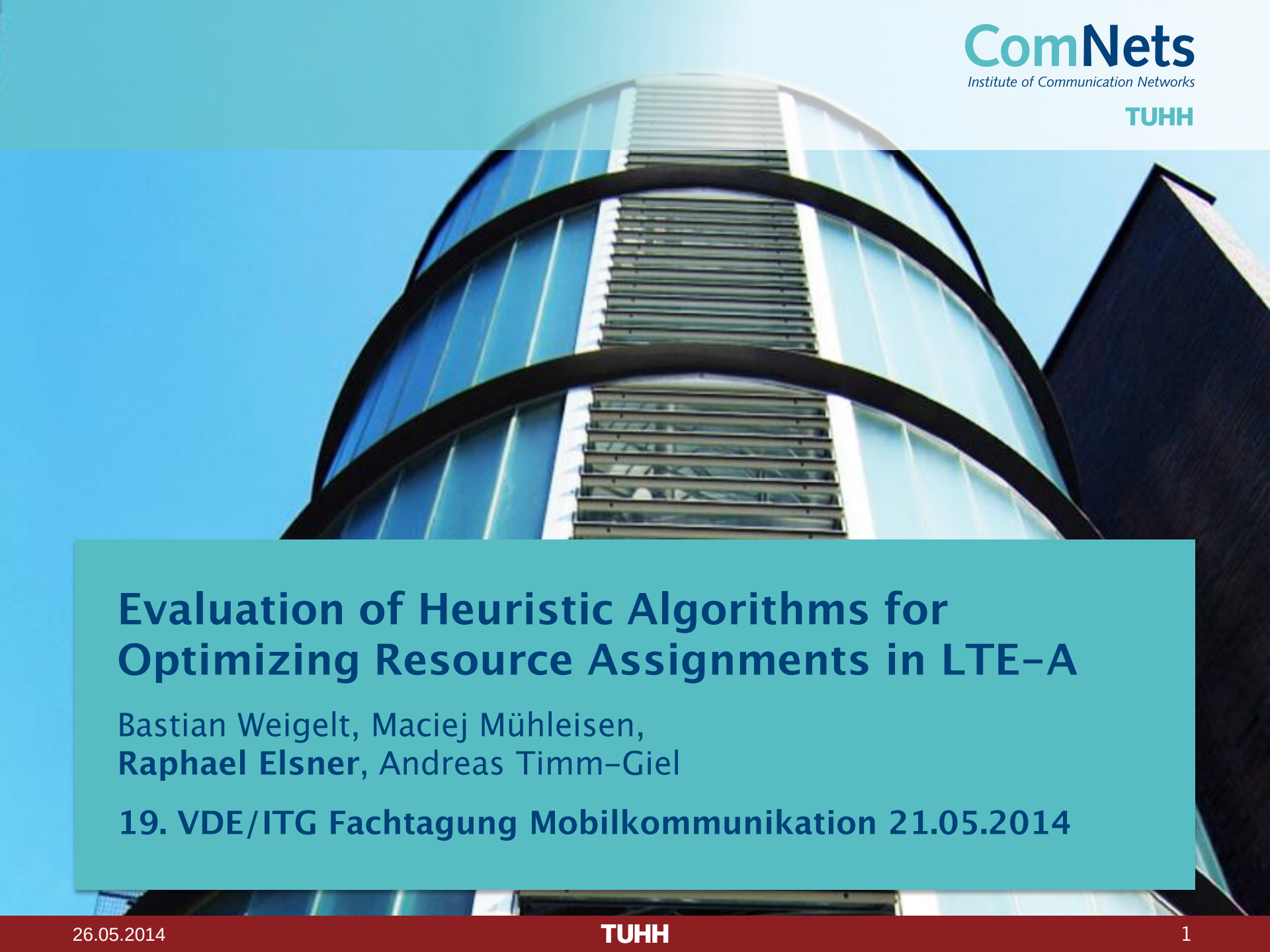

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Evaluation of Heuristic Algorithms for Optimizing Resource Assignments in LTE-A

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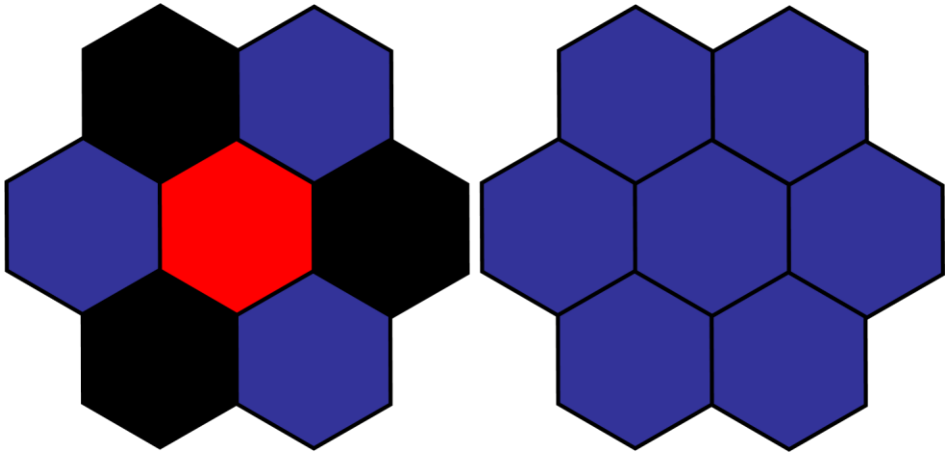
19. VDE/ITG Fachtagung Mobilkommunikation 21.05.2014

Agenda

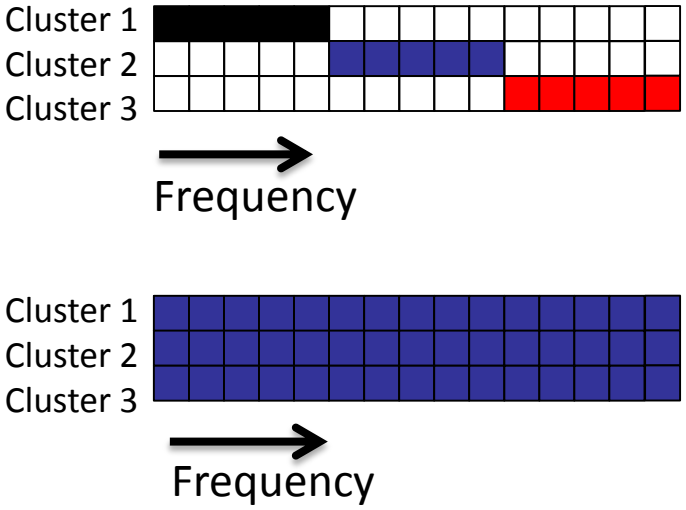
- Problem Formulation
- Heuristic Algorithms
- Simulation Results

LTE Resource Management

- LTE has a frequency reuse factor of one
- Interference mitigation is important
- Cooperatively managing resource assignments of multiple cells
- Increasing the aggregated system throughput
- Therefore increasing Cell Spectral Efficiency (CSE)



Reuse - 3 Reuse - 1



LTE Resource Management

Scheduling decisions

- Resources in frequency and time
- Modulation and coding scheme
- Transmission power
- Precoding (MIMO)

Objectives

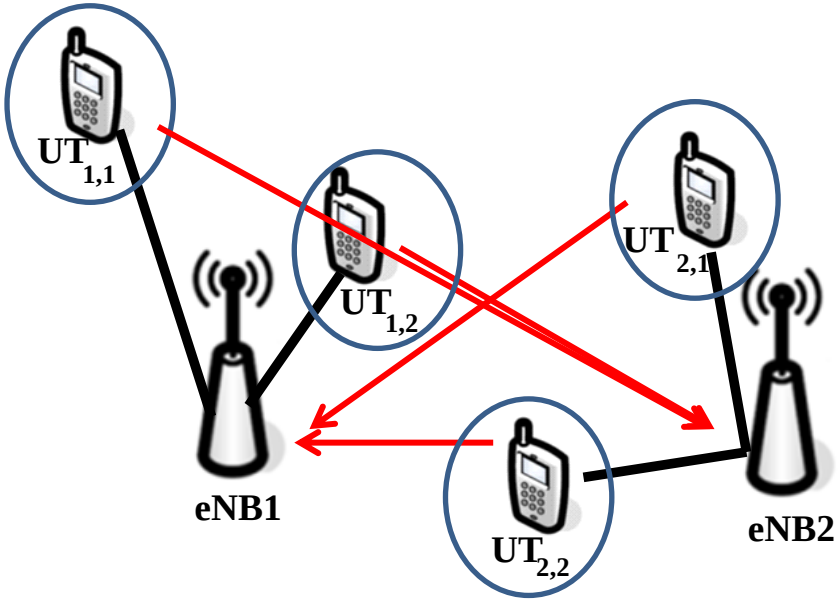
- Individual best throughput
- Best system throughput → Coordination
- Increasing cell edge user throughput → Coordination

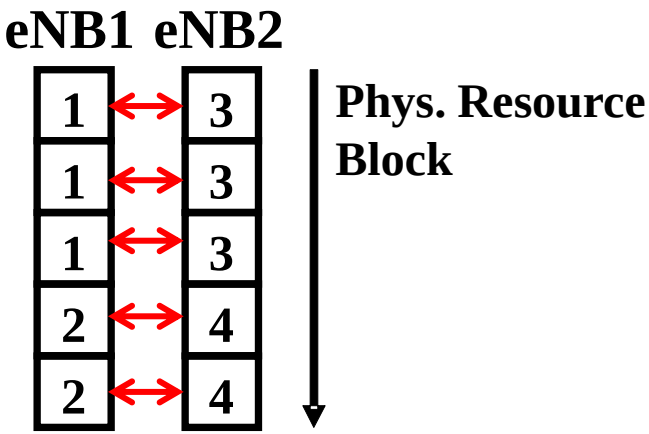
Nonlinear optimization problem

- Mapping of SINR to data rates using nonlinear functions
- SINR depending on several interfering users
- Needs simplification!

Simplification

- Each user has equal amount of resources
- Same amount of UTs per eNB (in one TTI)
- Each UT has only one interfering UT per other base station
- Calculate data rates depending on SINR before optimization





u PRB assigned to UT *u*

Signal

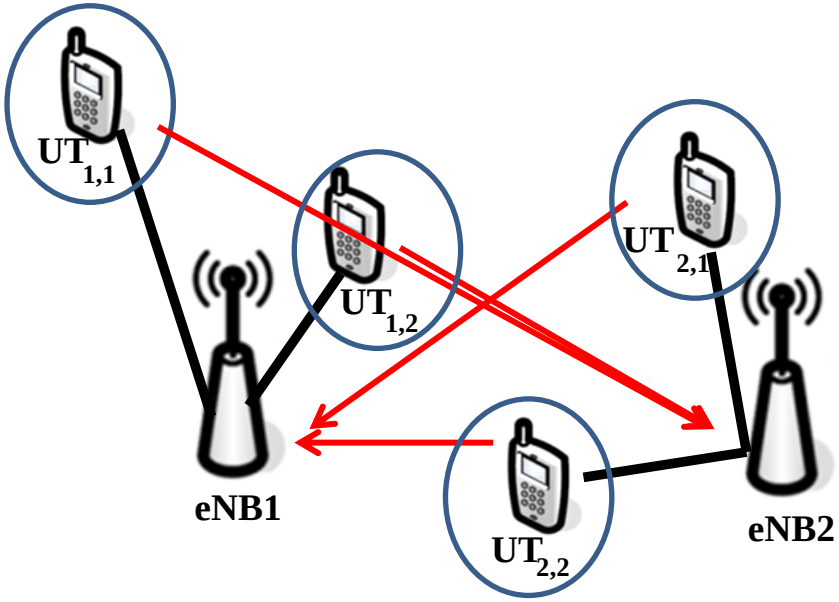
Interfering signal

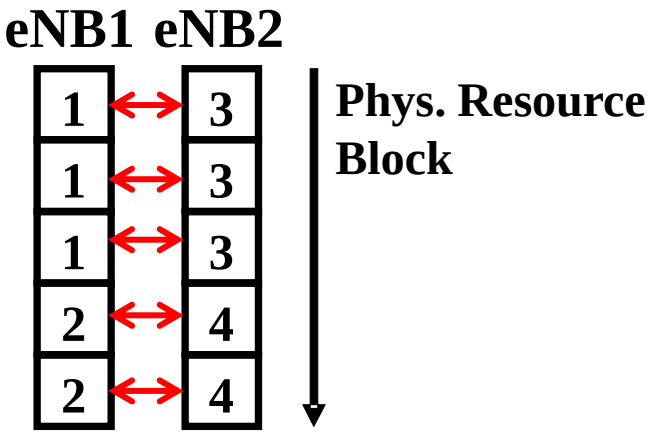
Example of possible resource assignment

Resource Assignment

Optimizing resource assignment of user terminals

- Which UTs transmit on same resources?
- Linear Assignment Problem





Example of possible resource assignment

u PRB assigned to UT *u*

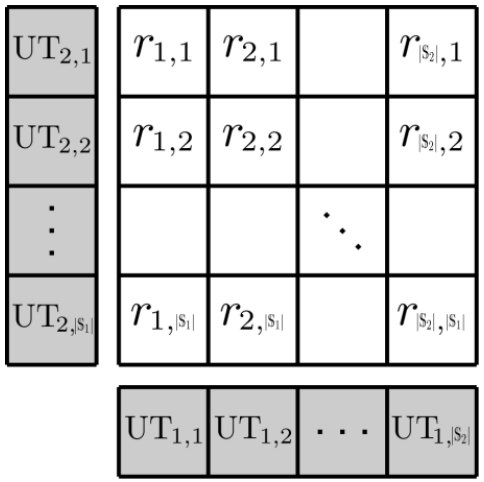
Signal

Interfering signal

Linear Assignment Problem

Which user terminals transmit on the same resources

- Assigning user terminals
- Optimal solvable in polynomial time
- Hungarian/Munkres Algorithm



$$\max \sum_{i=1}^{N} \sum_{j=1}^{N} c_{i,j} r_{i,j}$$

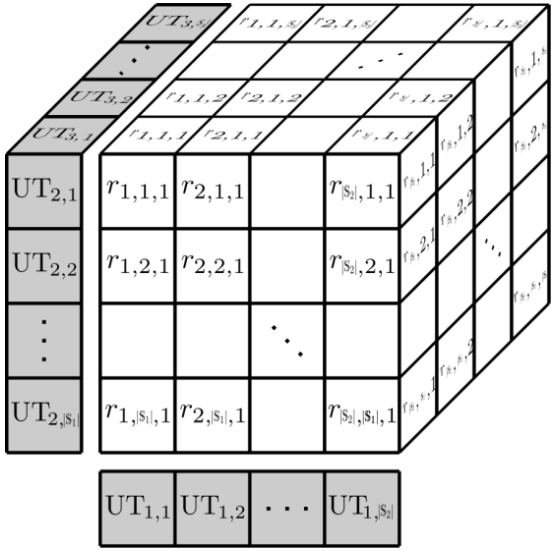
$r_{i,j}$: Elements of matrix with throughputs (rates)

$c_{i,j}$: Elements of permutation matrix ($c_{i,j} \in \{0, 1\}$)

Multidimensional Assignment Problem

For more than two base stations

- Multidimensional Assignment Problem
- Number of assignments: $(\#\mathrm{UT}\,!)^{\#BS-1}$
- NP-hard problem
- Heuristic algorithms



Heuristic Algorithms

1. Greedy Heuristic
2. Max Regret Heuristic

3. Greedy randomized adaptive search procedure (GRASP)

Greedy Heuristic

Simply always takes the assignment with best throughput

	$UT_{1,1}$	$UT_{1,2}$	$UT_{1,3}$	$UT_{1,4}$
$UT_{2,1}$	7	36	**44**	19
$UT_{2,2}$	20	**30**	40	28
$UT_{2,3}$	12	22	21	9
$UT_{2,4}$	14	4	19	13

$L = \{44,30\}$

Solution found by Greedy heuristic: 97

Optimal solution: 108

Maximum Regret Heuristic

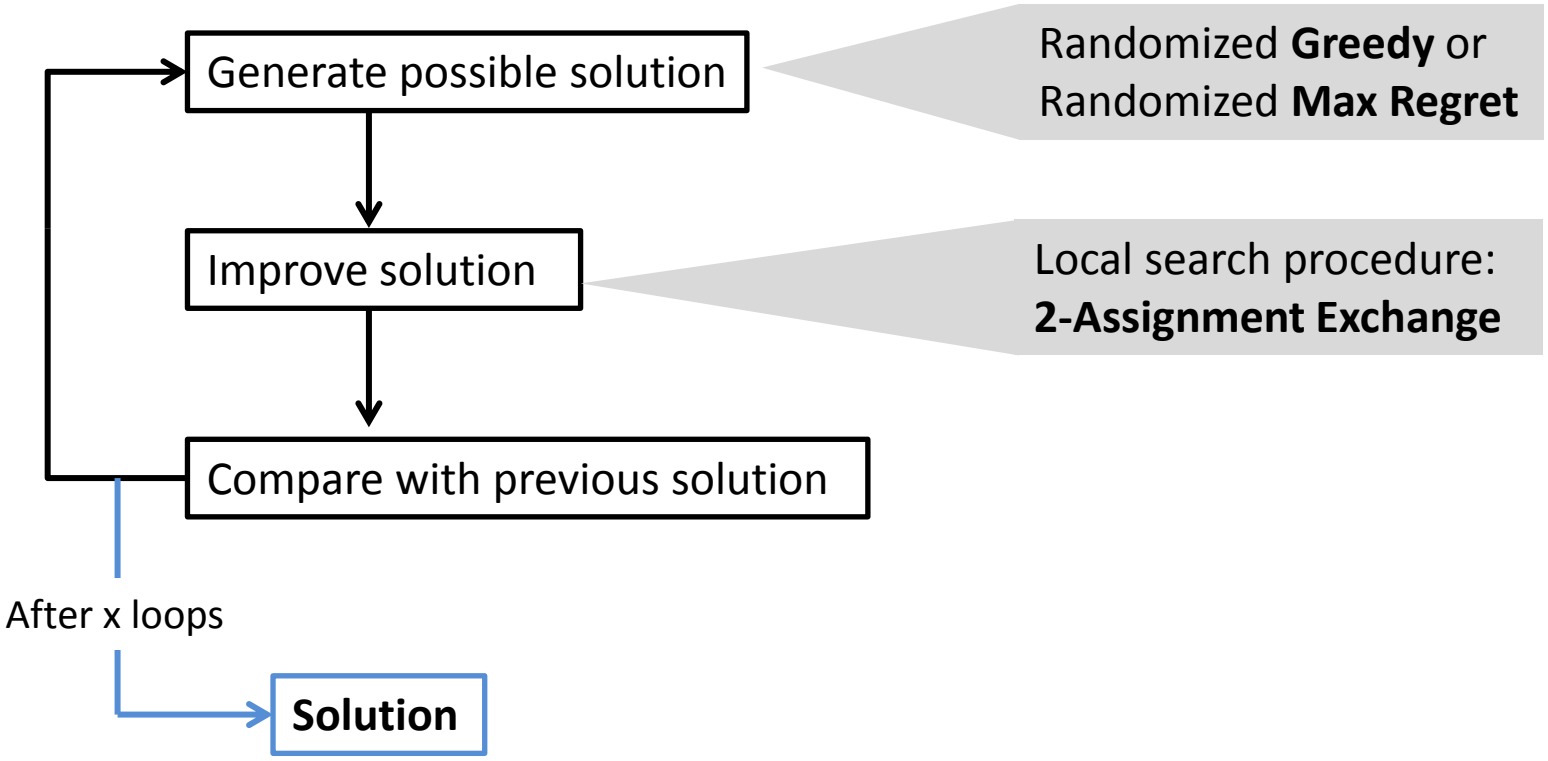
Calculates “regret” and takes the respective assignment

	$UT_{1,1}$	$UT_{1,2}$	$UT_{1,3}$	$UT_{1,4}$	
$UT_{2,1}$	7	**36**	44	19	**17**
$UT_{2,2}$	20	30	**40**	28	-
$UT_{2,3}$	12	22	21	9	5
$UT_{2,4}$	14	4	19	13	1
	2	14	-	3	

L = {40,36}

Solution found by Greedy heuristic: **97**
Solution found by Maximum regret heuristic: **101**
Optimal solution: **108**

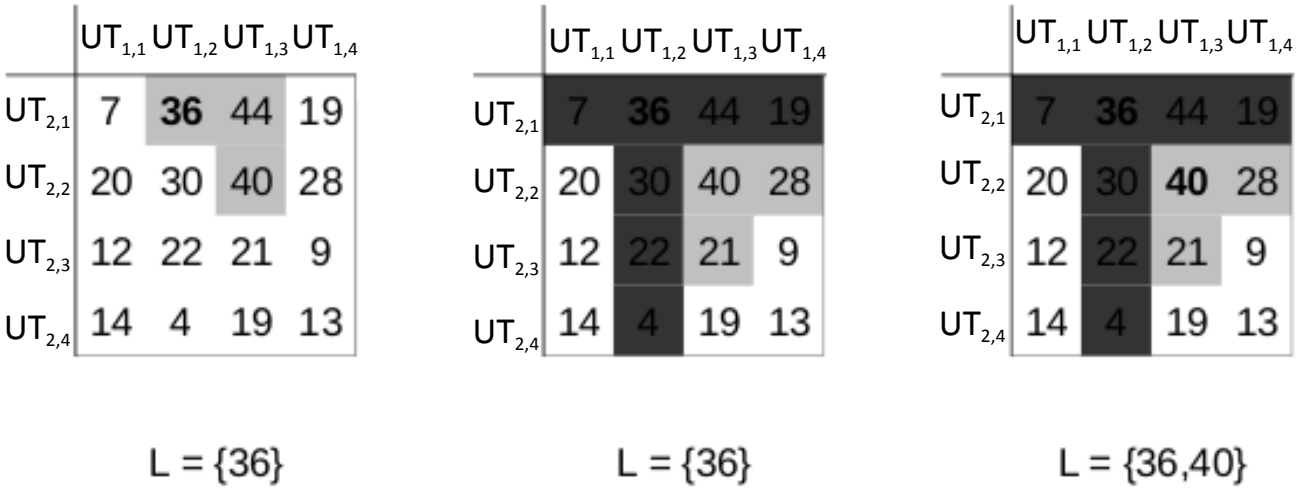
Greedy Randomized Adaptive Local Search Procedure (GRASP)



Improved Heuristic

Randomized Greedy

- Taking more than the highest value into account
- Picking one at random
- Randomized Max Regret similar



Example of randomized Greedy for a two-dimensional assignment problem

Local Search Procedure

Two Assignment Exchange

- Takes calculated solution
- Exchange of adjacent assignments
- Takes the better assignment

	$UT_{1,1}$	$UT_{1,2}$	$UT_{1,3}$	$UT_{1,4}$
$UT_{2,1}$	7	36	**44**	19
$UT_{2,2}$	20	**30**	40	28
$UT_{2,3}$	12	22	21	**9**
$UT_{2,4}$	**14**	4	19	13

L = {44,30,14,9}

44 + 30 < **40 + 36**

	$UT_{1,1}$	$UT_{1,2}$	$UT_{1,3}$	$UT_{1,4}$
$UT_{2,1}$	7	**36**	**44**	19
$UT_{2,2}$	20	**30**	**40**	28
$UT_{2,3}$	12	22	21	**9**
$UT_{2,4}$	**14**	4	19	13

	$UT_{1,1}$	$UT_{1,2}$	$UT_{1,3}$	$UT_{1,4}$
$UT_{2,1}$	7	**36**	44	19
$UT_{2,2}$	20	30	**40**	28
$UT_{2,3}$	12	22	21	**9**
$UT_{2,4}$	**14**	4	19	13

L = {40,36,14,9}

Example of two assignment exchange for two-dimensional assignment problem

Scenario

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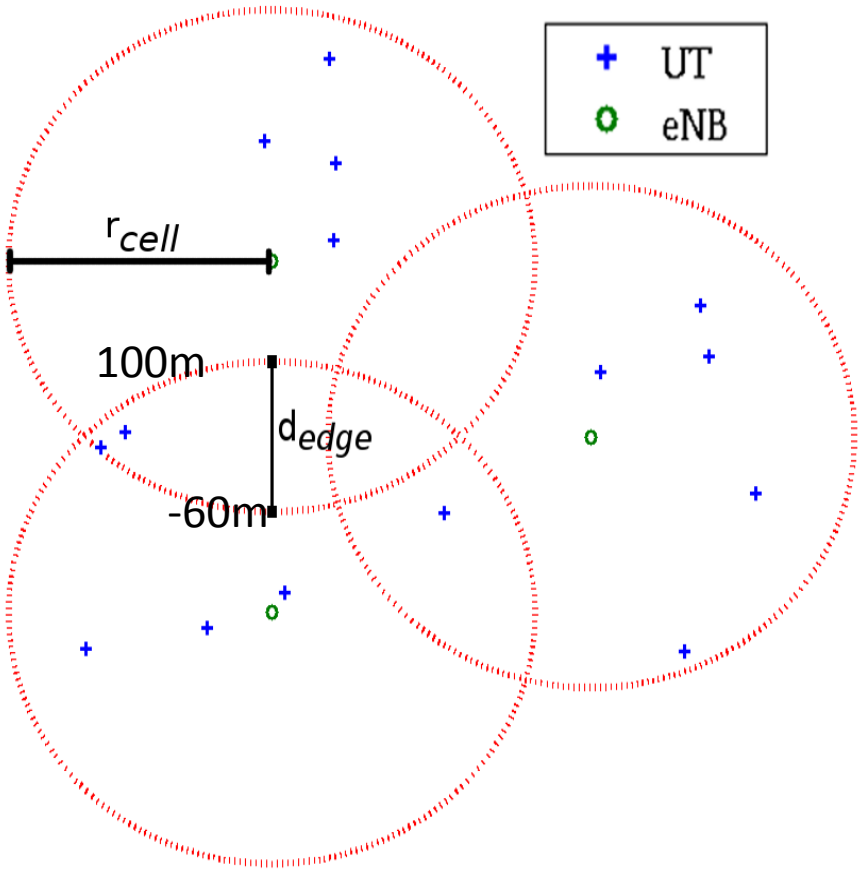
Simple LTE model in MATLAB

- 5 UTs per eNB
- 2 to 4 eNBs
- d_{edge} = - 200m to 100m
- r_{cell} = 100m
- Path-loss model: InH NLoS
- Bandwith: 20MHz

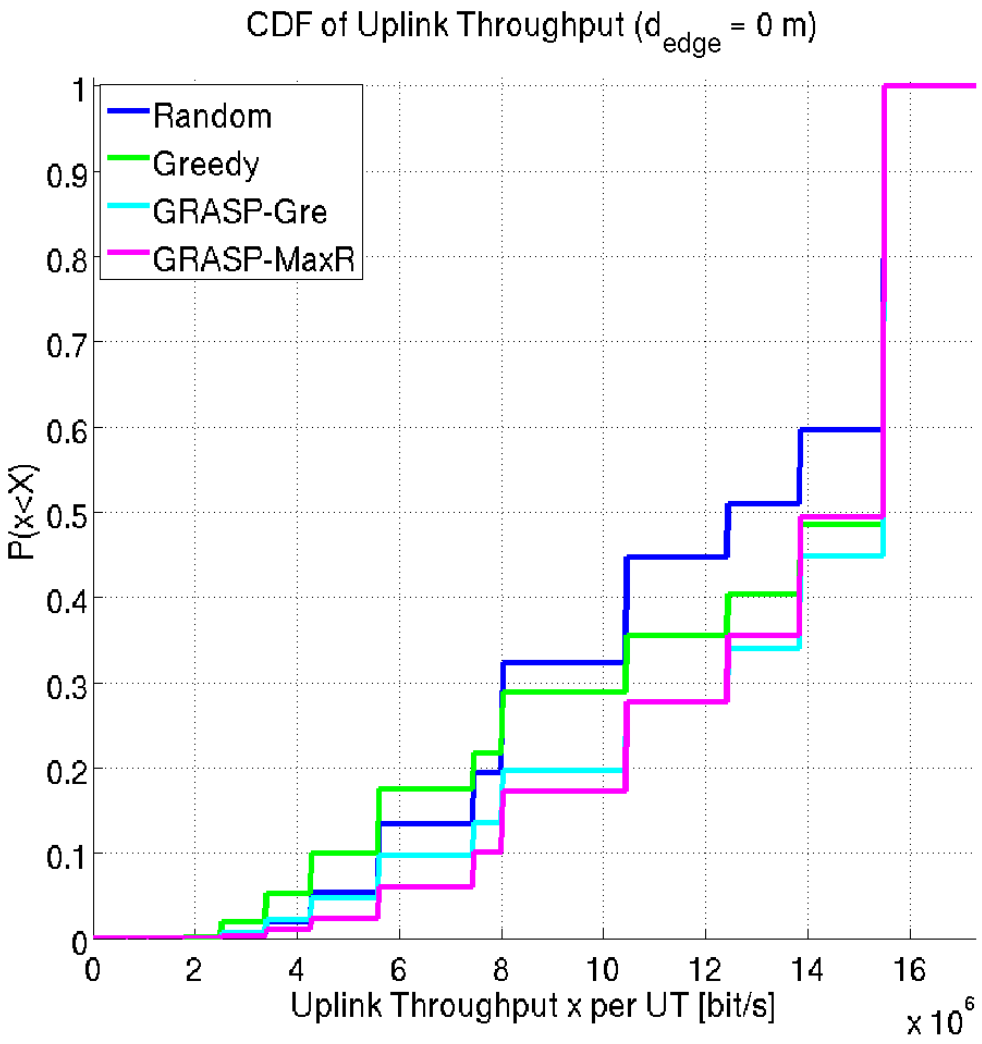


Algorithm parameter

- 4 loops of GRASP
- 3 highest values inrandomized Greedy / Max Regret

Algorithm results compared to random assignment

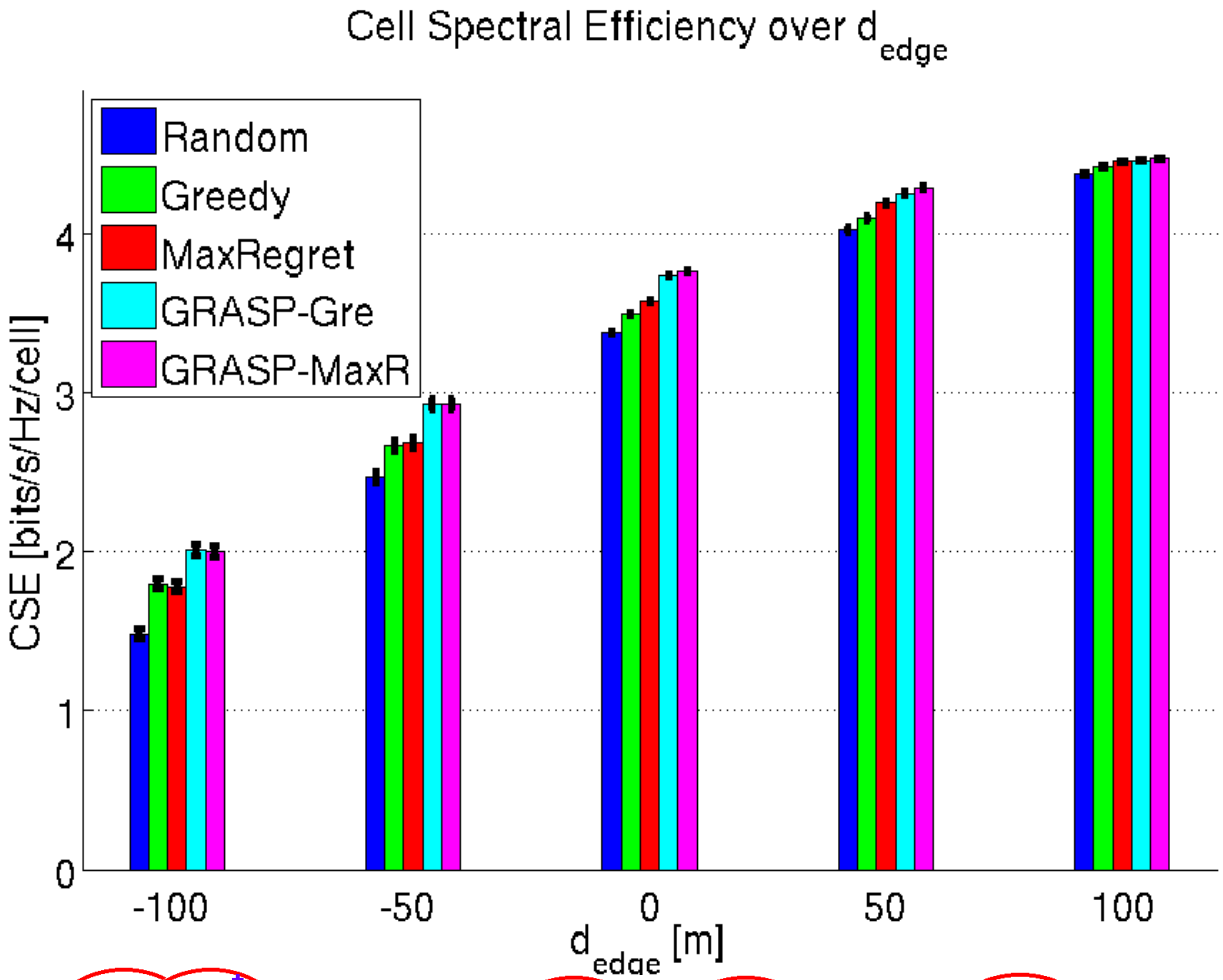
Results



r_{cell}: 100m
d_{edge}: 0m

3 Cells
5 User Terminals

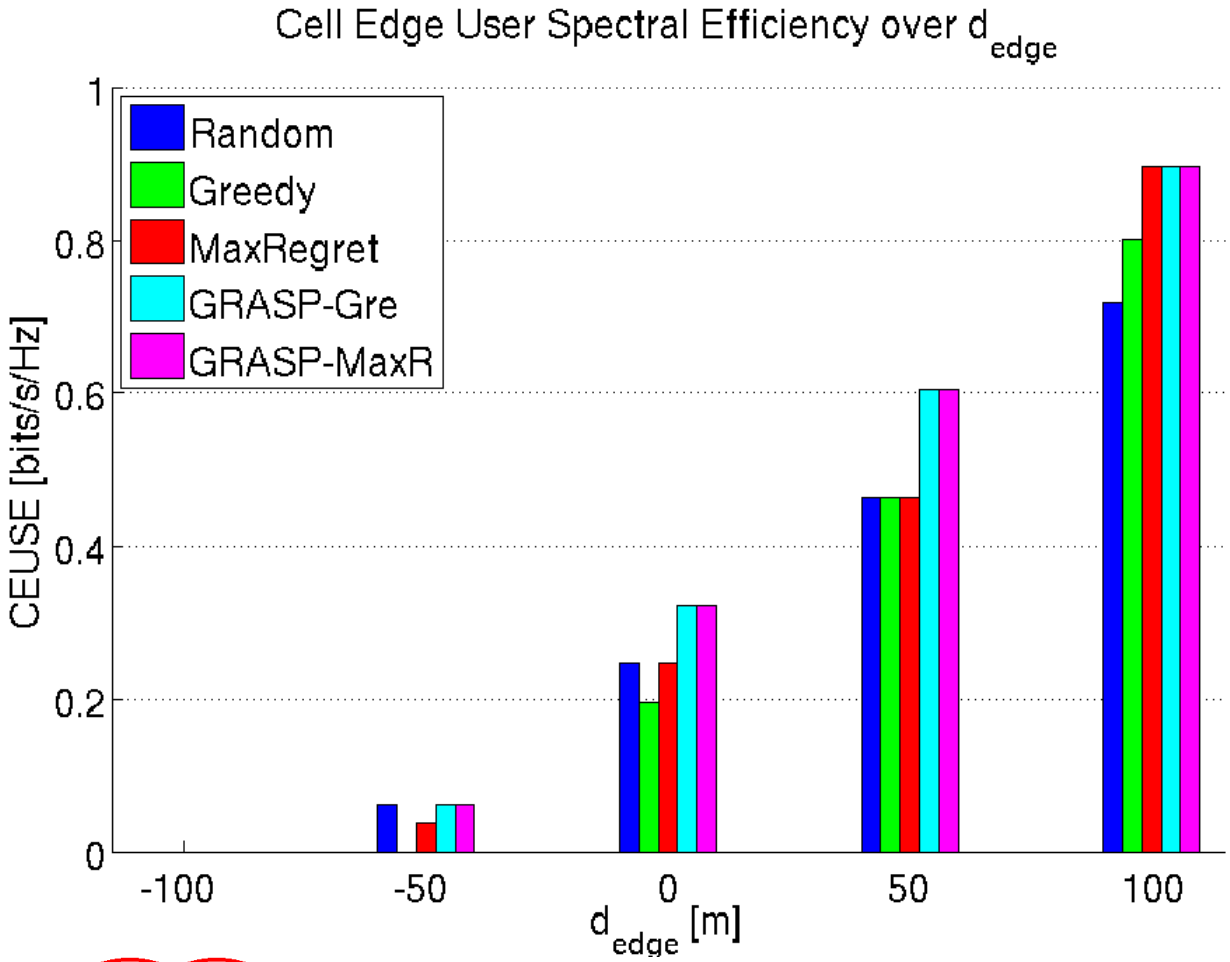
Cell Spectral Efficiency



r_{cell}: 100m
d_{edge}: -100m to 100m

3 Cells
5 User Terminals

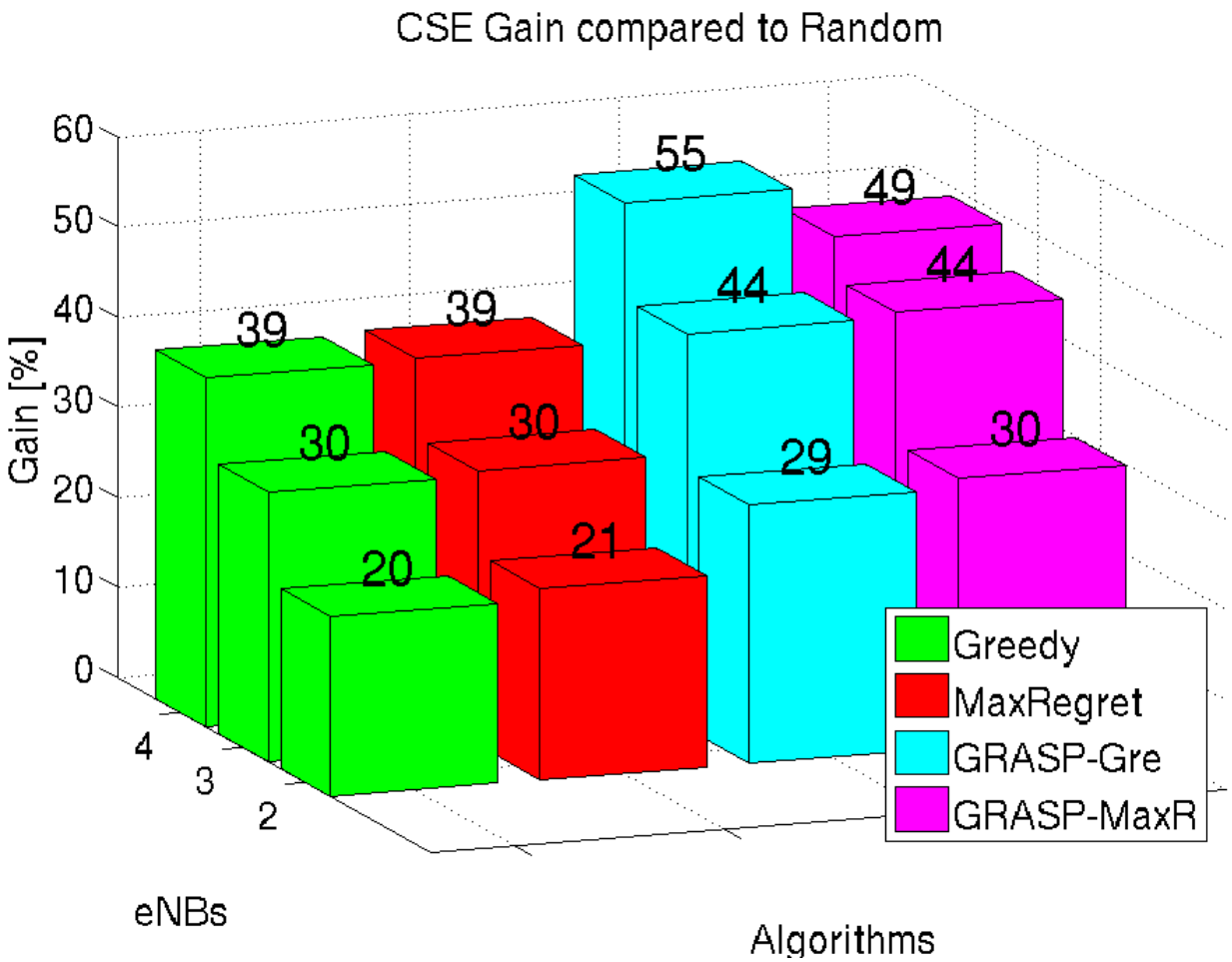
Cell Edge Users



r_{cell}: 100m
d_{edge}: -100m to 100m

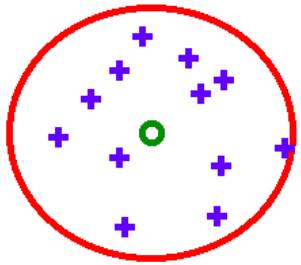
3 Cells
5 User Terminals

Gain in CSE over Random Assignment



r_{cell}: 100m
d_{edge}: -200m

2 to 4 Cells
5 User Terminals



Conclusion and Outlook

Summary

- Resource assignment problem formulated as Multidimensional Assignment Problem

Conclusion

- Metaheuristic GRASP shows better performance for Cell Spectral Efficiency (CSE) and Cell Edge User Spectral Efficiency (CEUSE) than other heuristics
- In some scenarios improvement of more than 50% compared to random assignment

Outlook

- Evaluation in system level simulator
- Relax restriction of same amount of Resource Blocks per UT and UTs per cell

Thank you for your attention.

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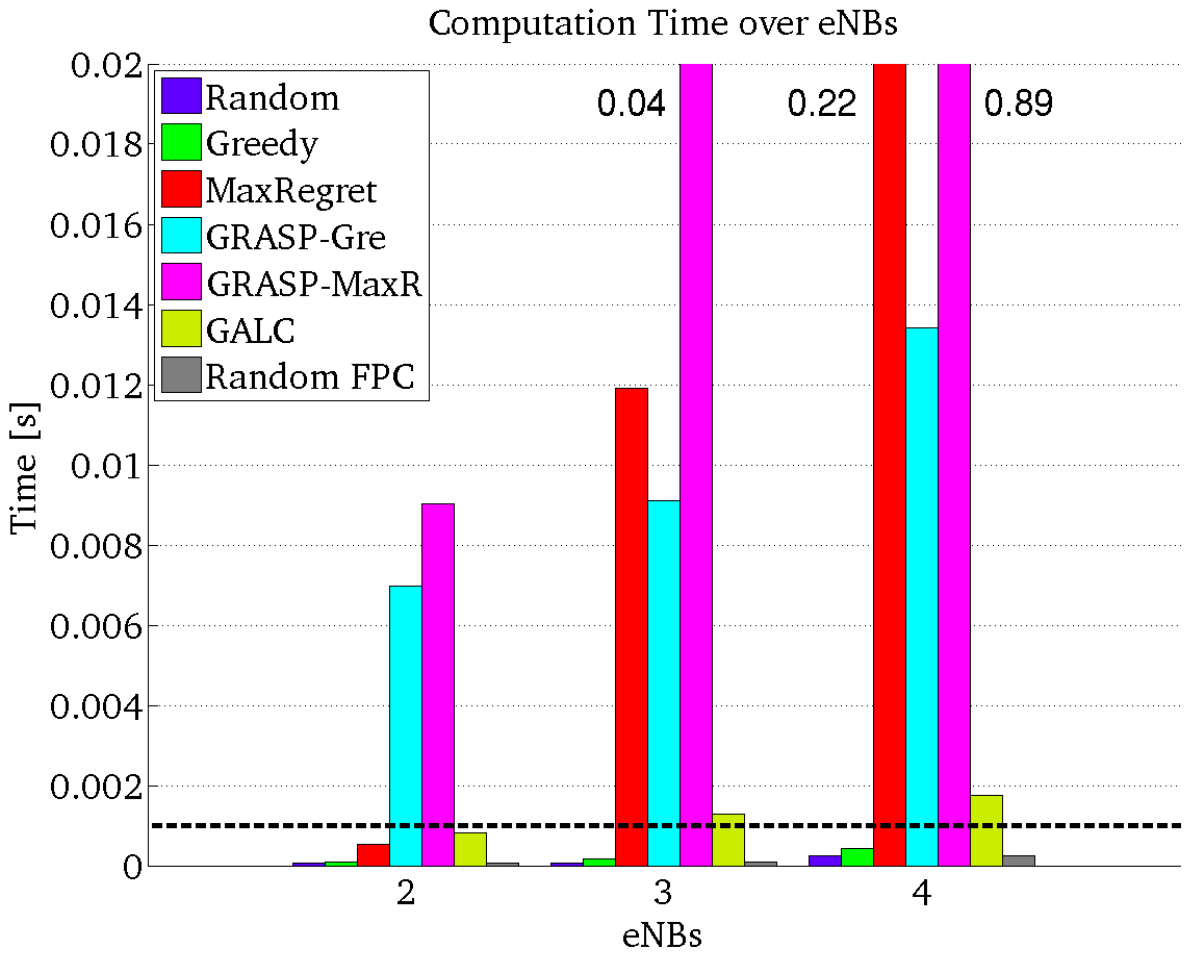
Computation Time



Computation time with 6 UTs per eNB