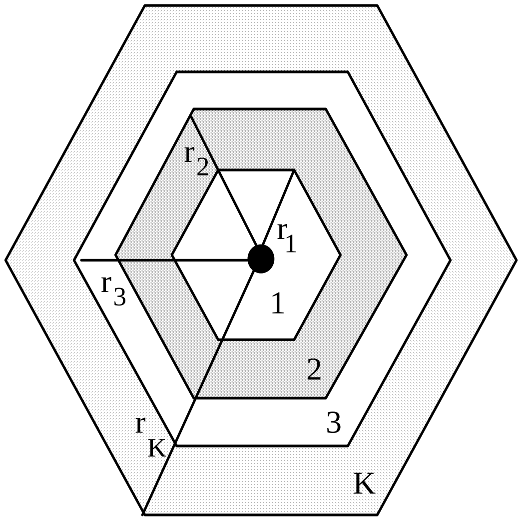
Advanced topics in radio resource management



Advanced topics in radio resource management

- Dynamic / Adaptive Channel Allocation
- Random Channel Allocation
- Discontinuous transmission (DTX)

Static (Fixed) channel allocation

- Limited knowledge about actual, instantaneous traffic situations and propagation conditions
  - Low resource utilization
  - Calls might be blocked even if there are channels available in adjacent cells!

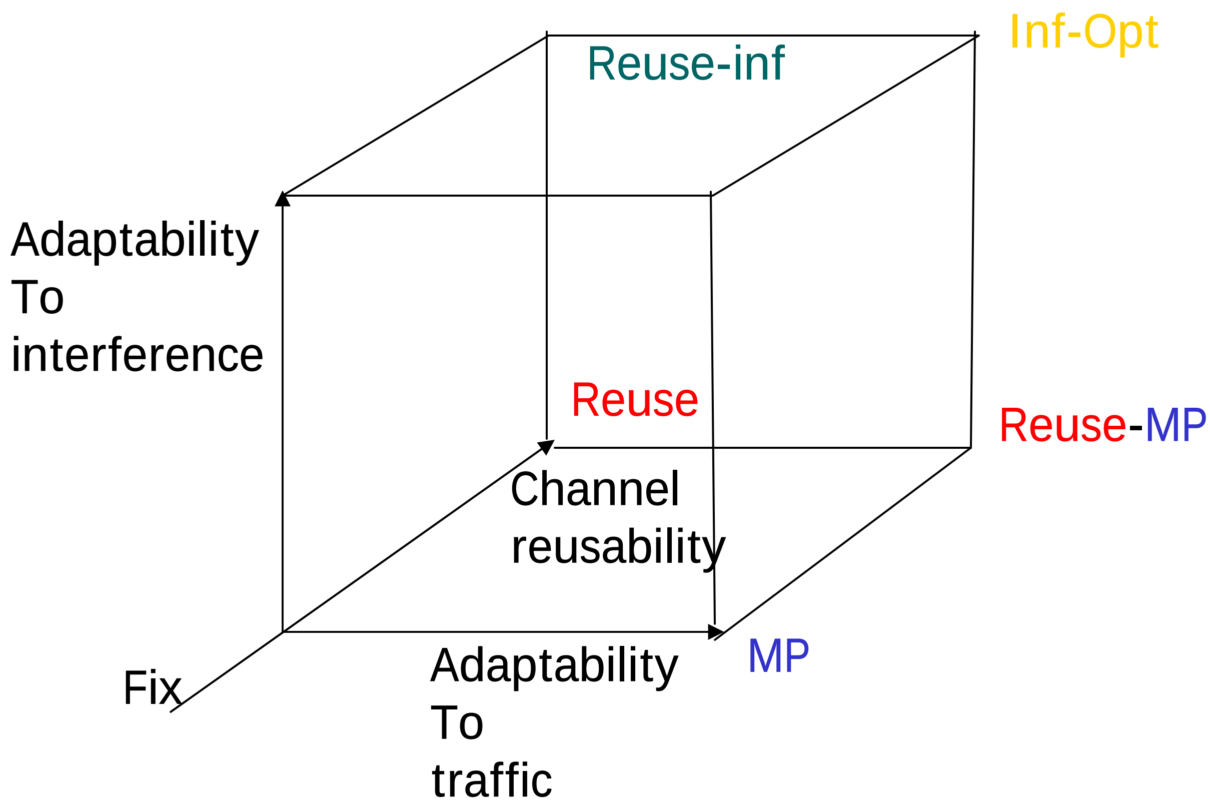
Static (Fixed) channel allocation

- FCA is based on measurements and predications of the average traffic load resulting
  - In an irregular cell area coverage
  - Different number of channels assignment for every cell
  - Much better resource utilization
  - However, it still has its limitations

Proposed solution!

- Adaptive/dynamic channel assignment
- Channels are placed in common pool and dynamically assigned based on the traffic and interference situation
- From teletraffic point of view:
  - FCA behaves like a small group of servers
  - DCA behaves like a large server → higher utilization

Dynamic Channel Allocation schemes



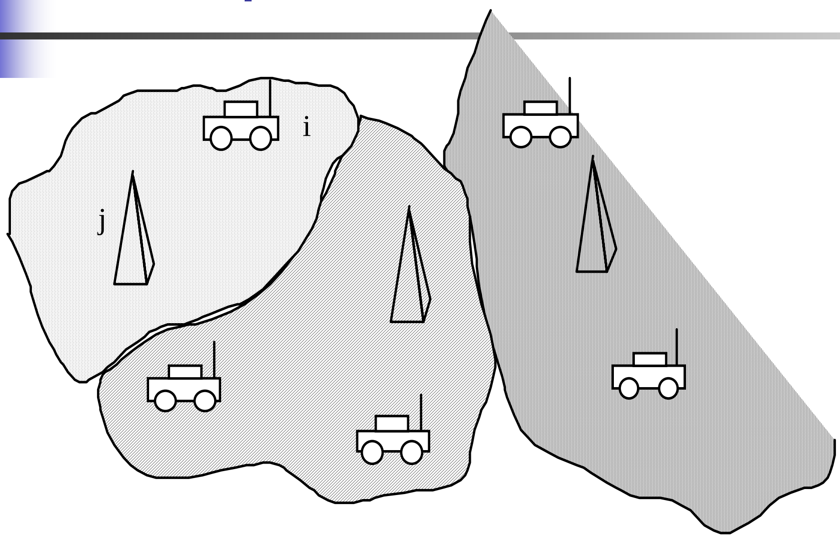
Available information

- Number of active users in the whole system (MP)
- Received signal strength (reuse)
- Background noise and interference
- Possible assignment could fall anywhere in the cube
- The best is located at Inf-Opt

Dynamic channel allocation

- Input measurements:
  - Traffic adaptive assignment
  - Signal Strength adaptation (Reuse Partitioning)
  - Interference adaptive assignment
- Adaptively
  - Preplanning / Learning / Real-time

Traffic adaptive schemes- the compatibility concept



$$C = \begin{pmatrix} C_{11} & C_{12} & .. & .. & C_{1K} \\ C_{21} & C_{22} & .. & .. & C_{2K} \\ .. & .. & .. & .. & .. \\ C_{K1} & .. & .. & .. & C_{KK} \end{pmatrix}$$

$C_{ij} = 1$: reuse feasible

- Graph theoretic problem
- Marginal gains at moderate/high loads
- Require large fade margins

Examples of traffic adaptive schemes

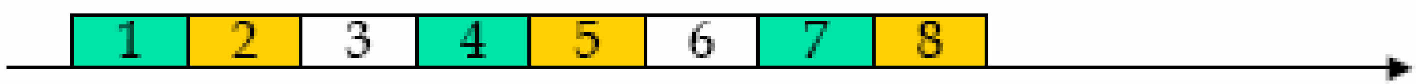
- Limited adaptively
  - Channel borrowing
  - Load sharing
- Full adaptively
  - “Maximum” packing

Traffic adaptive DCA - linear program formulation(1-D case)

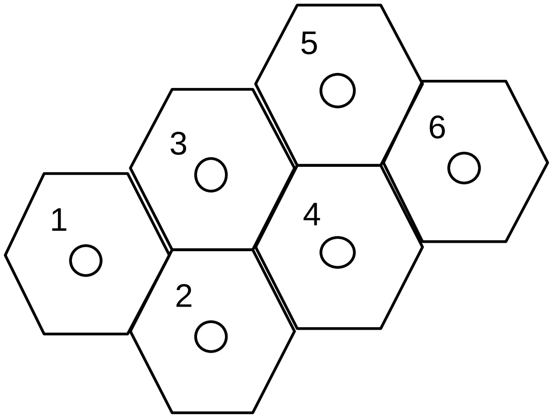
T_i = # assigned mobiles in cell i

$$\max \sum T_i$$

$$\sum_{i<j} I_{ij} T_i < C+1$$



Traffic Adaptive Scheme -Example



- C = 18
- M == { M_i } = { 7,6,2,4,8,6 }

Example: Incompatibility Matrix

$$I = \begin{pmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 \end{pmatrix}$$

Example: Static assignment

η = C/K = 18/3 = 6 channels/cell

Z= {1 0 0 0 2 0 }

$Z = \sum Z_i = 3$

The ”Greedy algorithm”

The Greedy - algorithm [2]

1) $A_1 = \min(M_1, C)$

……

i) $Y_i = C - \sum_{j=1}^{i-1} I_{ij} A_j$ $1 < i <= B$

$A_i = \min(M_i, Y_i)$

?

- This algorithm can be used if the compatibility matrix exhibits a band structure.
- B is the number of RAP

Greedy Algorithm:Example

M = { 7,6,2,4,8,6 }

1) **A =** {7, 0, 0, 0, 0, 0 }

2) Y_2 = 18-7 = 11
   A = {7, 6, 0, 0, 0, 0 }

3) Y_3 = 18-(7+6) = 5
   A = {7, 6, 2, 0, 0, 0 }

4) Y_4 = 18-(0+6+2) = 10
   A = {7, 6, 2, 4, 0, 0 }

6) Y_5 = 10 - 4 + 6 = 12
   A = {7, 6, 2, 4, 8, 0 }

7) Y_6 = 12 - 8 + 2 = 6
   A = {7, 6, 2, 4, 8, 6 }

Z = 0

All mobiles successfully assigned!

Observations:

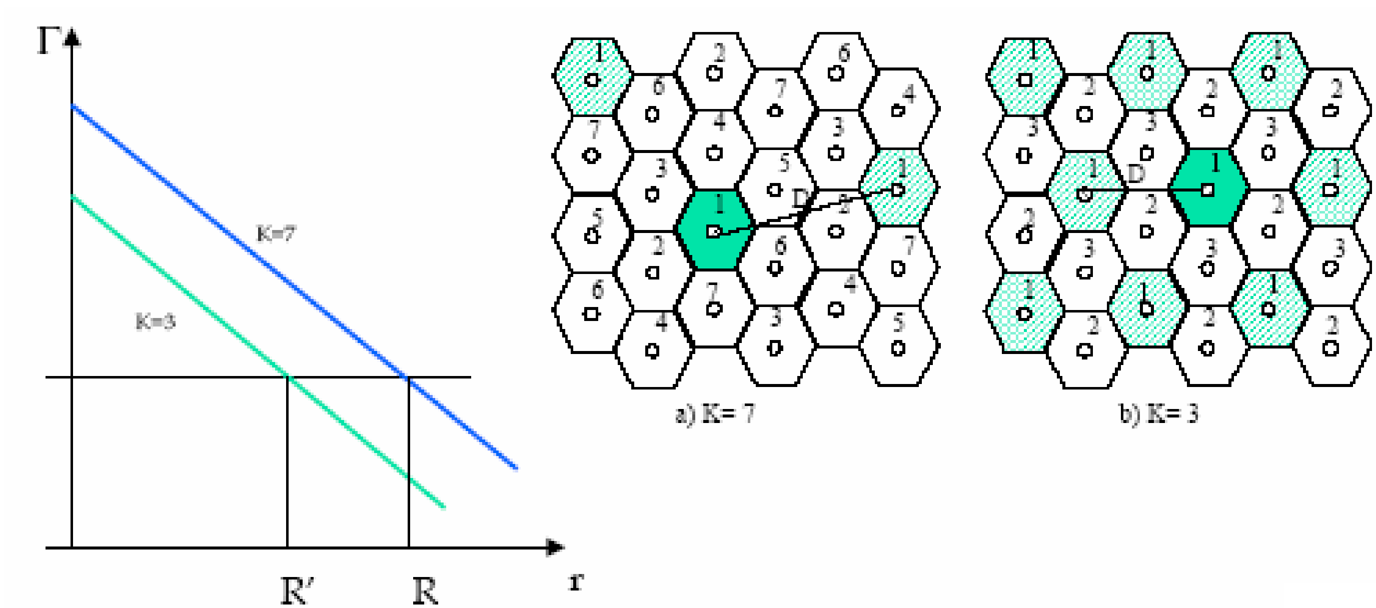
- Optimal DCA is highly complex
- Adaptive (heuristic) algorithms are very effective when the traffic fluctuations are very large compared to the number of available channels
  - For low and moderate traffic load DCA shows 30-50% capacity gain
  - For heavy traffic, the relative improvement is reduced
- Average reuse distance is greater than that in FCA

Observations (cont.):

- Compatibility matrix is based on worst case calculations (mobile position, propagation phenomena, interference, etc.)
- Then, such design needs large margin regarding reuse distance and will likely be inefficient

Signal strength based allocation

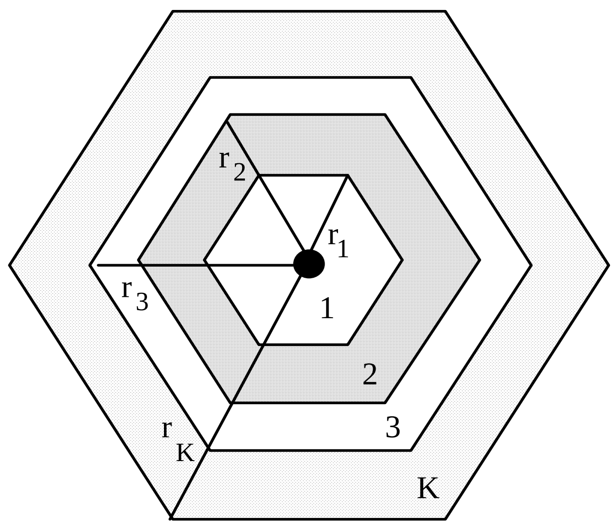
- SIR (Γ) drops as the cell boundary is approached
- Terminals in the interior of the cell would tolerate a lower reuse distance
- Several overlaid cell plans with different reuse distances are combined



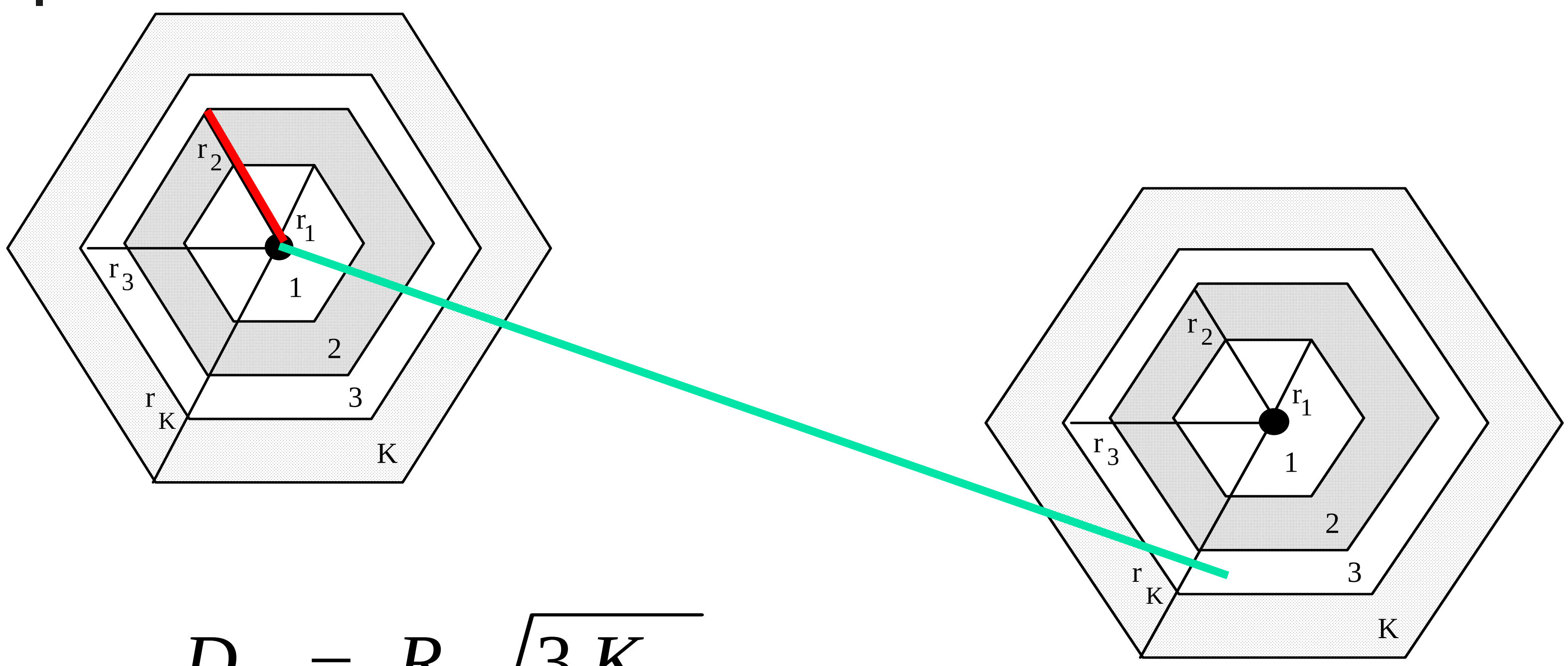
Reuse partitioning

- Overlaid cell plans with different reuse distances
- Chose channel based on signal strength
- Mobiles with high RSS may use poor (high interference) channels
- L clusters with size K_i

$$K_1 < K_2 < \ldots < K_L$$



Reuse partitioning (Cont.)



$$D_i = R\sqrt{3K_i}$$

Reuse partitioning - simple analysis

- Neglect the fading phenomena
- Assume high load

$$\Gamma^{U}(r) \approx \frac{1}{7}\frac{D^{\alpha}}{r^{\alpha}} = \frac{9}{7}\frac{R^{\alpha}}{r^{\alpha}} K_i^2 \geq \gamma_0$$

- For $\alpha = 4$

$$r < R\left(\frac{9}{7\gamma_o}\right)^{1/4}\sqrt{K_i} = r_i$$

- A terminal in zone *i* may use a cell plan with cluster size K_i or larger.

Reuse partitioning – channel assignment

- Define a capacity allocation vector, c_i is the number of channel assigned to cell plan *i*

$$\mathrm{c} = (c_1, c_2, \cdots, c_L)$$

- Define the available channels constraint C

$$\sum_{i=1}^{L} c_i K_i \leq C$$

- The total number of channels available in a cell is given by $c_o = \sum_{i=1}^{L} c_i$

Observations

- Only the terminals in the center will have access to all these c_o
- Terminals on the perimeter are limited to the c_L channels of the outermost zone
- RP effectively splits the existing cell pattern into smaller zones
- Average number of channels available for mobile will increase
  - Relative traffic variation will increase
  - Under high load, the failure assignment is lower that FCA
  - But under low load, the result is worse
- Obtaining an optimal **c** for lowest assignment failure rate is a tedious optimization problem

Observations (Cont.)

- To obtain a good performance, it is necessary to combine RP with a traffic adaptive scheme
- Borrowing channels from zones of higher indices

Optimal RP channel allocation

- Assume **c** = $(c_1, c_2, \ldots, c_L)$ assignment is made
- For a given pattern of traffic $M' = \{M_i\}$
  - Assign min(M1, c1) channels from cell plan 1 to terminals in zone 1.
  - Let Z1 = max(0, M1 - c1) is the excess calls and add Z1 to the next zone.
    - (i) Assign min(Mi+Z_{i-1} , ci) channels from cell plan i to terminals in zone i or zones with a lower index (excess from zone i-1). Let Zi =max(0, Mi+Z_{i-1} - ci).
    - L) Assign min(ML, cL) channels from cell plan L to terminals in zone L.

      Z = ZL =max(0, ML+Z_{L-1} - cL).

Reuse partitioning - performance

- If M_i exceeds c_i ,the algorithm lets these calls (overflow) to the zones outside zone i.
- To evaluate the assignment failure rate υ, we need to evaluate the probability distribution of the excess calls; Z_i

$$\Pr[Z_i = z|c] = \begin{cases} \sum_{j=0}^{c_i} \Pr[M_i \le c_i - j]\Pr[Z_{i-1} = j|c], z = 0 \\ \sum_{j=0}^{z+c_i} \Pr[M_i = c_i + z - j]\Pr[Z_{i-1} = j|c], z > 0 \end{cases}$$

$$\upsilon(c) = \frac{1}{\lambda}\sum_{j=1}^{\infty} j \Pr[Z_i = j|c]$$

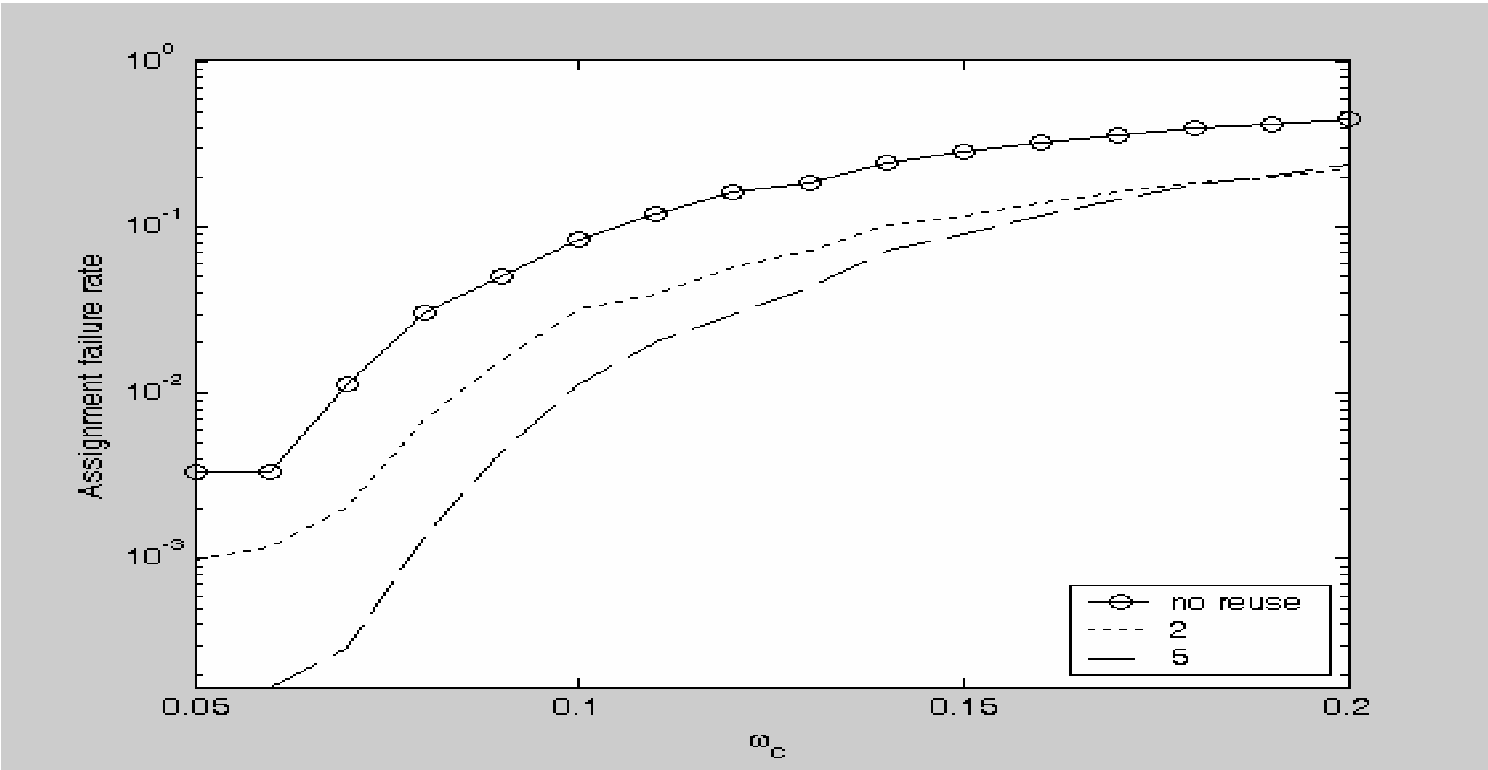
Reuse partitioning – performance (cont.)

- The global optimum can be obtained by minimizing υ(c)
- The minimizing vector c can be found by exhaustive search over all possible vector satisfying

$$\sum_{i=1}^{L} c_i K_i \leq C$$

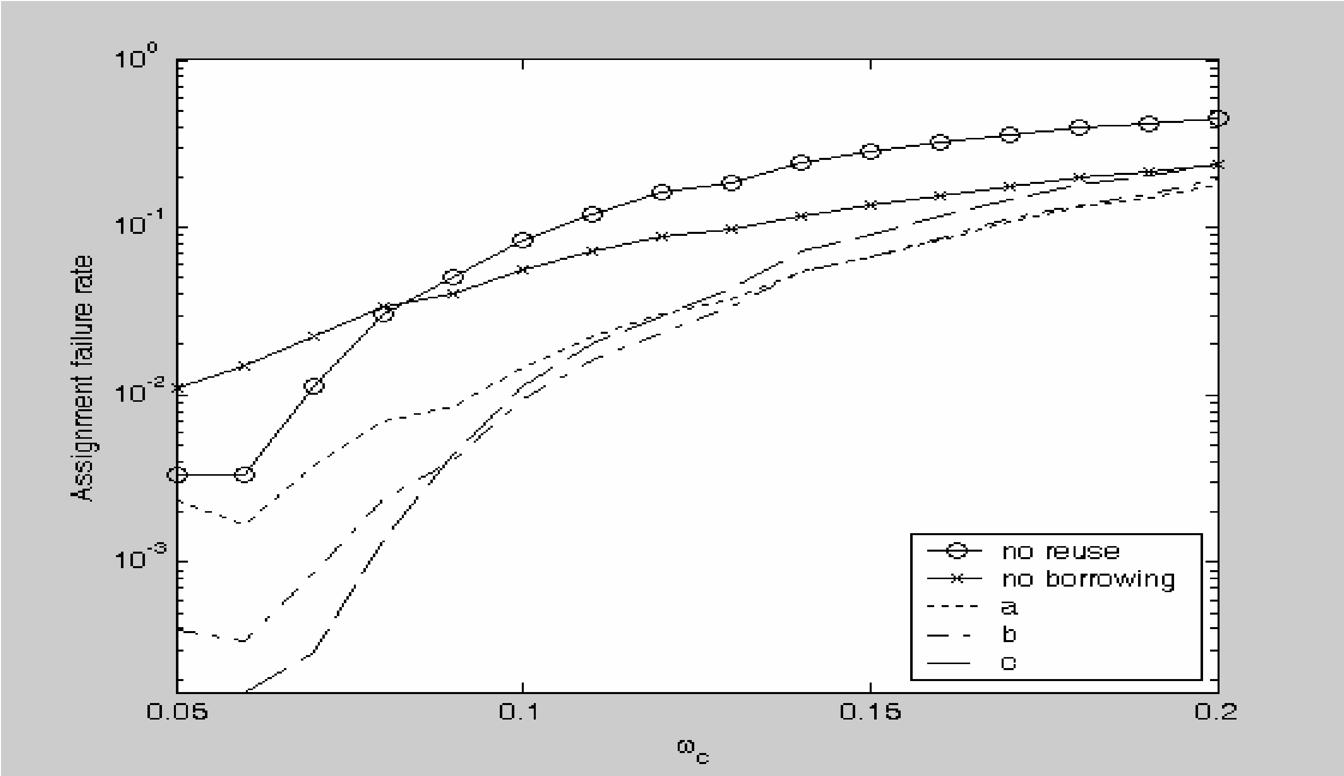
Reuse partitioning - performance

- C = 100 channels
- Gains of 50 -100% in capacity
- Most gain achieved by going from one to two “zones”

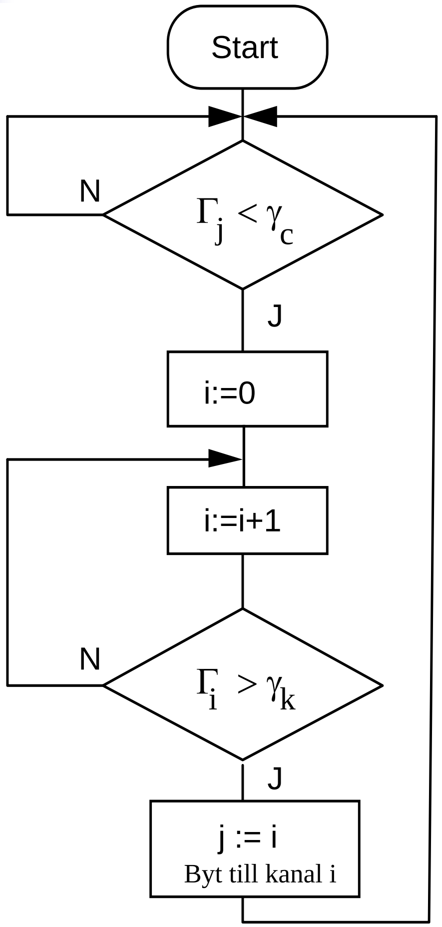


Reuse partitioning - capacity allocation

- C = 100 channels
- Borrowing important
- No capacity allocation optimal for all loads



Interference based DCA

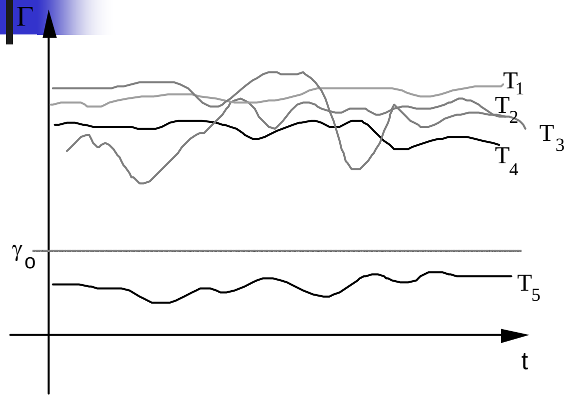


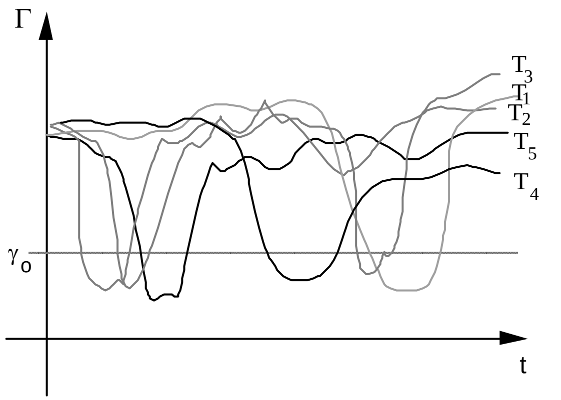
- Ad-hoc schemes
- Rapid channel selection (reassignment) based on simple interference measurement
- Performance gains 50-100%
- No (?) stability problems

Examples of interference based schemes

- Real time schemes
  - DECT
- Learning schemes
  - Channel segregation

Random Channel Allocation





- Average interference over time
- Use error control coding to lower outage probability
- Anything that can be done to reduce the average interference enhances capacity
- Trunking efficiency