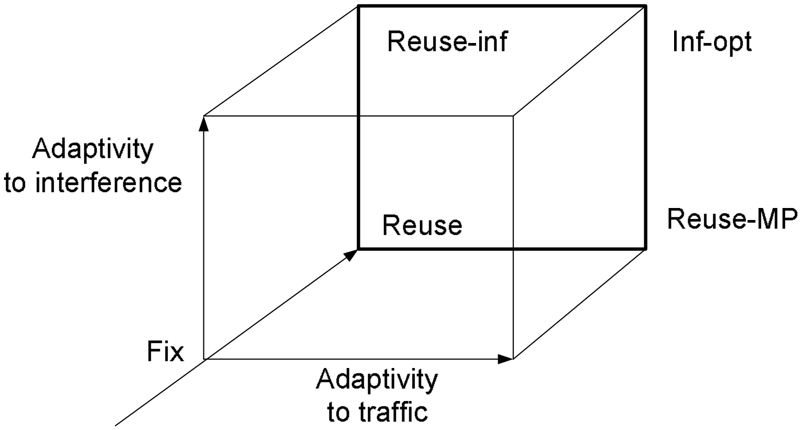
Dynamic Channel Allocation

- The network load fluctuates
  - Channel conditions vary
  - Number of active terminals changes
  - Interference level changes
- Design margins have to be added for guaranteeing low interference ratio
  - Low number of channels in each cell
  - Fixed Channel allocation leads to low utilization
    - problem severe when there are few channels per BS
- The margins are needed since the knowledge of the load at every time moment is limited
- With more sophisticated interference prediction tools better allocation possible
  - Preliminary measurements
  - Interference estimation based on particular terrain
- The allocation still based on average traffic load and average propagation conditions

Dynamic Channel Allocation

- Channel allocation based on real time measurements
  - All the channels in a common pool
  - Channels allocated based on the situation in the network
- Teletraffic point of view
- FCA operates as a set of small servers
- DCA as a big pool of servers

Classification of DCA algorithms



- Fix – FCA
- Inf-opt - optimal usage of information
- Corners use knowledge:
  - MP - number of active users in every cell
  - Reuse - power level of users
  - Interference (background noise) measurements

- Centralized DCA
  - Needed for estimating the optimal values that are used for comparing performance of practical algorithms
  - Uses global knowledge for allocating resources in the whole network
  - Impractical due to the high signaling demand and algorithm complexity
- Distributed DCA
  - Relies on the locally available information

Comparison FCA versus DCA

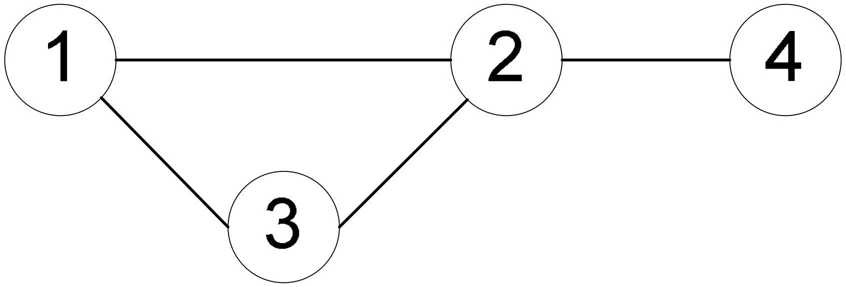
- FCA - Blocking rate similar to dropping rate during handovers
  - DCA has higher call blocking at medium and high load in the network
- FCA - Forced call termination
  - DCA the same channel can be reused in the next cell
- DCA requires for each BS to be able to transmit at all possible channels

Traffic adaptive channel allocation

- The channels are allocated in accordance to the current (measured) cell loading
- Channels are not allocated in advance but based on the measurements
- Interference analysis methods are similar to the ones in FCA
- Worst-case design
  - The propagation conditions are described and estimated based on the cells compatibility

Cell compatibility

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



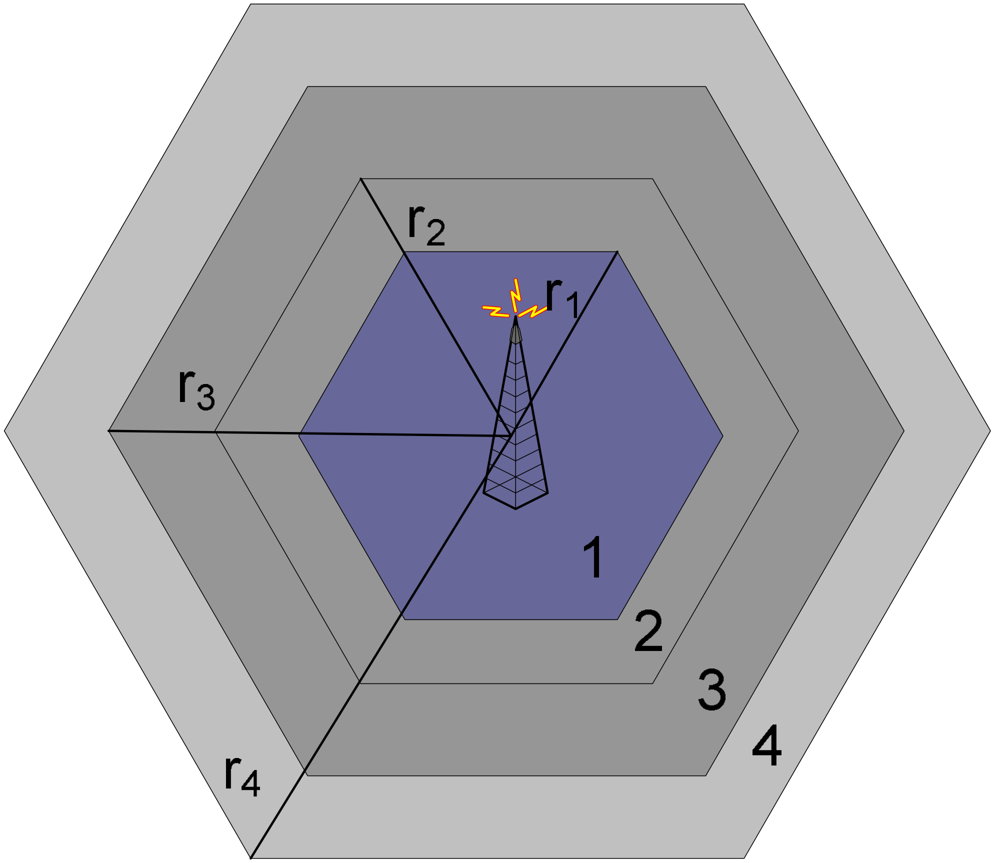
- **I** the compatibility matrix
- If two cells are compatible they can not use the same channel
- To allocate all the channels based on compatibility is very complex

Maximum Packing (MP) scheme

- New call is blocked only if there is no possible channel allocation (no possible combination of allocated channels).
- MP calculates the minimum number of channels for serving instantaneous demand while satisfying compatibility constraint.
- MP can be interpreted as A graph coloring scheme
  - Maximize the number of colors each cell can have such that the neighboring cells do not have same colors
- Optimum algorithm is NP-complete
  - No good algorithm exist

Reuse Partitioning

- Pure traffic adaptive scheme assumes worst-case propagation situation
- RP adapts to the propagation conditions
- Instead of using single cell plan several overlapped cells with different reuse distances are used.
  - Terminals close to BS select the channel from the set with short reuse distance
  - Terminals close to the cell border select channel with large reuse distance
- If the frequency is used only near to the BS the reuse distance can be reduced


r2
r1
r3
1
2
3
4
r4

- Cell is split into L areas – K_l cluster sizes

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

- A cell plan with K_i has to be used for terminals up to the distance r from the cell center.
- A cell plan with K_i channel groups has reuse distance $D_i = R\sqrt{3K_i}$
- The signal power is $\Gamma^u\left(r\right) = \dfrac{D^4}{7r^4} = \dfrac{9R^4}{7r^4}K_i^2$

$$\Gamma^u\left(r\right) > \gamma$$

- The cell plan K_i can use with all terminals up to distance

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

- Capacity allocation vector
- Total number of channels limits the choice of the allocation vector
- The total number of channels available in the cell

Summary of RP

- RP is splitting the cell pattern into smaller areas
- Only terminals near to BS can use all the channels
- The average number of channels available to the terminal is increased
- Number of terminals competing for particular set of channels is decreased, that increase relative traffic variation
- Good performance at high traffic load
  - Lower assignment failure than in FCA
- For low traffic load the traffic variation and the performance of RP DCA is worse than FCA
- Good performance requires RP combination with traffic adaptive scheme
  - Channels should be possible to be borrowed from other zones

Optimal RP algorithm [Zander and Frodigh]

M_i describes the number of active terminals in zone i

- Assign $min(M_1, c_1)$ channels from the cell plan 1 to terminals in zone 1. $Z_1=max(0,M_1-c_1)$
- Assign $min(M_i+Z_{i-1},c_i)$ channels from the plan i to terminals in zone i or zones with lower index.

$$Z_i = max(0,M_i + Z_{i-1}-c_i)$$

- Assign $min(M_L+Z_{L-1}, c_L)$ channels from the plan L to terminals in zone L.

$$Z=Z_L=max(0,M_L+Z_{L-1}-c_L)$$

The vector Z_i describes how many channels have to be borrowed from zones with higher index

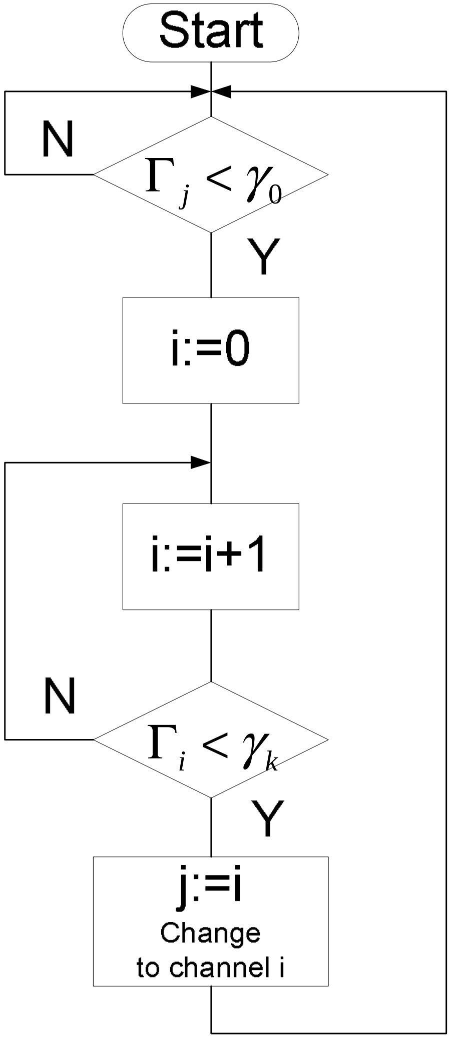
The total number of assignment failures is the demand for additional channels in last zone Z_L

- Figure 7.7

Interference-based DCA schemes

- Traffic adaptive RP based on conservative estimates of propagation and interference
- Not knowing the attenuation powers α requires reservation of larger interference margins
- It is better to use actual measured interference levels not the averaged estimates.
- Measurement based approach is implemented in real life systems

Measurement based scheme



- The SIR is continuously compared with the threshold
- If the SIR is below the threshold a new channel is searched for

- The algorithms becomes very sensitive for the threshold level and can change channels very often

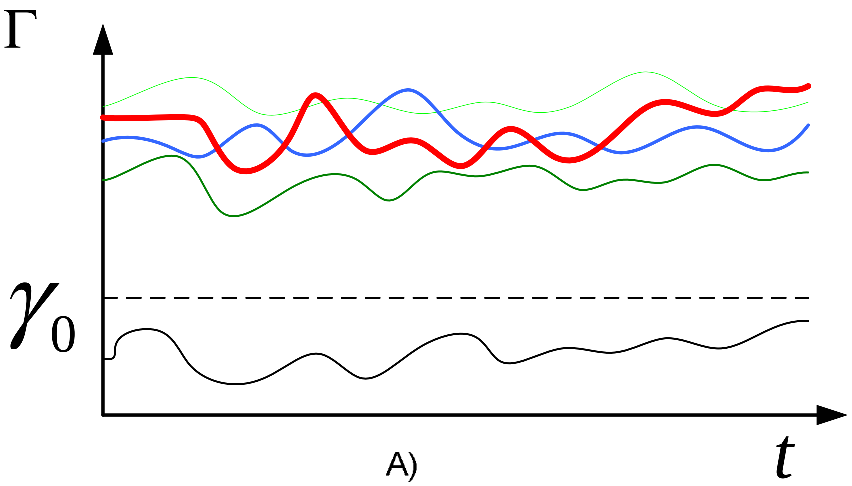
Orthogonal frequency hopping

Random channel allocation

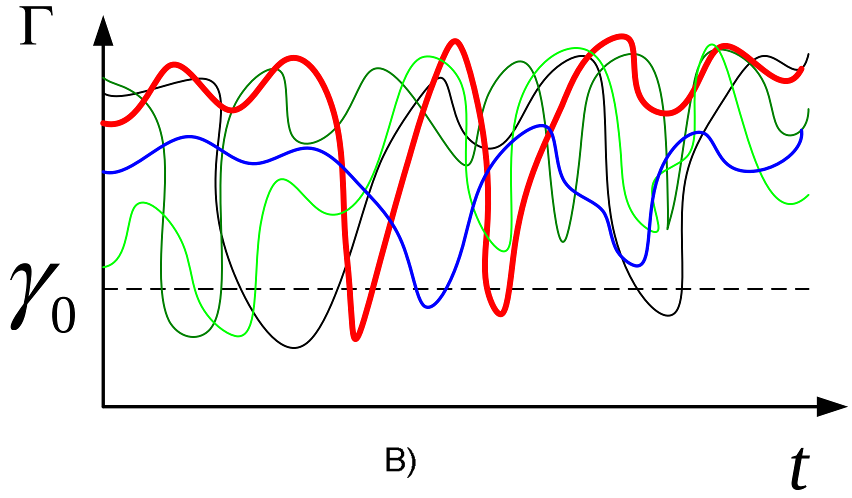
- Frequency hopping (FH) intends to introduce frequency diversity
- Can also be used for protecting against interference
  - Very effective in combination with error correction schemes
- Orthogonal frequency hopping can also be interpreted as a channel allocation scheme
  - Channel allocation is changed accordingly to hopping sequence

- Connection between assignment failure rate and the interference rate
  - Tradeoff between the number of available channels and interference level
- The lack of channels worse issue than decreased quality
  - To reduce blocking probability increase the amount of channels per BS (reduce reuse distance)
  - For avoiding interference
    - Better coding schemes
    - Better modulation schemes

Typical interference environment



A)



B)

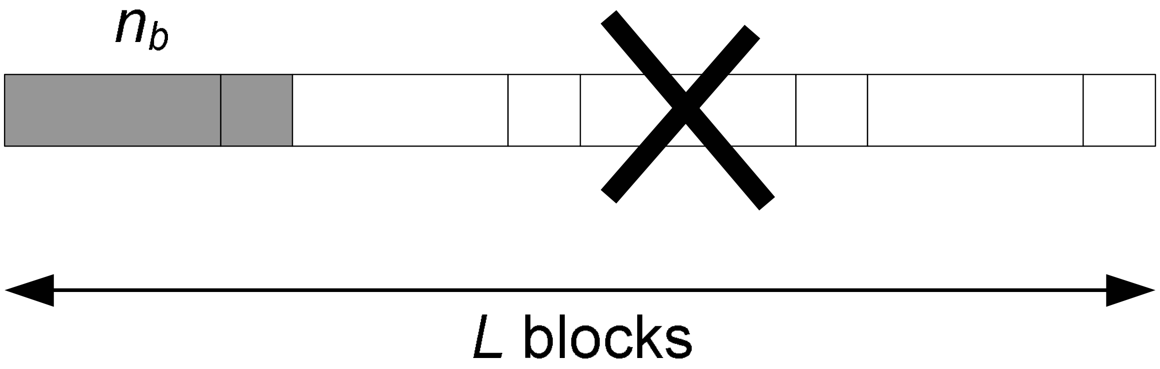
- The outage rate is the same
- Fast moving users (B)
  - Outage is distributed among the users.
  - If the user moves fast enough the bad channel state can be corrected by error correction coding.

- The diversity better for higher mobile speed
- The mobility of the terminals can not be controlled
- Mobility can be mimicked -> change frequencies
  - Random channel allocation
- Interference is different at different frequencies
- By changing the channels the average outage probability is not impacted
  - Average outage probability – probability that a randomly selected terminal is in outage
- The frequency hopping itself does not improve the performance of the system
- The interference situation becomes easier to handle
  - The severe interference environment last shorter time
  - Lost bits can be corrected by error correction

- Purpose of changing channels among the users is to distribute the channel conditions among the users
  - At each channel different interference condition
- In narrowband FDMA changing channels corresponds to a frequency hopping system
  - Good in frequency selective channel
- Any permutation of the orthogonal waveforms have the same property
  - Permutation of timeslots in TDMA
  - Permutation of spreading codes in CDMA

- Can be used with static channel allocation
- Channels collected into groups.
- The time interval when the terminal uses some particular channel is called *chip*
- All the terminals change the channels synchronously at the same time.
  - Helps to maintain orthogonality among the users in the same cell
- The hop rate can not be very high
  - Difficult to maintain synchronism between the terminal and BS
  - Slow frequency hopping

Error control scheme in FH system



- The data is spread over multiple blocks L
- Each block has n_b coded bits
- The blocks are transmitted in different frequencies
- Each block can be lost due to the bad channel
- If outage probability is χ in average χL blocks are in fades.
- Error correction should be able to correct at least all the bits in χL blocks.

Example

- A mobile system has C=100 channels (without coding). Coding rate is r =2/3. The block is correctly decoded when SIR > 9 dB
- The code is capable to detect all erroneous blocks with negligible amount of error detection bits.
- The channels are assigned randomly and interference among the users in the same cell is avoided.
- The propagation is distance dependent

  α= 4
  - Log-normal fading σ = 8 dB
- Estimate the capacity of the uplink and compare it with the static channel allocation with assignment failure better than 5%

- The C/I for some random terminal *i* in access port *j*

$$\Gamma_i = \frac{P_0}{\sum_k X_k P_k G_{kj} + N_0}$$

X_k is the binary activity vector

P_0 is the power control target at the receiver

- C/I can be assumed to be independent from *i* – same for all the terminals
- The total outage rate can be simulated as a function of load
- The coded system has $C\,r = 67$ channels available

- Figure 8.3

- Table 8.1

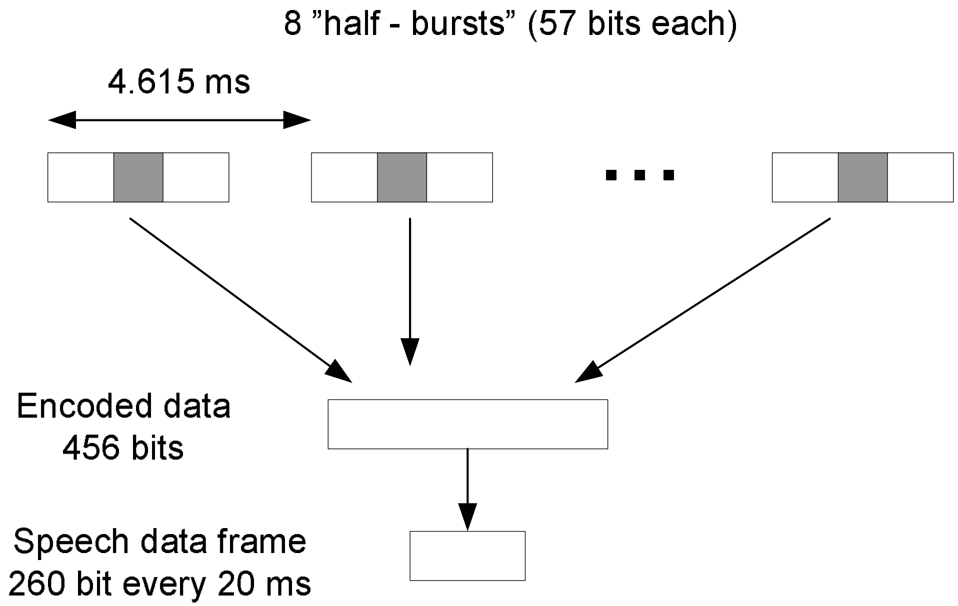
- The frequency hopping system works best with low system load and high number of channels
- The system becomes interference limited
- In downlink - the interference in next timeslot is difficult to estimate
    - Due to the hopping in each next interval interference generated from different set of users – no correlation

Slow frequency hopping

- The frequency hopping needs large code words.
- The number of blocs should be large
  - Easy to construct codes that can correct certain number of errors distributed randomly
    - Handled by interleavers
- The delay becomes a problem
  - If hop sequence is f_c frequencies L/f_c
- Tradeoff between the error control performance and delay.

FH in GSM

- One hop 4.615 ms -> 217 hops/s
- Hopping sequence of length 64 are specified
- If there are Q frequencies -> total 64Q sequences can be defined
- The hopping sequence is identified by two number
  - MAIO mobile allocation index offset
  - HSN hopping sequence number (one of 64 sequences)
  - HSN=0 cyclic hopping all the terminals have the same hopping pattern – same interference
- The speech coding scheme is theoretically capable to correct half of the frames.



- Speech coding is spread over 8 half bursts (57 bits)
- The code rate is 0.5
- Code can correct 2 bursts out of 8

FH performance in GSM

- Figure 8.5 – 8.7

Performance of the GSM frequency hopping system as a function of the number of frequencies