ICT course:

Mobile Wireless Communications

Lecturers:
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ICTLab

Course Schedule: 36 hours

- Lectures: 24 hours

1. Introduction
2. Characteristics of mobile radio environment:
   - Propagation
   - Fading and mitigations
3. Cellular concept
4. Modulation techniques
5. Multiple Access techniques
6. Coding for error detection and correction
7. Applications – Mobile network Generations:
   - GSM
   - 3G/LTE-4G
   - 5G and future of mobile networks (discussion)

- Exercises: 12 hours
- References:

[1]. Mischa Schwartz: Mobile Wireless Communication, CAMBRIDGE UNIVERSITY PRESS, 1st Edition (2005)
[2]. Wireless Communications: Principles and Practice (2nd Edition) by Theodore S. Rappaport
[3]. Google

Lecture 3: Cellular Concepts

- Introduction of cells:
- Channel allocation
  - SIR calculation
  - Problem of traffic handling capacity
    - Traffic density (load)
    - Probability of call blocking: Erlang-B formula
    - Sizing a cell
- Probabilistic signal calculations
- Power control

Introduction of cells

- Introduction of cells:
  - Why?
    - Allocated spectrum is limited
    - Number of carriers vs huge number of users

    →Need to increase capacity
  - Cells: geographic clusters controlled by a base station
  - Reuse channel in different cells → increase capacity:
    - Same bandwidth, same area and more channels

- How reusing channel increases capacity?

B = 25 MHz, 832 channels x 30kHz

In a given area = N cells

- If no reuse channel: 832 channels
- If 3-cell reuse:
  - dividing 832 channels into 3 groups
  - 1 group each cell: 277 channels/cell
  - Reuse each group after 3 cells (2 cells separating cells)
  - 277N usable channels

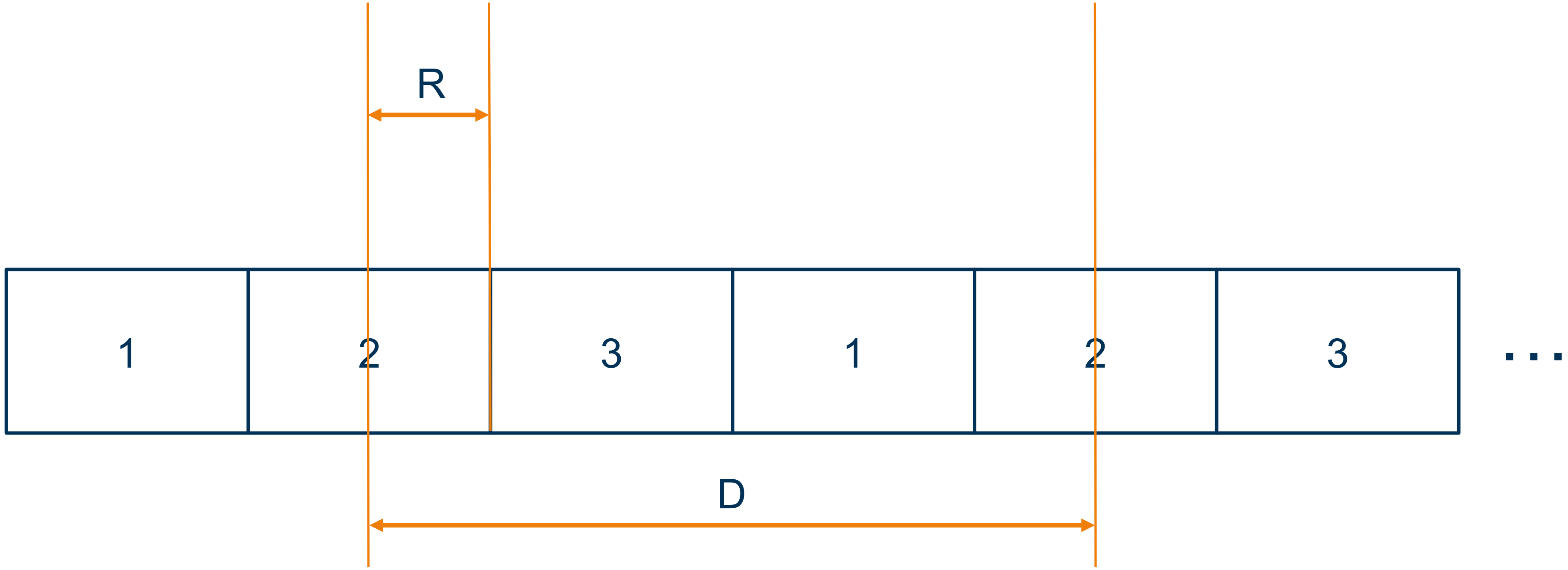
If N > 3 then capacity increases

1	2	3	1	2	3	…

Channel allocation

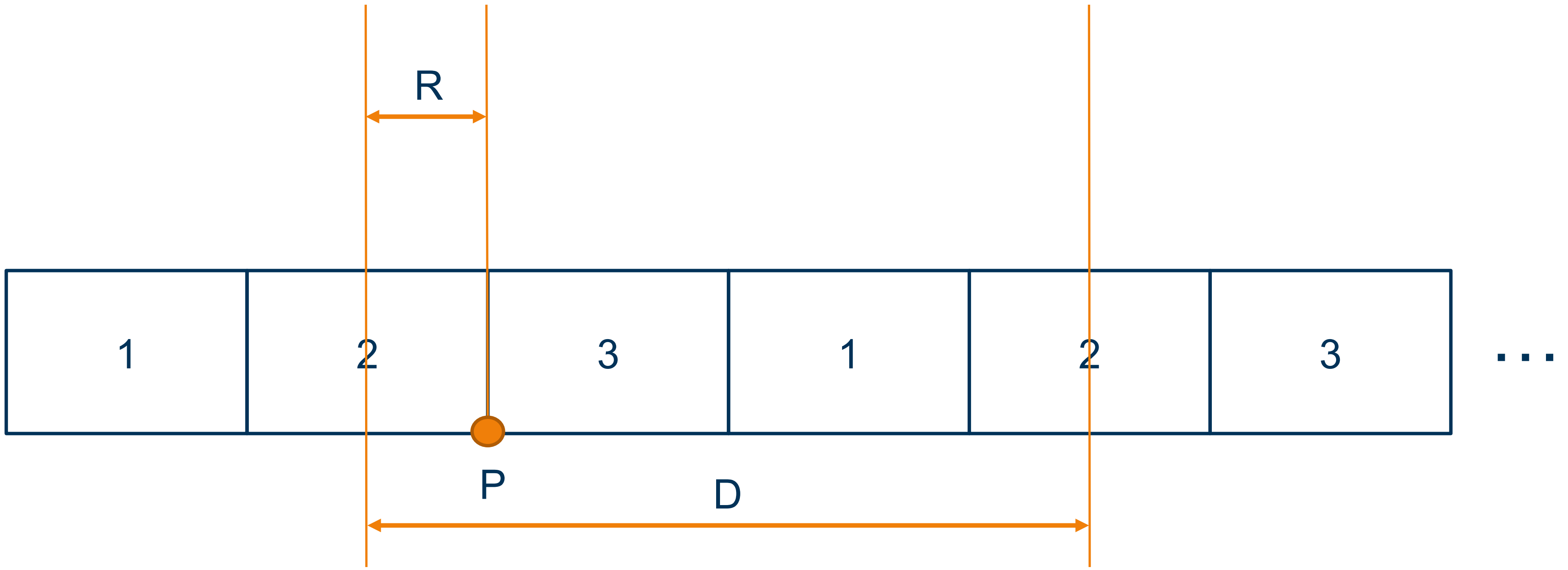
- Channel allocation:
  - Inter-channel interference: from cells assigned same frequency
  - The assignments must be spaced far enough apart geographically to keep interference to tolerable levels.
  - Tolerable interference: Signal to Interference Ratio (SIR)/Carrier to Interference Ration (CIR)

$$SIR > SIR_{threshold}$$

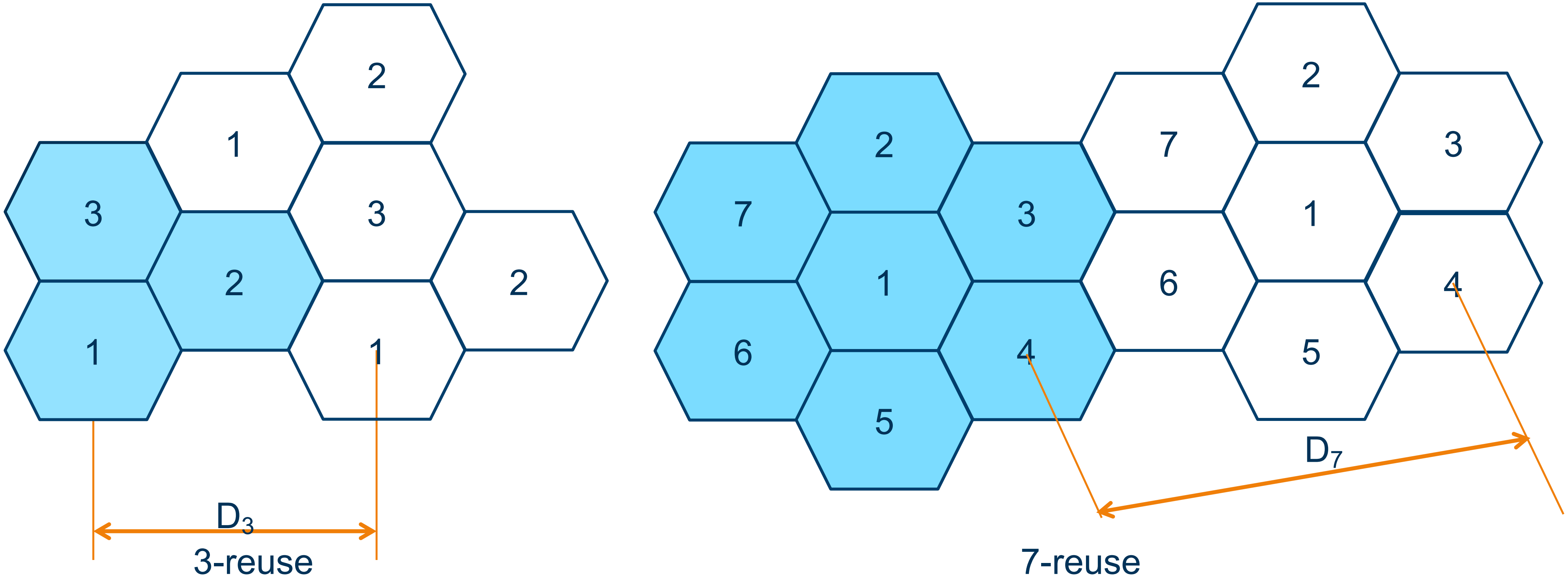


- SIR Calculation:
  - 1-Dimensional cell cluster:
    - Average receive power: $P_r = P_t . d^{-n}$
    - d_i: distance from point P to inference source

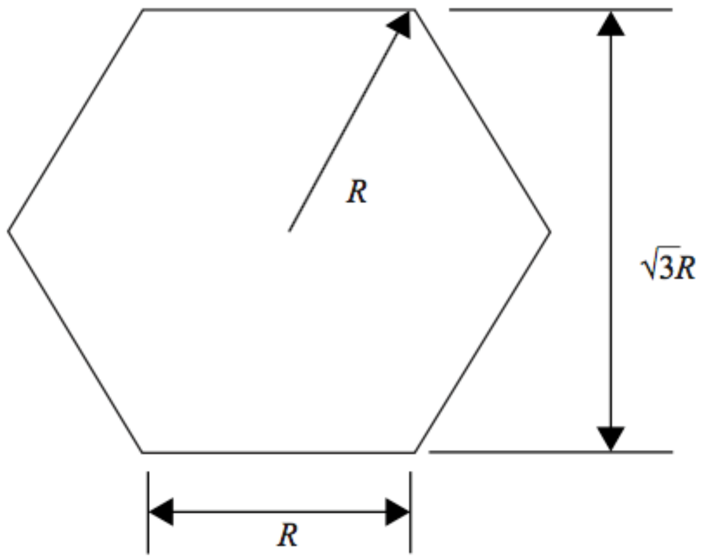
$$SIR = \frac{P_{r,\text{signal}}}{P_{\text{r,interference}}} = \frac{P_t . R^{-n}}{\sum P_t d_i^{-n}} \longrightarrow SIR(\mathrm{D},\mathrm{R}) = ?$$



- 2-Dimensional cell clusters:
  - Cluster size: Number of cells in a cluster, C
  - Distance between two closest interfering cells: D

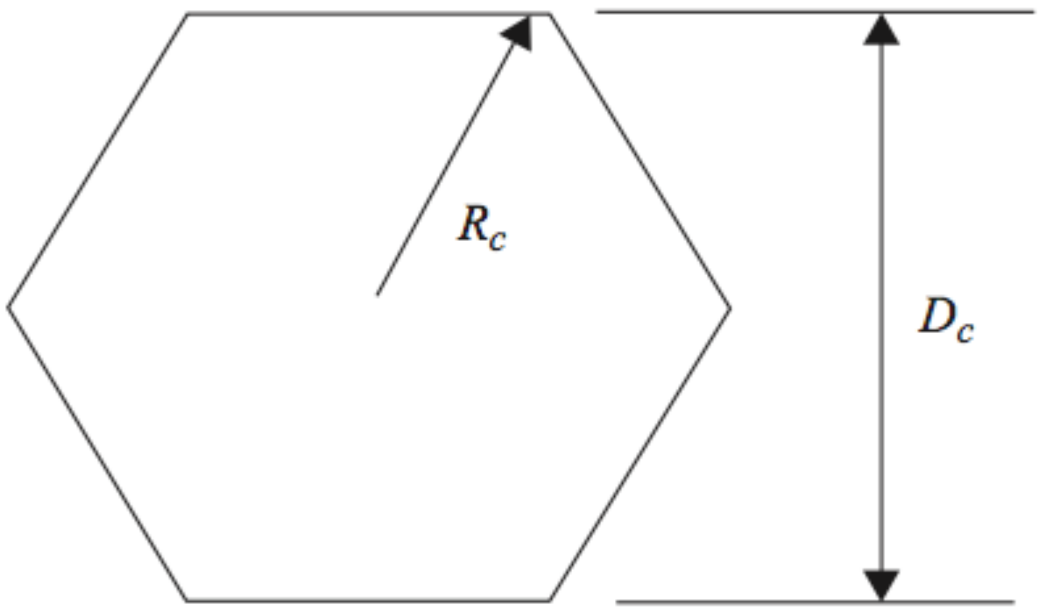


$$C = i^2 + j^2 + ij \quad i, j = 0,1,2 \ldots$$



Hexagon:

$$a = \frac{3\sqrt{3}R^2}{2}$$

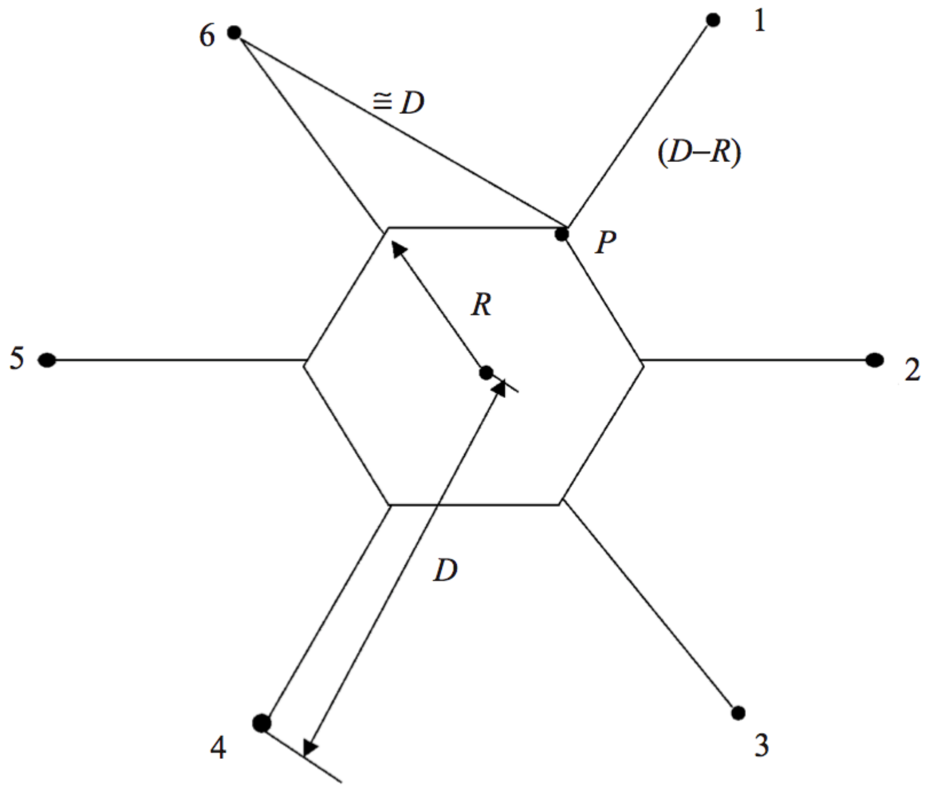


Larger hexagon: covers C smaller hexagon

$$C = \frac{A_C}{a}$$

$$D = \sqrt{3C}R$$

- SIR at point P:



Six first-tier interferences, approximate location

$$SIR \approx \frac{1}{\left(\frac{D}{R}-1\right)^{-n}+\left(\frac{D}{R}+1\right)^{-n}+4.\left(\frac{D}{R}\right)^{-n}}$$

Exercise 1.1

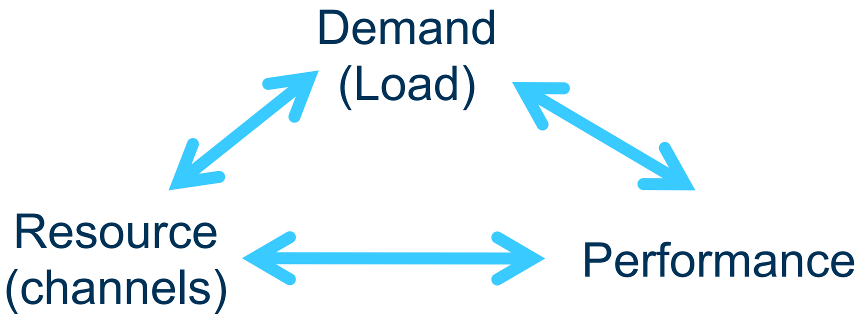
- Calculate down-link SIR at point P in 3-reuse case. Assume the simplest path-loss model $g(d) = 1/d^3$

- Repeat with 7-reuse case

Exercise 1.2

- Calculate the worst-case uplink SIR assuming the co-channel interference is caused only by the closest interfering mobiles in radio cells a distance $D = 3.46\,R$ away from the cell. Assume the simplest path-loss model $g(d) = 1/d^4$

- Traffic handling capacity:
  - Problem statement:



  - Probability of call blocking (Erlang-B formula):
    - Assumption:
      - Arrive calls obeys a Poisson distribution with arrival rate λ (calls/s)
      - Call lengths have exponential distribution with average value $\frac{1}{\mu}$(s)
      - Traffic density (Load) A : average number of call attempts per time unit
      - Number of available channels: N

$$A = \frac{\lambda}{\mu}$$

$$P_B = \frac{A^N/N!}{\sum_{n=0}^{N} A^n/n}$$

- Sizing a cell:
  - Problem:

A large cell (a given area)

$P_b, N, C,$

Mobile density

→ Applying cellular concept

$R = ?$

Example:

- 832 frequency channels and C = 7 reuse
- $P_B \leq 1\%$
- A typical user makes 200-second-long calls once every 15 minutes on the average
- Assume that users are uniformly distributed over the cell. In a rural region, the density of mobile terminals is two terminals per km2.
- Cell radius R =?

Probabilistic signal calculation

- Probabilistic signal calculations:
  - Considering fading in above calculations

- Power control on uplink:
  - Why need to control power of mobile terminals:
    - Keep $SIR > SIR_{threshold}$
  - How?
    - SIR is measured at BS for each mobile
    - BS sends power control message to mobiles in its cell
    - Mobiles adjust its transmitted power
  - Strategies:
    - Distributed balancing algorithm (DBA):
      - Adjusting provided that SIR meets maximum achievable SIR for all mobiles γ^*

$$\gamma^* = \max(\min \gamma_i)$$

    - Distributed power control algorithm (DPC)
      - Adjusting until $\gamma_i = \gamma^*_{max}$ (be defined by Meyerhoff power balance algorithm)