Dynamic Channel Allocation for Mobile Communication Networks

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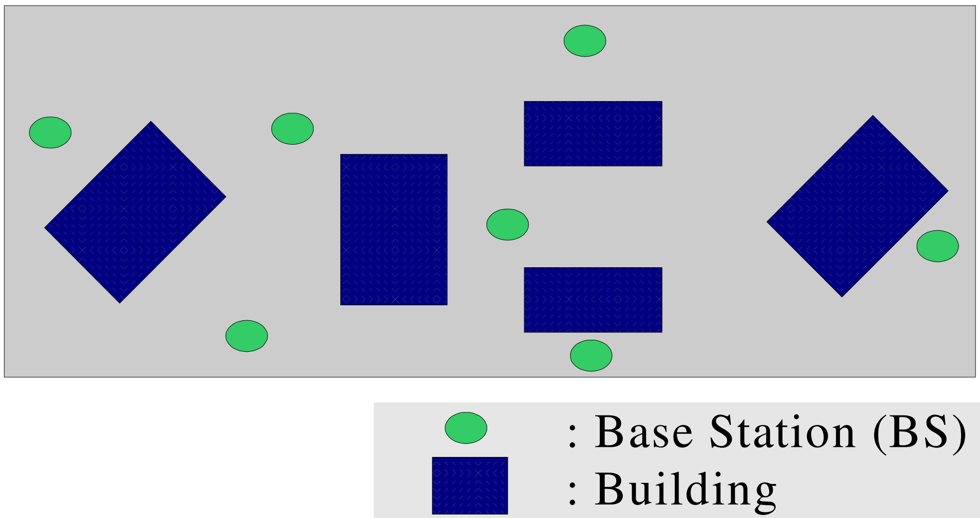
The Problem

- Allocation of frequencies to the Base Stations (BSs) in a given urban scenario (ns-2)



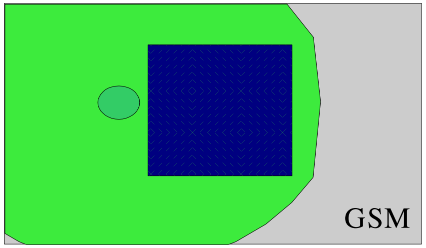
Characteristics:

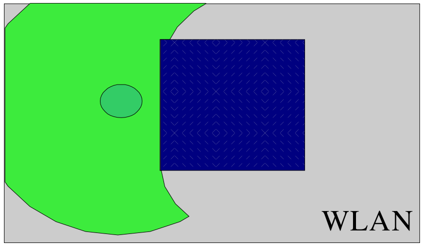
- Operating band of 5 Ghz
- High path loss
- High density BSs

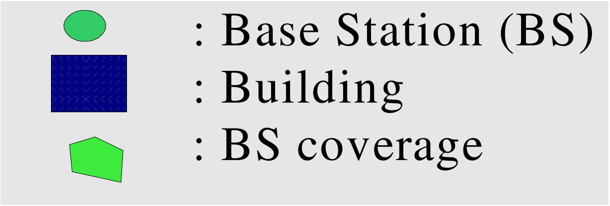
- The Challenge:
  - Examine existing solutions and algorithms
  - Implementation

Existing solutions for GSM and problems

- GSM vs. Wireless LAN (WLAN):



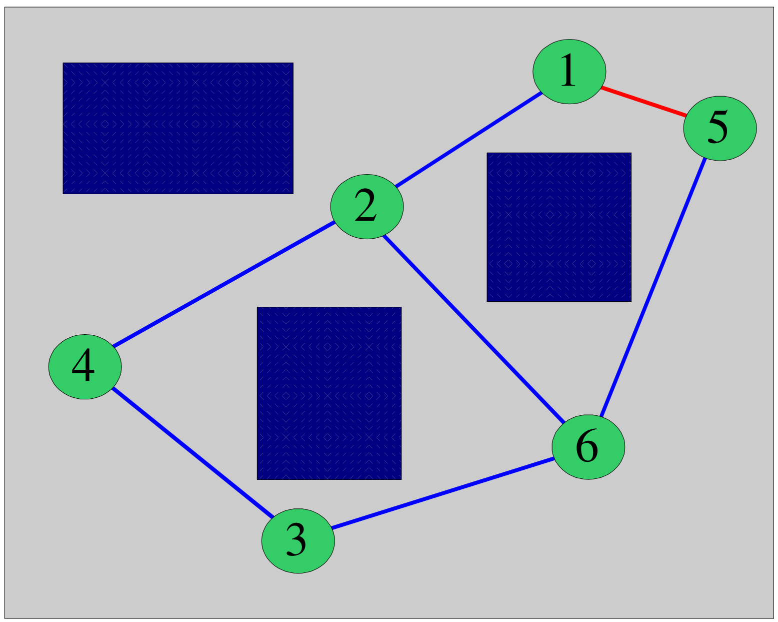




- GSM
  - Operating band of 800 Mhz, low path loss, virtually everywhere
  - The topology is usually modelled with *restricted* graphs: Trees, planar graphs, planar point graphs, disc graphs
  - Existing algorithms: performance guarantee of O(*p*), where *p* is the graph max degree
- WLAN
  - Operating band of 5GHz, much greater path loss, multihop
  - High density graph, O(*p*) is growing exponentially. New, more efficient algorithms needed, also without obstacle-free environment requirements

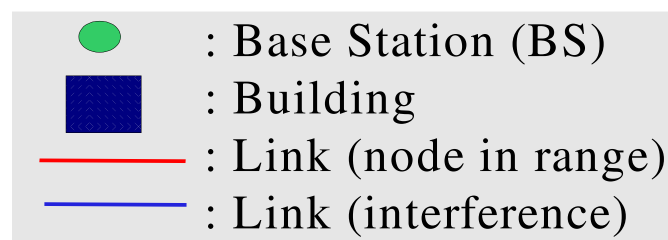
Data

- Available data:
  - Node distribution (BSs and users positions on the grid)
  - Calculated interference matrix
  - Calculated demand vector
    $D(D_1, D_2, \ldots, D_n)$



	1	2	3	4	5	6
1	0	1	0	0	2	0
2	1	0	0	1	0	1
3	0	0	0	1	0	1
4	0	1	1	0	0	0
5	2	0	0	0	0	1
6	0	1	1	0	1	0

Interference matrix, 6 BSs



Assignment strategies

- Centralized approach:
  - Central entity is present, as a master server
    + Expected higher spectral efficiency
    - Additional signaling overhead
    - Additional hardware expenses for backbone infrastructure
    - Computational complexity of the algorithm

- Decentralized approach:
  - No central entity present
    + Standalone BSs
    + No hardware expenses for backbone infrastructure
    + Algorithm is quite simple
    - Expected lower spectral efficiency

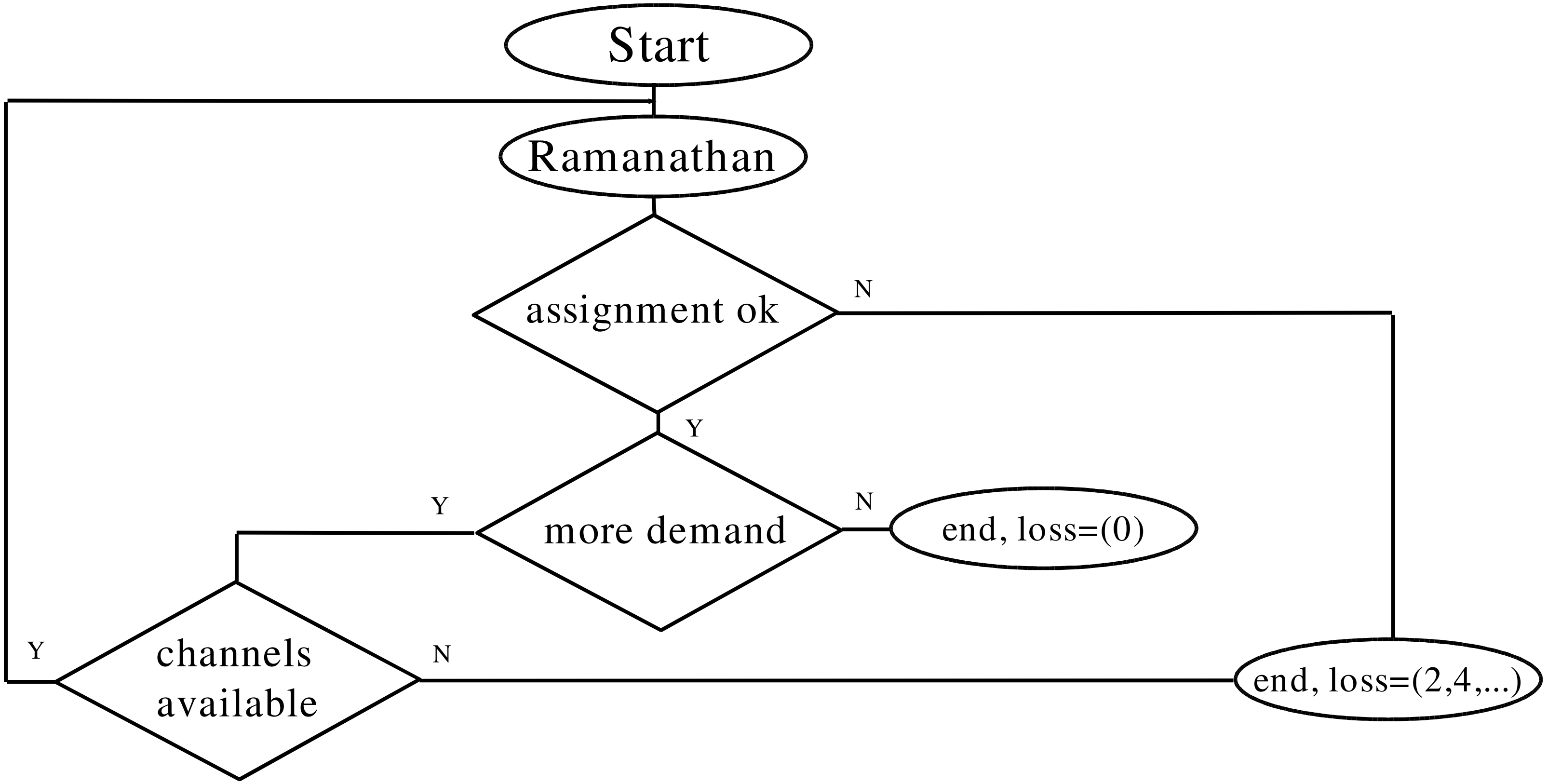
Centralized approach (S. Ramanathan)

- Performance guarantee (run-time) of O(*T*), where *T* is the *thickness* of the graph G: the minimal number of planar graphs into which G can be partitioned.
- O(*T*) implies an O(1) performance guarantee solution for most of the real-life networks, because *T* can be usually be bounded by a smaller number (compared to *p*).
- In typical multihop networks, thickness is several orders of magnitude less than *p* – more scalable solutions.
- The thickness itself doesn't have to be calculated, thus the algorithm is with a polynomial complexity.
- No restrictions to the graph, considering an obstacle-free environment.

Centralized approach (S. Ramanathan)

- Assignment
  - Labelling phase
    - Assign to each vertex a *unique* label between 1 and n, where n is the total number of vertices
    - Two ordering heuristics:
      - Minimal Neighbour First (MNF)
      - Progressive MNF (PMNF)
  - Coloring phase
    - Colors are assigned in a greedy fashion to the ordered nodes from n down to 1: first available color is taken, which doesn't violate the restrictions (interference matrix)

The algorithm, adopted



Each turn, a demand of 1 is satisfied for each station (if applicable). Used channels (colors) are ignored in the next turns.

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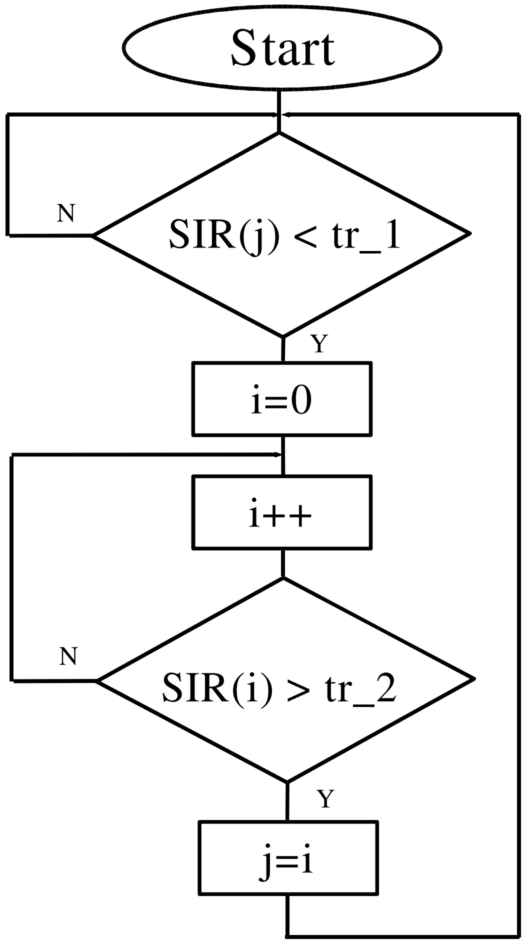
Decentralized approach

Originally Beck & Panzer algorithm, adopted as random



- SIR: Signal to Interference Ratio (the quality of the signal)
- tr_1: treshold for low quality signal, if reached, change frequencies
- tr_2: treshold for good quality signal, if reached, stay on this frequency.
- The choice of the tresholds determines the performance and the stability of the algorithm.
- Optional 'priority vector' $Q=(Q_1, Q_2,\ldots,Q_n)$ (Furuya & Akaiwa)

The implementation

- Existing tool: city_prop, provides the decay matrix, node data (.scn)
- Implemented:
  - Read out the data from the .scn file
  - Calculate the interference matrix for the BSs, and the demand
  - Calculate the channels distribution
  - Write the results to file

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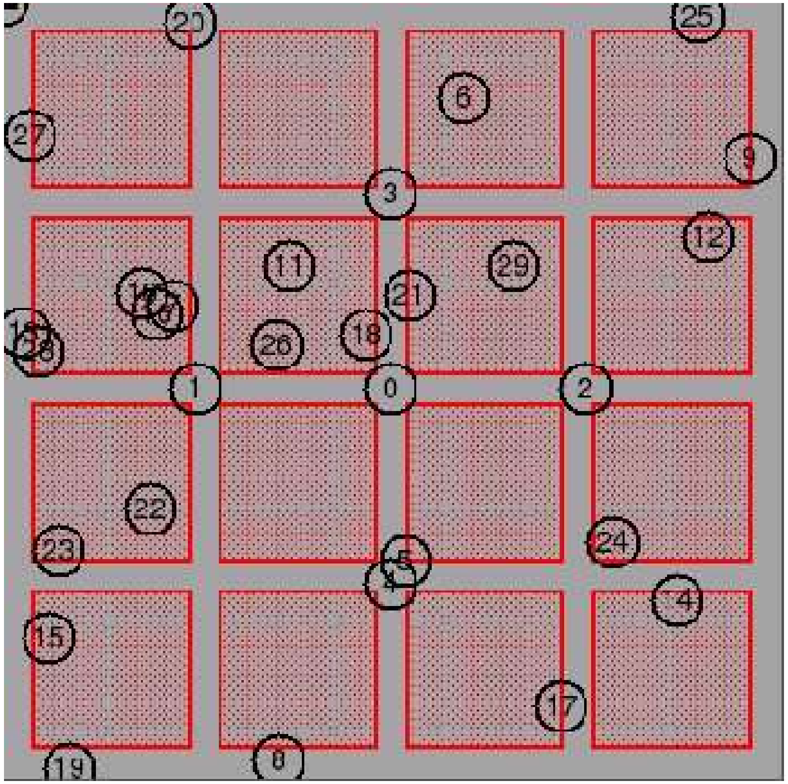
The implementation

- Two calculation modes:
  - Distribution list – the channel assignment list for each BS
  - Average – statistics for the given urban scenario
    - calc_average():
      for (i 1 to 1000) do
        » order(rand), color()

    - Randomized sets:
      for (i 1 to 20) do
        » randomize_nodes (with or without BSs)
        » order(MNF), color()
        » order(PMNF), color()
        » calc_average()

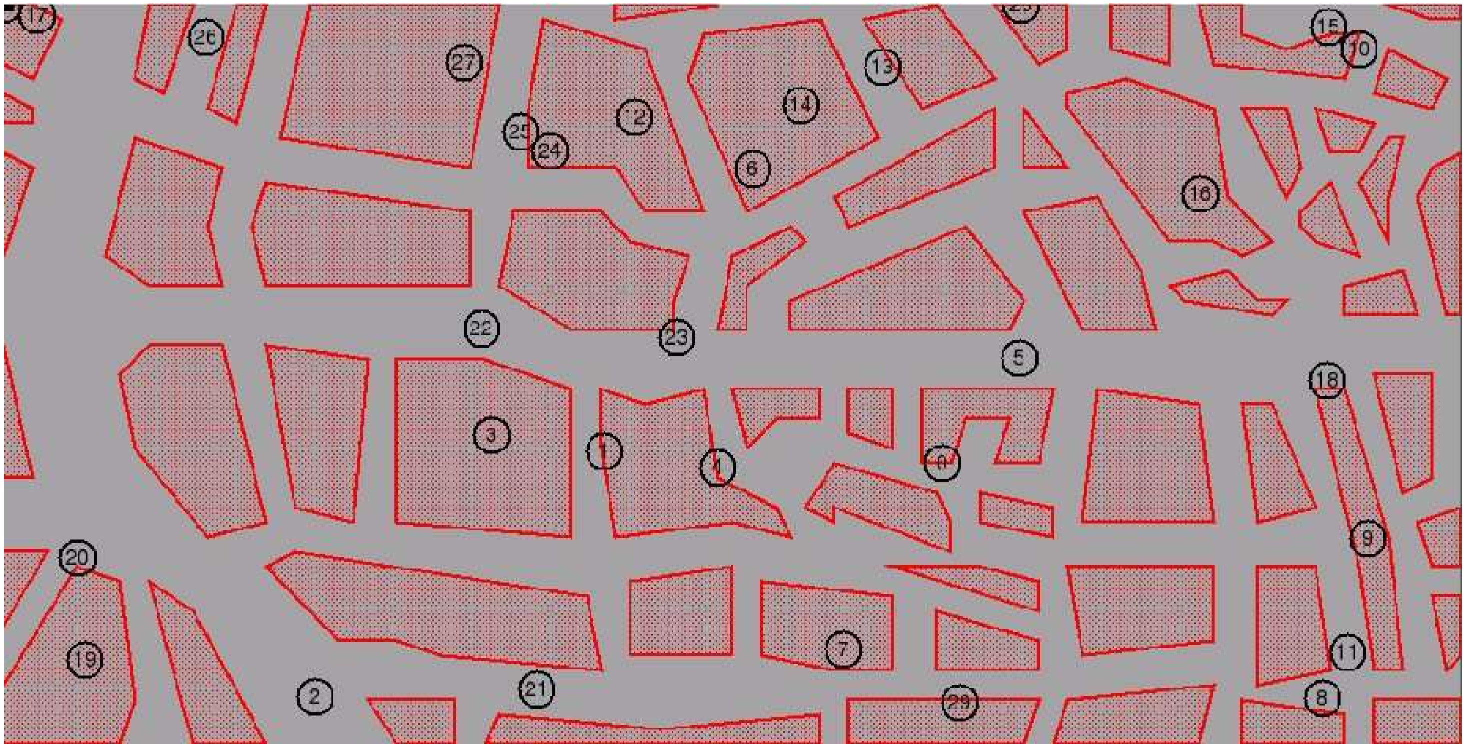
Simulation Scenarios – Manhattan

Dimensions 400x400, 100 to 500 nodes, 20% are BSs



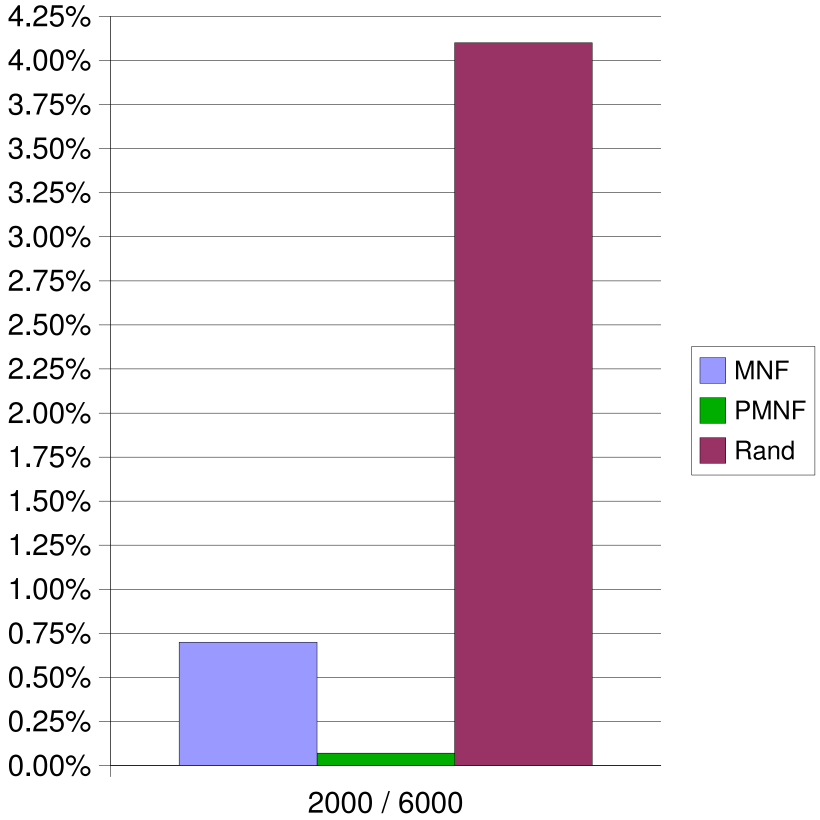
Simulation Scenarios - Munich

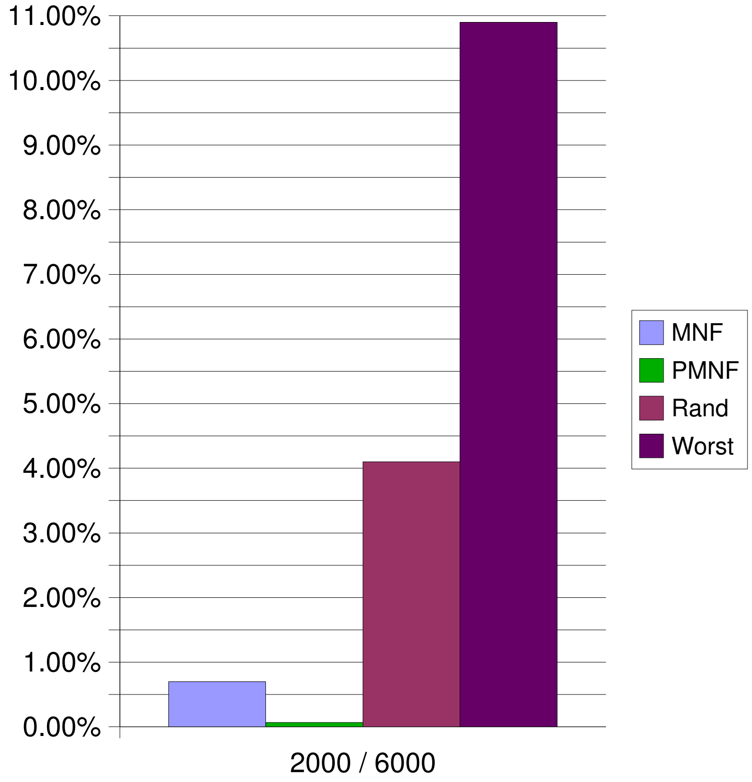
Dimensions 1000x500, 2000 nodes.



Results, free-space high load

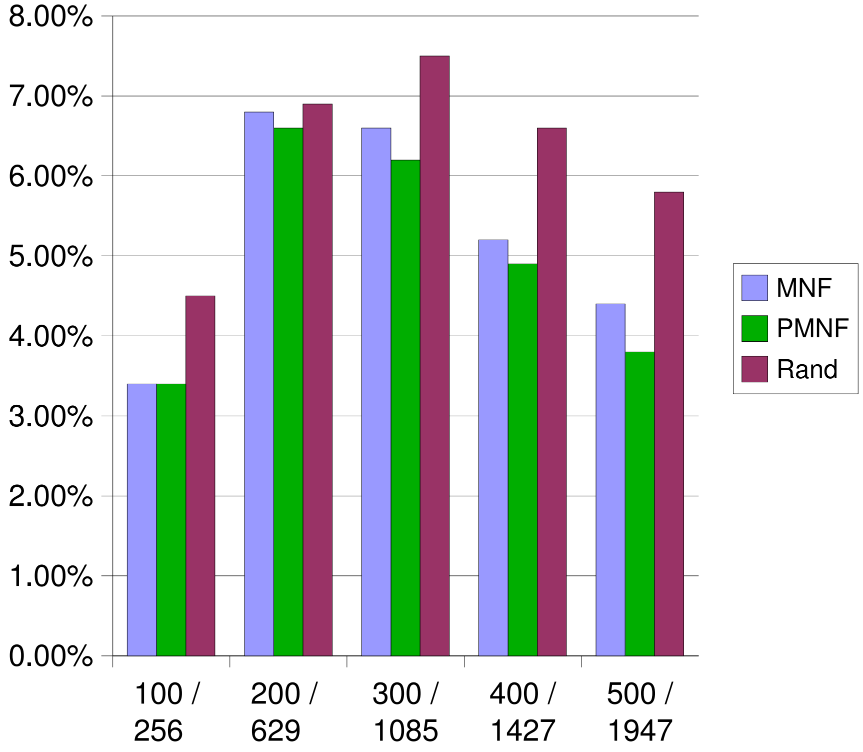
Free-space, 2000 nodes, 200 Bss, total demand loss

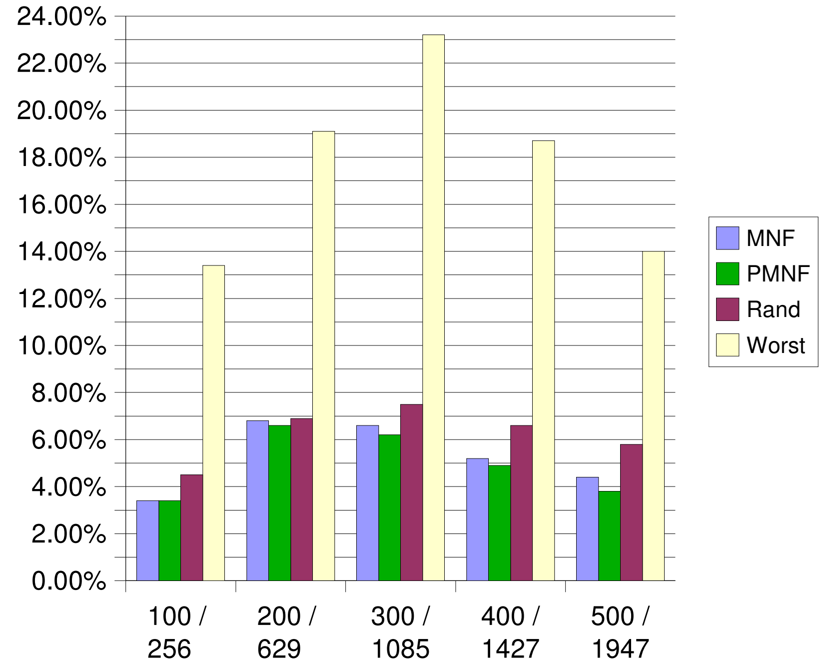




Results, Manhattan

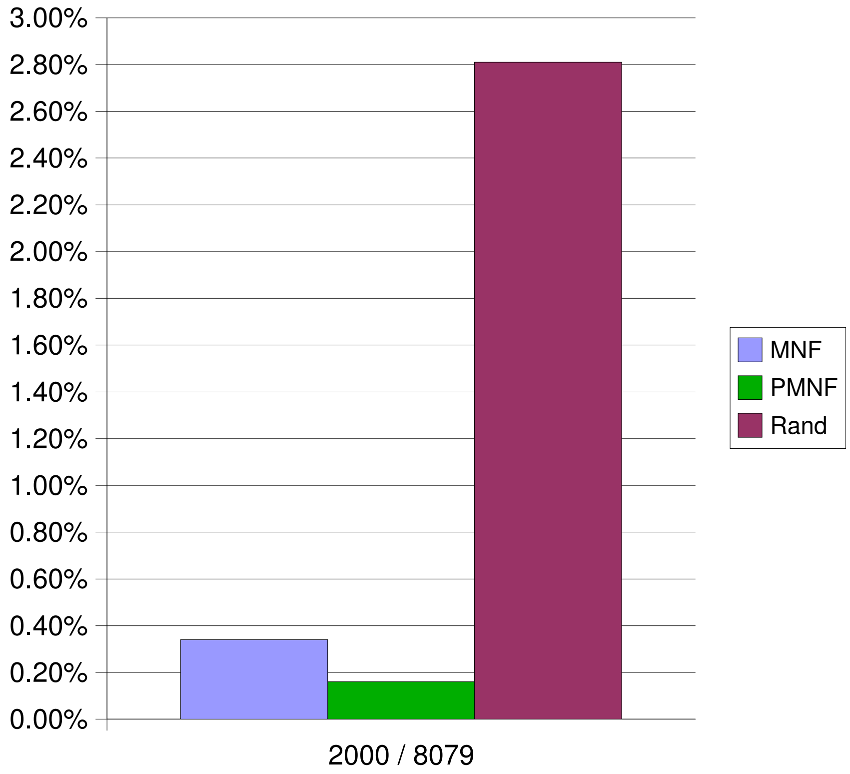
Manhattan scenarios. 20% BSs, 20% channels. The graphs show the total demand not met, compared to the optimum found.

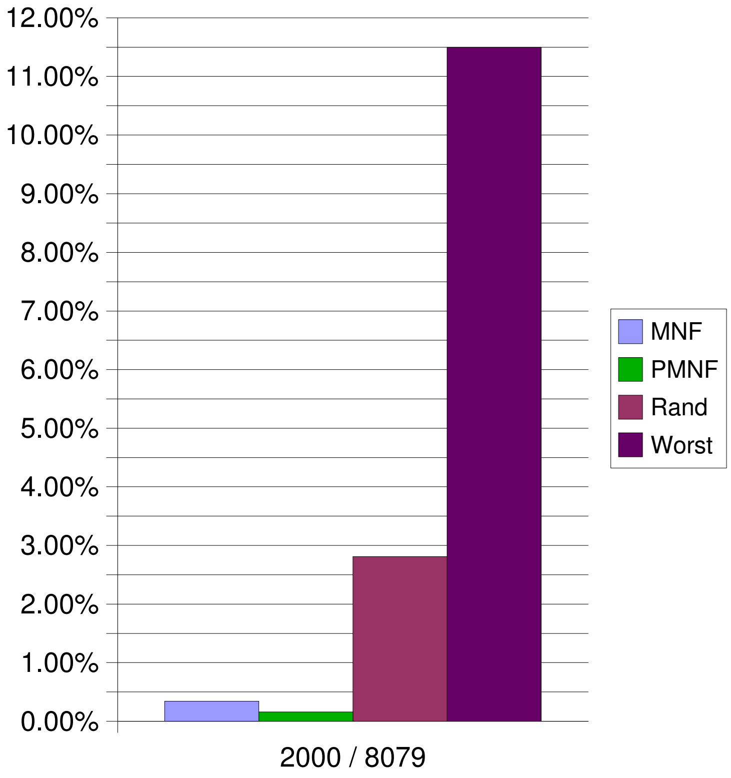




Results, Munich

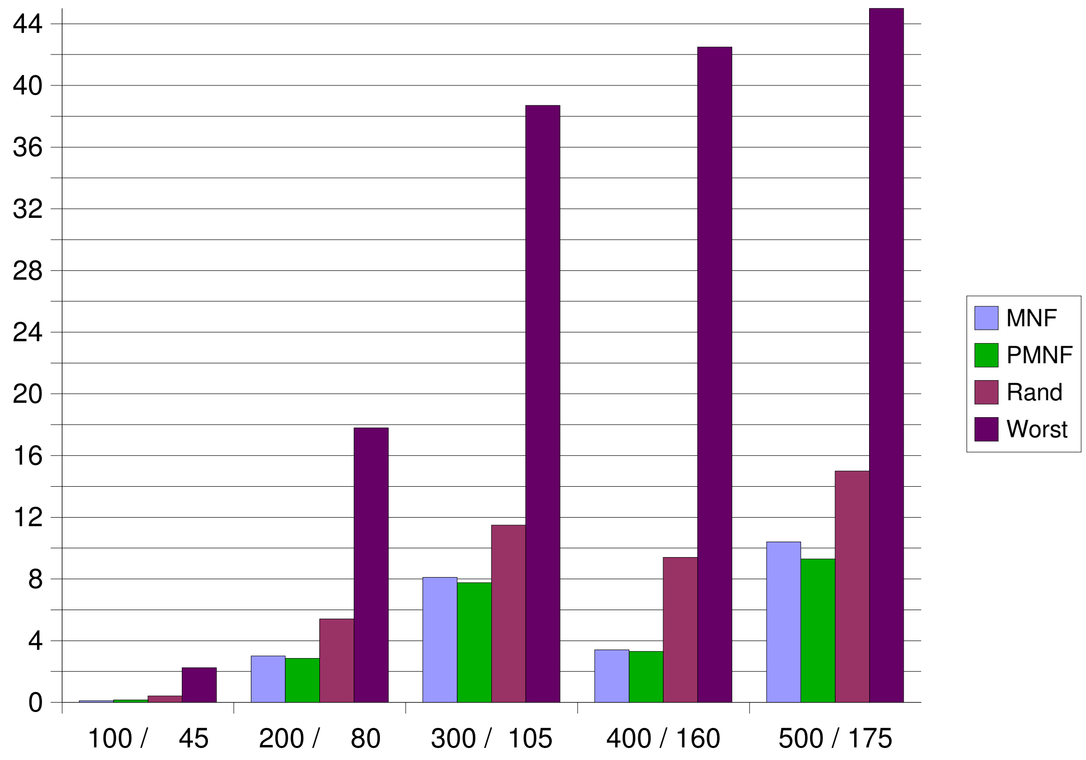
Munich scenario, 2000 nodes, 200 Bss. The graph shows the total demands not met, compared to the optimum found.





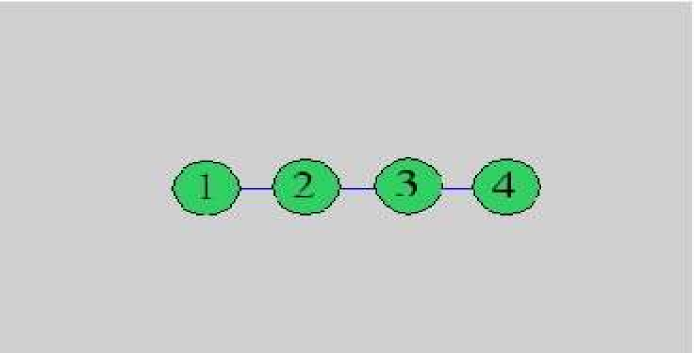
Results, channel demand

Manhattan scenarios, 20% Bss, 240 channels available. The graph shows the requested additional channels, compared to the optimum found.



Analysis

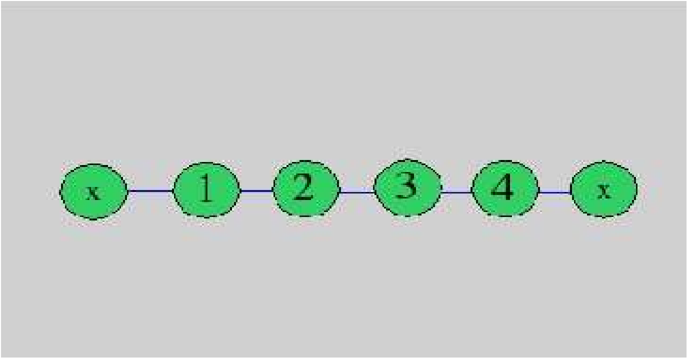
Centralized and decentralized comparison



Optimum coloring using 2 colors.
PMNF, MNF: 1, 4, 2, 3 -> coloring 3, 2, 4, 1
Rand: possible coloring 1, 4, 2, 3 (3 colors)

Analysis

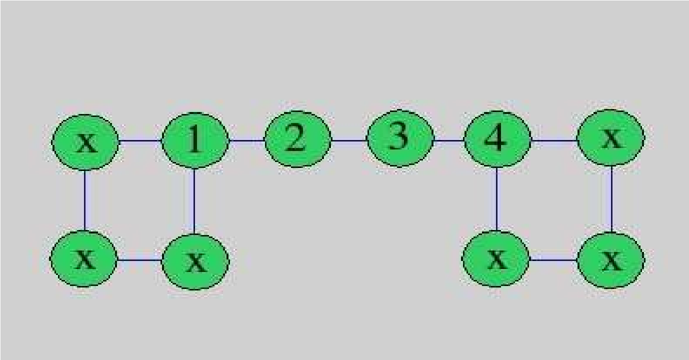
MNF and PMNF comparison



PMNF as before
MNF might color it with 3 colors

Analysis

PMNF imperfection



MNF - uses 3 colors always
PMNF - 2 or 3
RAND - 2 or 3

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Outline

- A step forward is already done
- To implement run-time decentralized simulation
- Add GUI
- Add the possibility to chose the ordering for coloring
- Possible implementation of hybrid solutions

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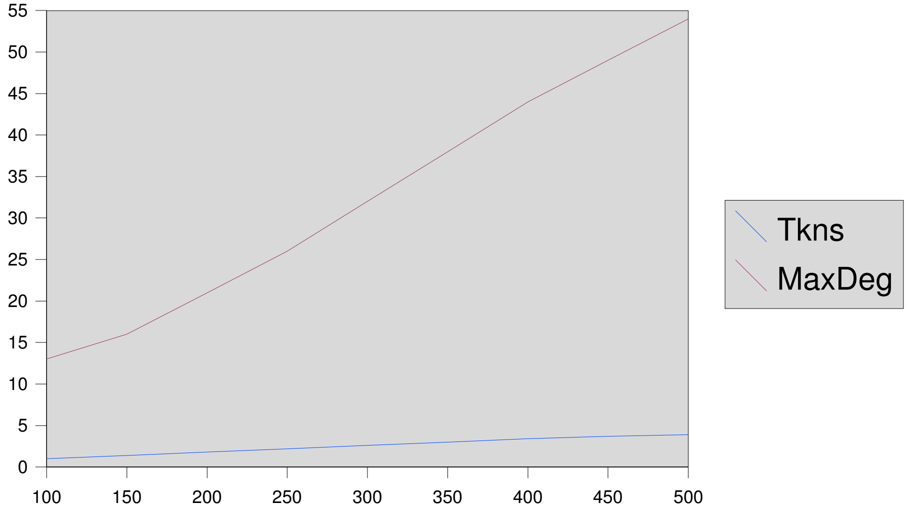
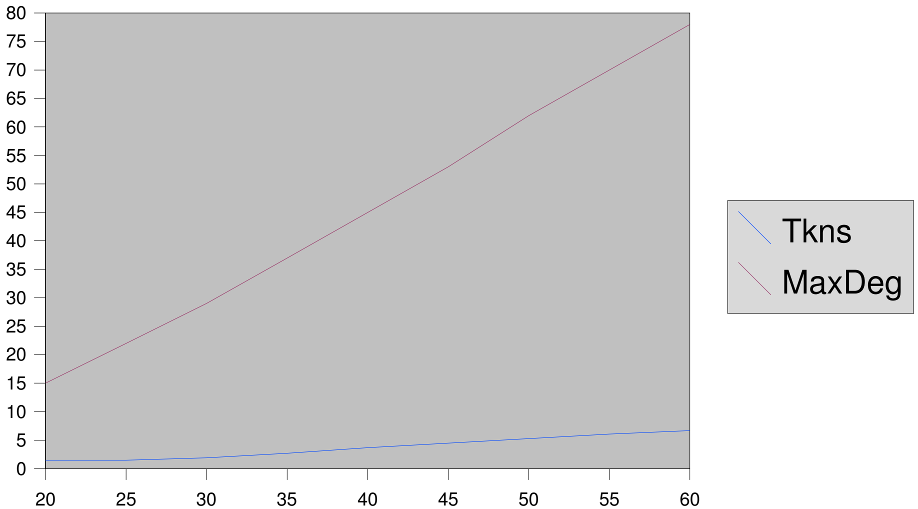
Thank you for your attention

Annex 1: Thickness and Max. degree



(a) Number of nodes



(b) Node Transmission Range

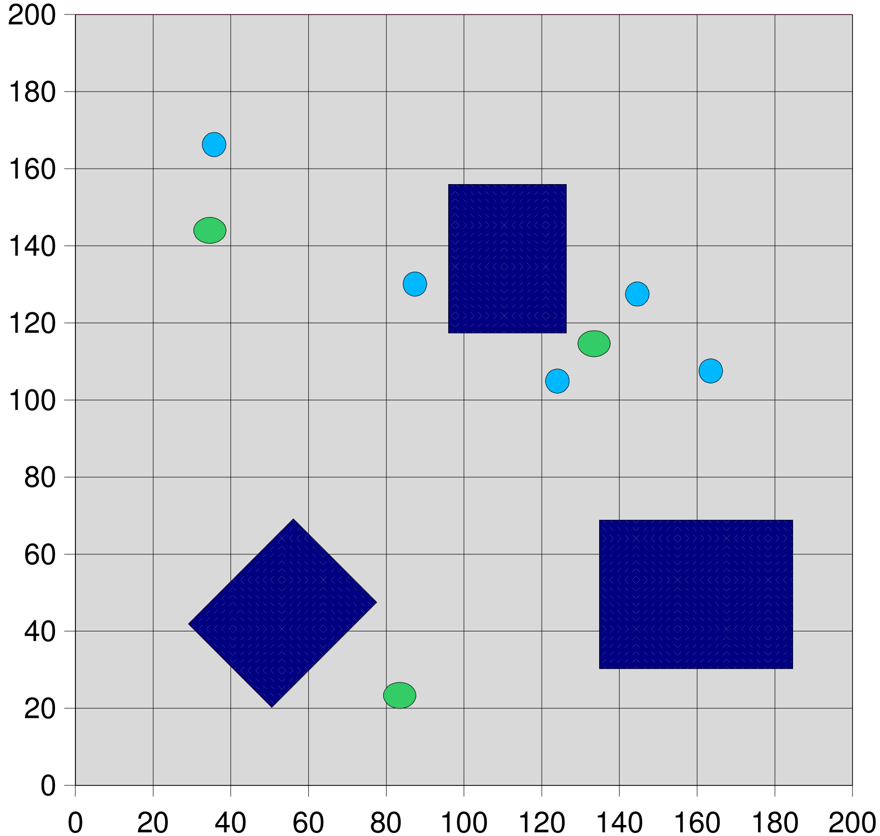
Max. degree and thickness versus:

(a) number of nodes, with each node having a range of 40 units.

(b) range of node, with 400 nodes.

Experiments conducted by placing nodes randomly on a 400x400 grid. (S. Ramanathan)

Annex 2: The decay matrix



200x200 simulation field, with 20x20 metric

Simulation field 200x200, metric 20, the decay matrix is with dimensions 100x100: 100 cells summary, contains the path loss data for every pair.