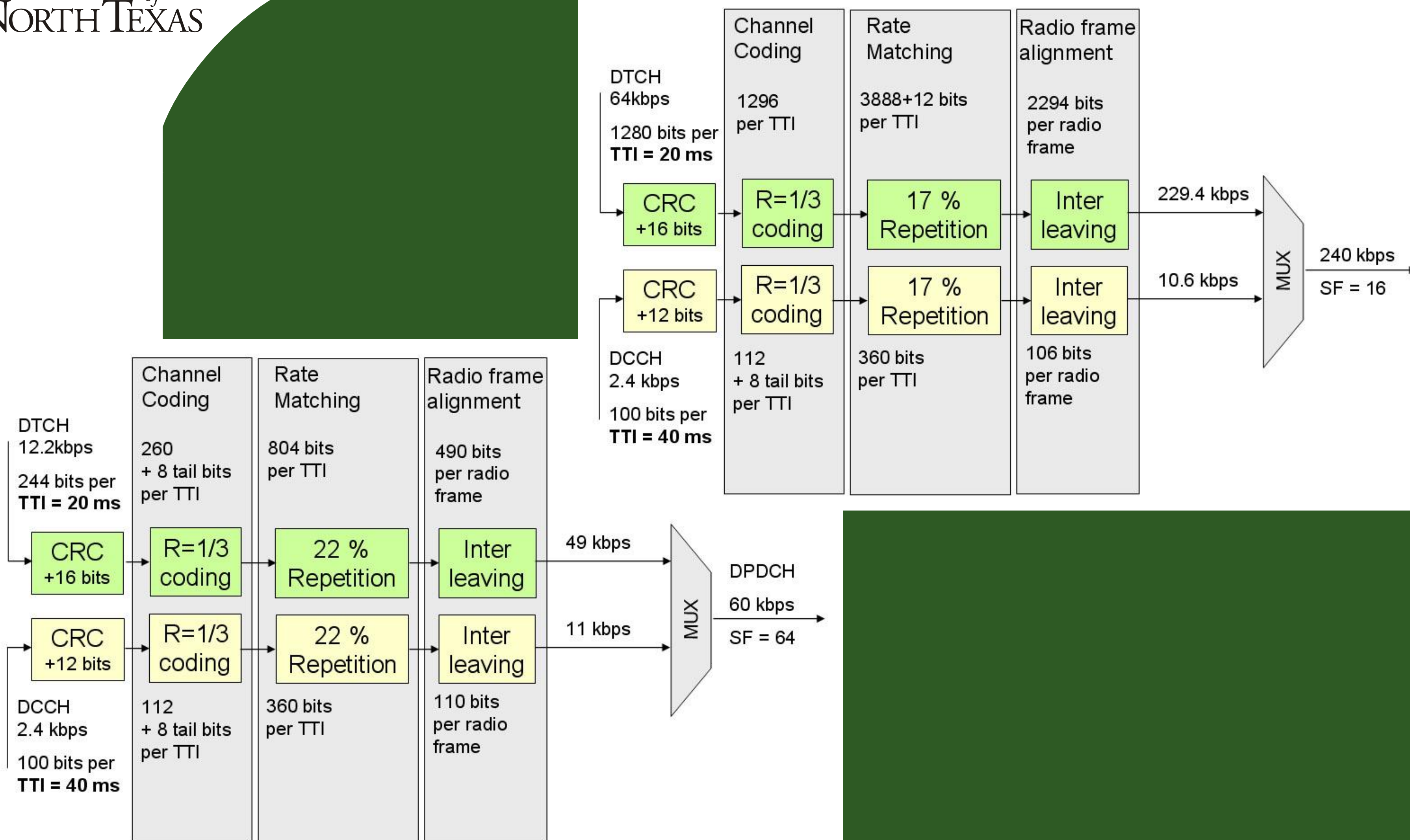
- Channelization codes: separate communication from a single source
- Scrambling codes: separate MSs and BSs from each other



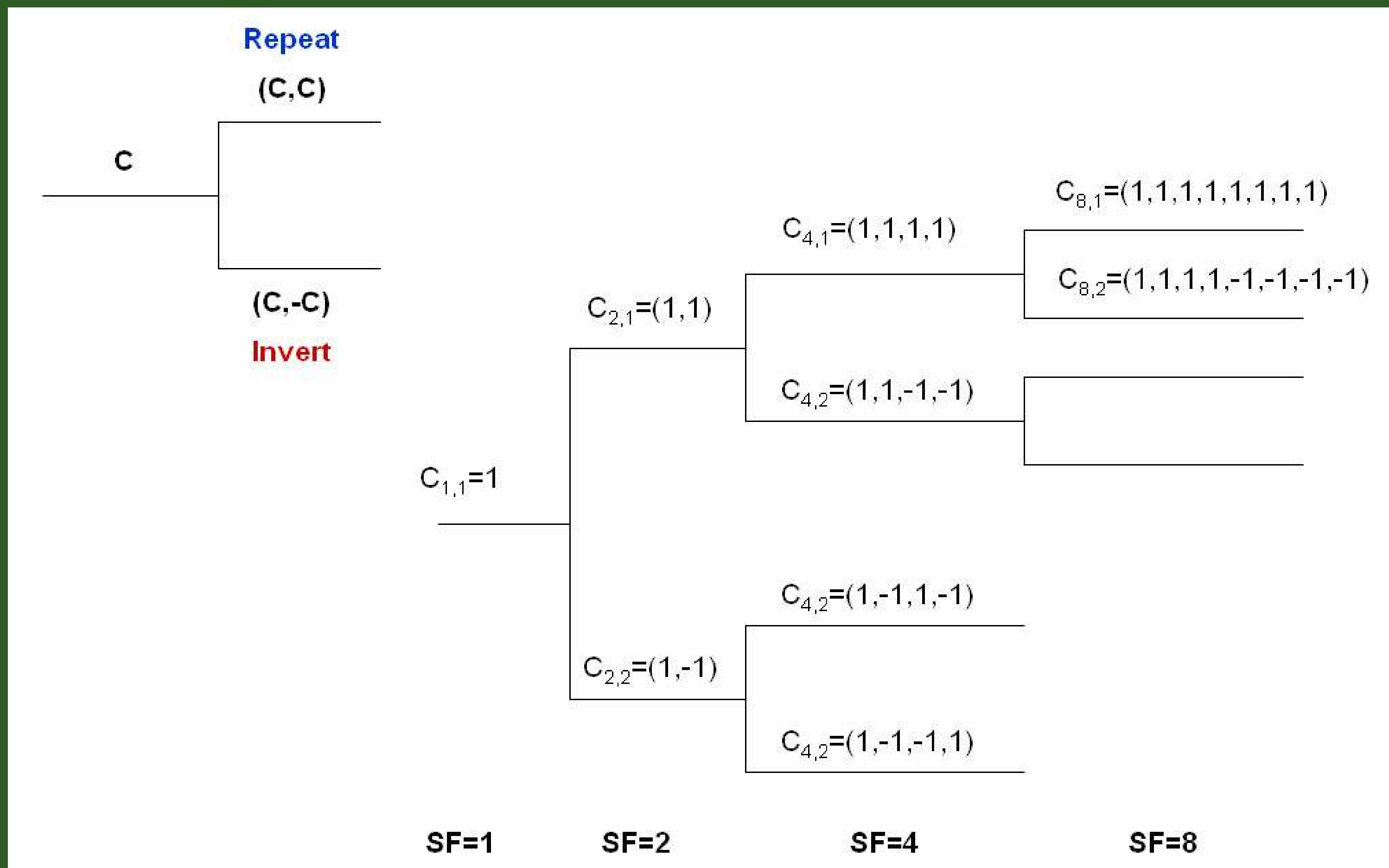
Main differences between WCDMA and IS-95 air interfaces

	Channelization code	Scrambling code
Usage	Uplink: Separation of physical data (DPDCH) and control channels (DPCCH) from same MS Downlink: Separation of downlink connections to different MSs within one cell.	Uplink: Separation of MSs Downlink: Separation of sectors (cells)
Length	Uplink: 4-256 chips same as SF Downlink 4-512 chips same as SF	Uplink: 10 ms = 38400 chips Downlink: 10 ms = 38400 chips
Number of codes	Number of codes under one scrambling code = spreading factor	Uplink: Several millions Downlink: 512
Code family	Orthogonal Variable Spreading Factor	Long 10 ms code: Gold Code Short code: Extended S(2) code family
Spreading	Yes, increases transmission bandwidth	No, does not affect transmission bandwidth

Spreading Factor



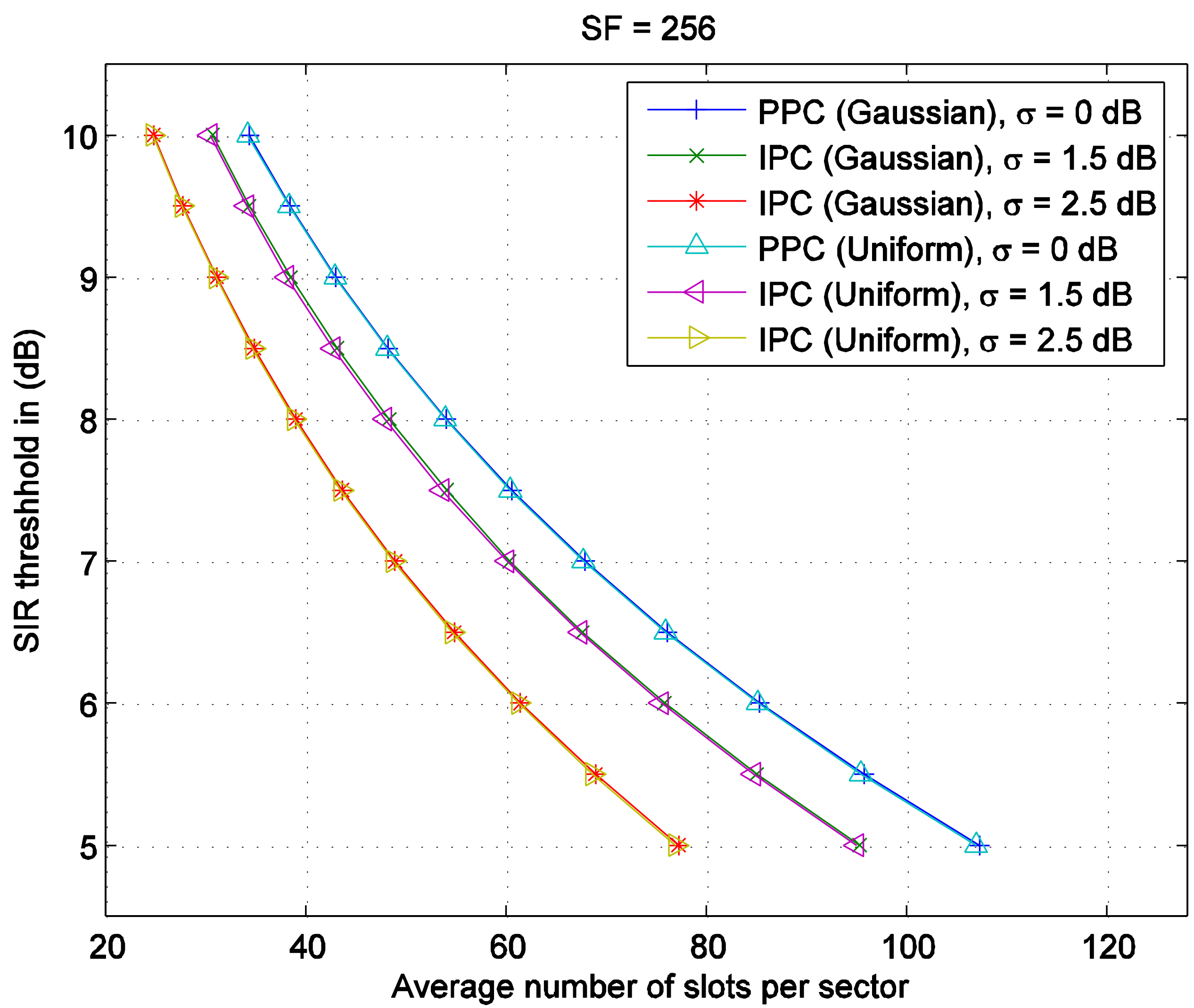
Orthogonal Variable Spreading Factor (OVSF) codes



Simulations

- Network configuration
  - COST-231 propagation model
  - Carrier frequency = 1800 MHz
  - Average base station height = 30 meters
  - Average mobile height = 1.5 meters
  - Path loss coefficient, m = 4
  - Shadow fading standard deviation, σ_s = 6 dB
  - Bit energy to interference ratio threshold, τ = 9.2 dB
  - Activity factor, ν = 0.375
  - Processing gain, W/R = 6.02 dB, 12.04 dB, 18.06 dB, and 24.08 dB for Spreading Factors equal to 4, 16, 64, and 256.

Numerical Results



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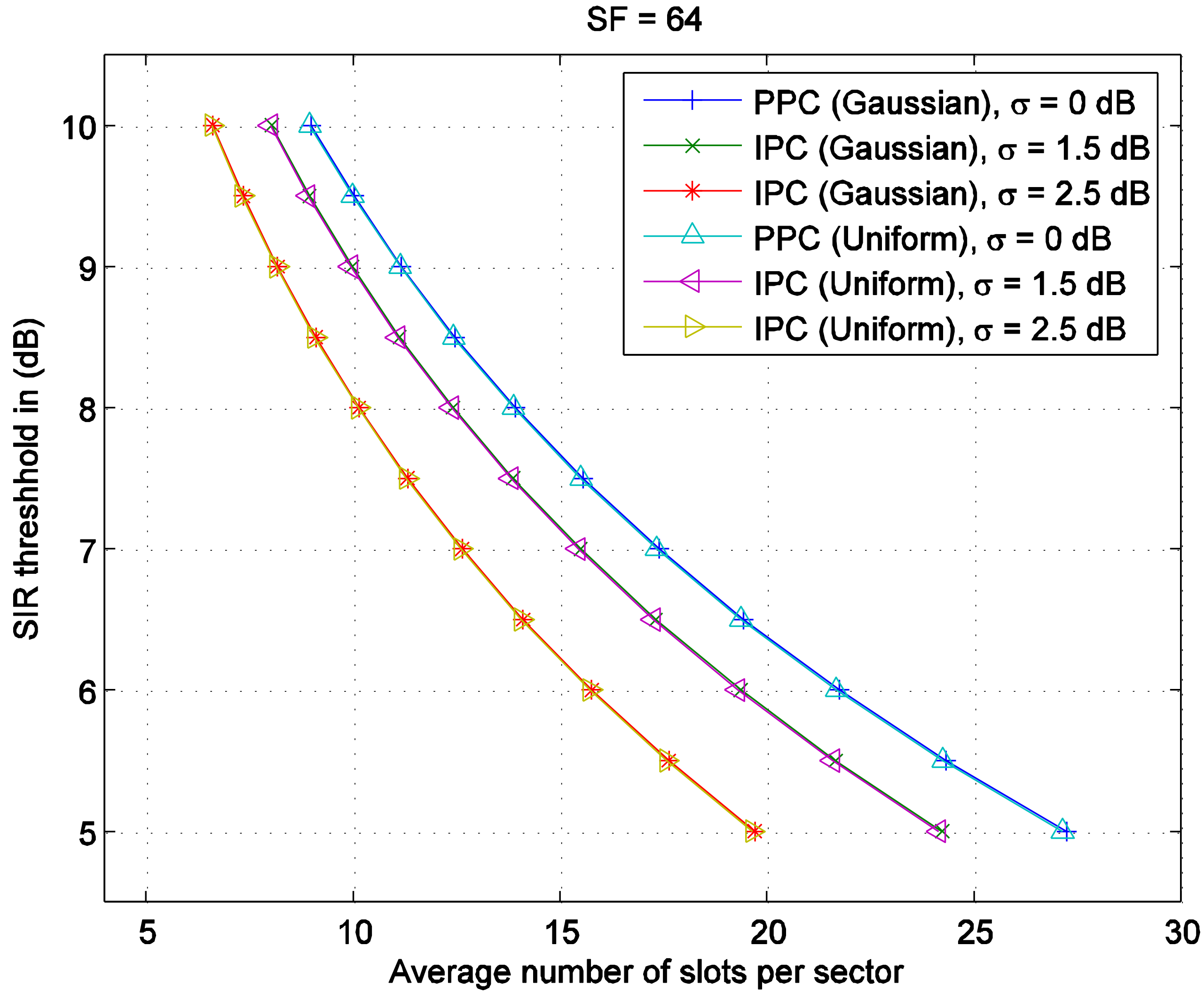

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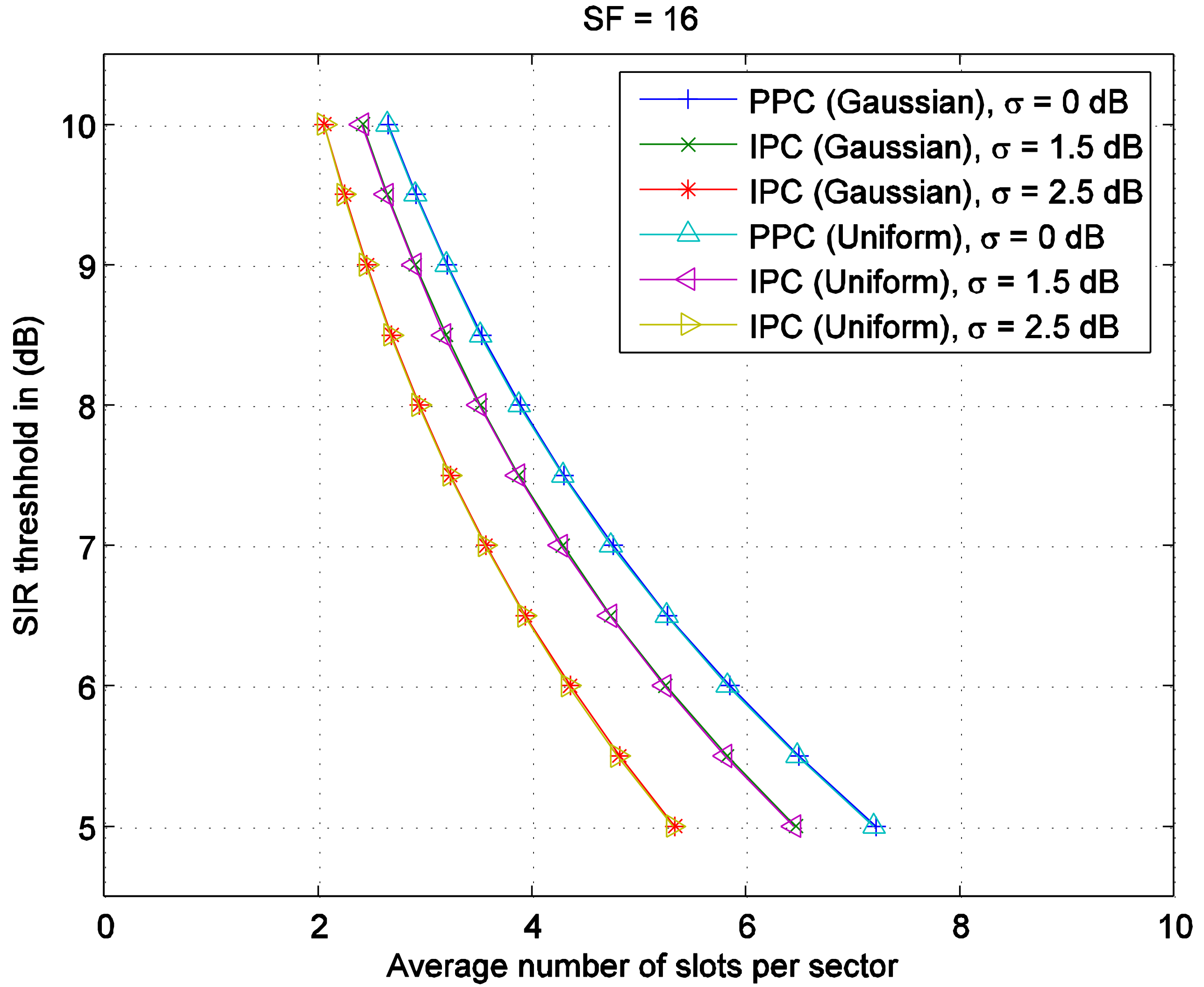
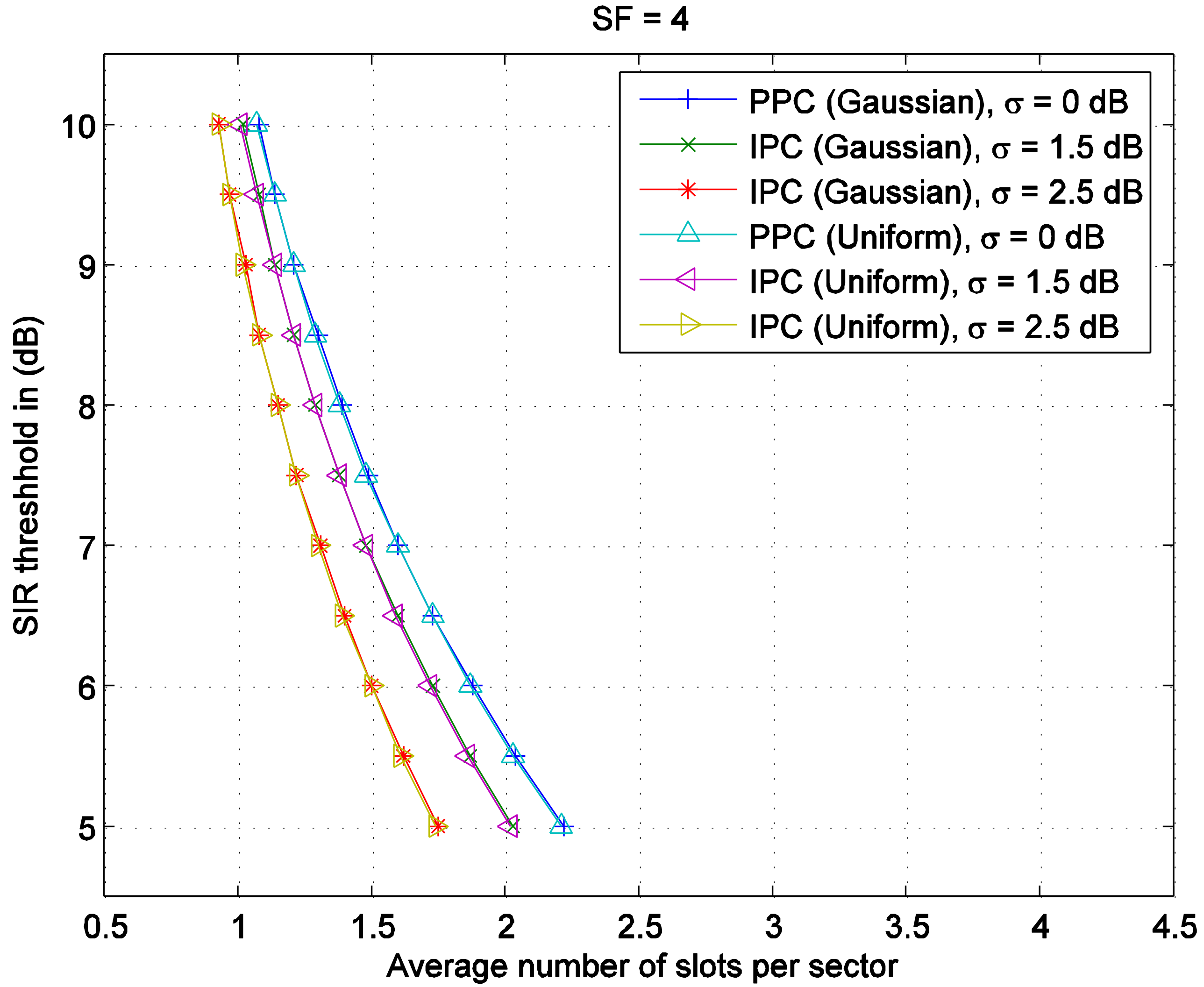
Numerical Results



Numerical Results



Results of Optimized Capacity Calculation

- The SIR threshold for the received signals is decreased by 0.5 to 1.5 dB due to the imperfect power control.
- As expected, we can have many low rate voice users or fewer data users as the data rate increases.
- The determined parameters of the 2-dimensional Gaussian model matches well with the traditional method for modeling uniform user distribution.

Thank You!!

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Questions?