Simulation of self-x algorithms

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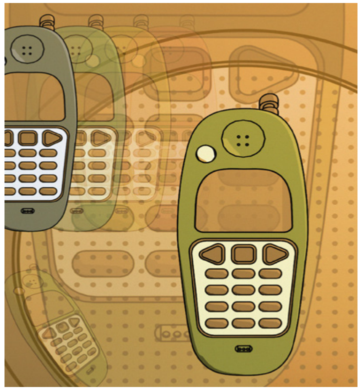
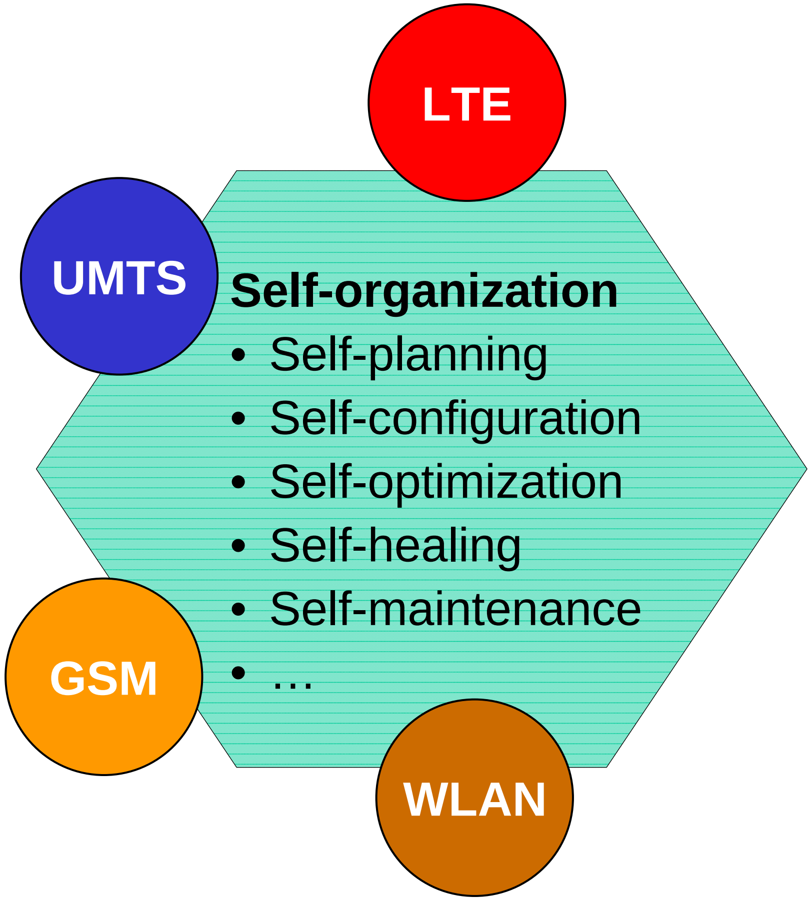


Overview

- Motivation
- Simulation of operator use cases - examples
  - ⇒ System level simulation
  - ⇒ Cell outage compensation
  - ⇒ Home NB parameter optimization
  - ⇒ Interference coordination
- Knowledge based reconfiguration
- Dynamic spectrum management by RL
- Conclusions

Motivation

- **Complexity** and **heterogeneity** of radio access networks is dramatically increasing
- **High cost pressure** requires improvement of operational efficiency
- Usability of future wireless access solutions should be improved ("**plug&play**")
- Introduction and deployment of **new wireless services and systems** should be accelerated.



→ SON / Self-x functionalities are mandatory for future radio networks!

System level simulation: Common evaluation framework

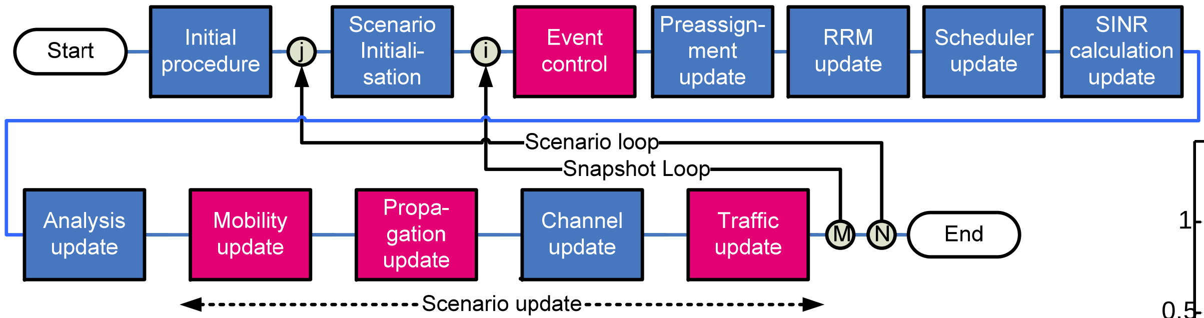
- **10 different simulation environments in E3-WP3 → categorization of partners' simulators according to functionalities studied**
- **Common assumptions and KPI's for simulation**

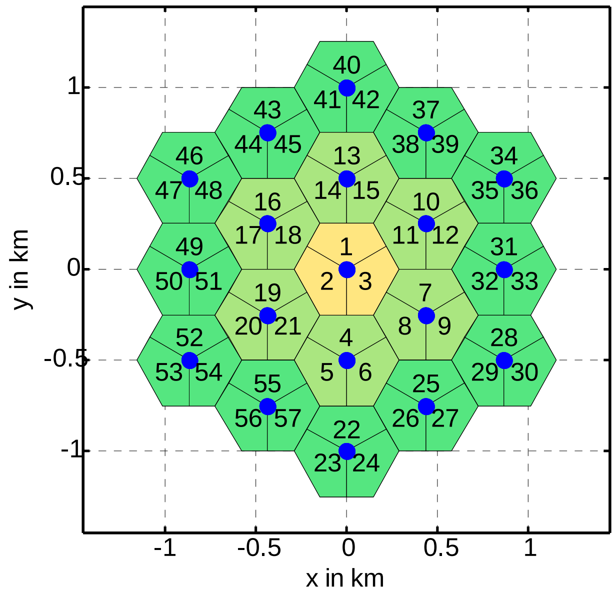
	Class A Network & System Level Simulator	Class B System Level Simulator	Class C System Level Simulator
Categorisation	Protocol & Dynamic system behaviour	Dynamic system behaviour, Snap-shot based	Snap-shot/Quasi-static based
Examples of functionalities addressed	JRRM, self-x	JRRM, DSM, self-x	Self-x
Simulated time scale	Up to several hours	order of minutes	Order of seconds
Basic features	Modelling of protocols, dynamic user behaviour	Semi-dynamic change of user behaviour	Quasi-static positions of users
Cell/System configuration	Multi-cell, multi-RATs	Multi-cell, multi-RATs or single RAT	Multi-cell, single RAT
Main outputs	• Network throughput • Service outage	• System throughput • User TP (DL, UL) • Call/packet blocking/ dropping rate • Spectrum utilization	• System throughput • User distribution • SIR distribution

Simulator example: LTE system simulator for self-x

⇒ **evaluation of self-x algorithms based on system-level simulations for a LTE mobile network.**

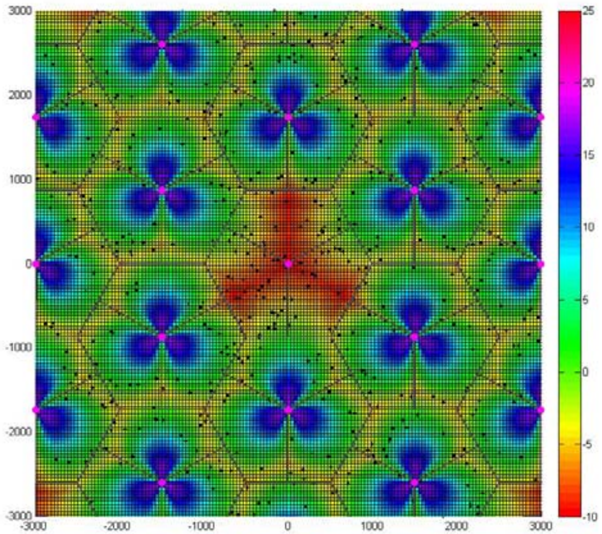
⇒ **Self-x use cases implemented: handover optimization, load balancing, cell outage compensation, and radio parameter optimization for home base stations.**



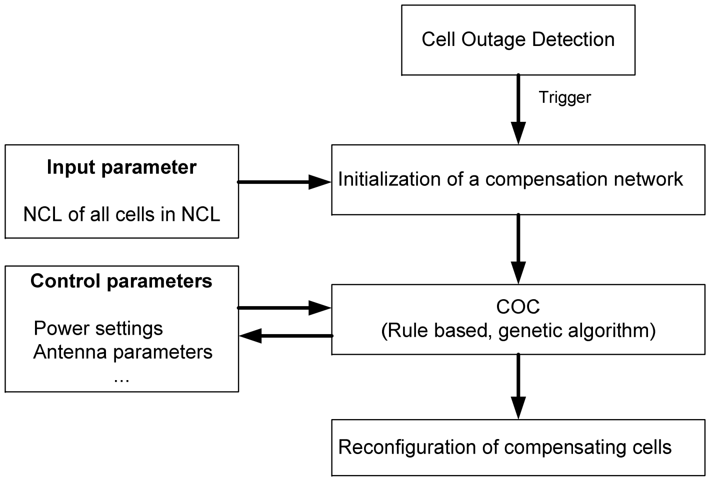


Cell outage compensation

- Best possible compensation of coverage loss due to BS failure by COC mechanism
- Trade-off between
  - ⇒ Reassignments of lost UE to the network
  - ⇒ Additional interference introduced by compensating cells with changed parameters (e.g. increased TX Power)

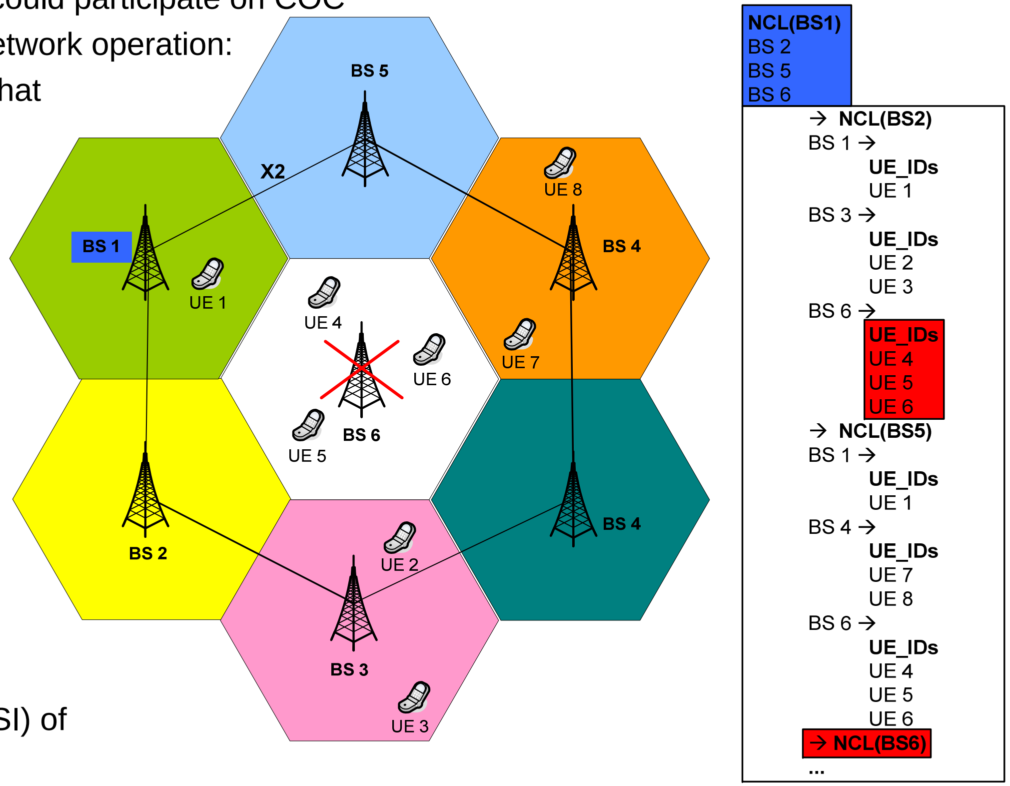


Cell outage situation with a random set of UEs



Cell outage compensation

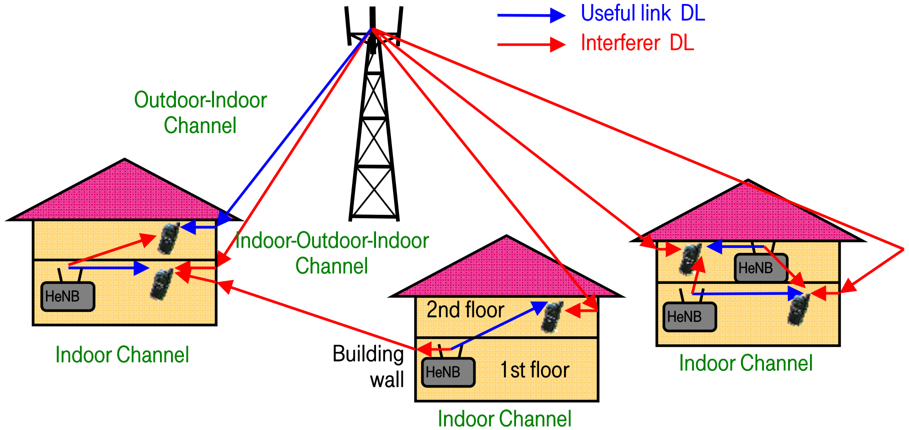
- Idea of the creation of a compensation network
- Compensation network consists of all cells which could participate on COC
  - ⇒ Needs additional information out of daily network operation:
    - Neighbour Cell List (NCL) of all cells that appear in a NCL of a cell
    - E-UTRAN Cell Identifier (ECI) of all cells appearing in foreign NCLs
    - UE IDs of all UEs assigned to foreign cells
- Communication via X2 Interface (decentralized solution)
  - ⇒ Every cell takes the Neighbour Cell List (NCL) of all neighbours, detected by its own NCL
  - ⇒ Knowledge of all E-UTRAN Cell Identifier (ECI)s which are useful to compensate cell outage in principal
  - ⇒ Every cell takes constantly the IDs (e.g IMSI) of all UEs that are assigned to their direct neighbours which appear in the NCL
  - ⇒ → Knowledge of all UE IDs of affected UEs, if cell outage occurs
  - ⇒ → Knowledge of all UEs which are reassigned to cells in the neighbourhood



Simplified example for the information search mechanism to create a compensation network

Home NB parameter optimization

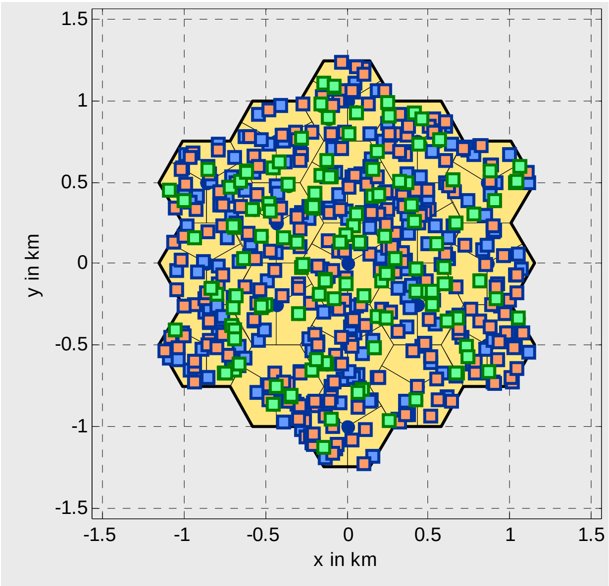
- Radio parameter optimization of Home Base Stations (HBS) in a co-channel situation
  - ⇒ Same RF carrier for HBS and Macro Base Station (MBS)
- Trade-off between
  - ⇒ Additional resources provided by each HBS
  - ⇒ Additional interference for MBS and existing HBS introduced by each new HBS
- Key benefits
  - ⇒ Improved indoor coverage
  - ⇒ Additional capacity provided by HBS
  - ⇒ Cost-efficient connections to the core network via DSL

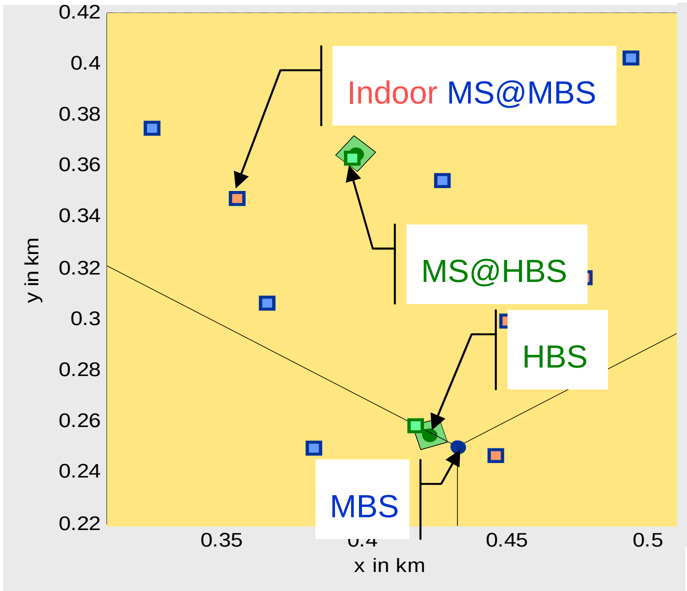


Co-channel situation for the downlink direction

Home NB parameter optimization

- Example for the distributions of mobile stations (MS) and home base stations (HBS)



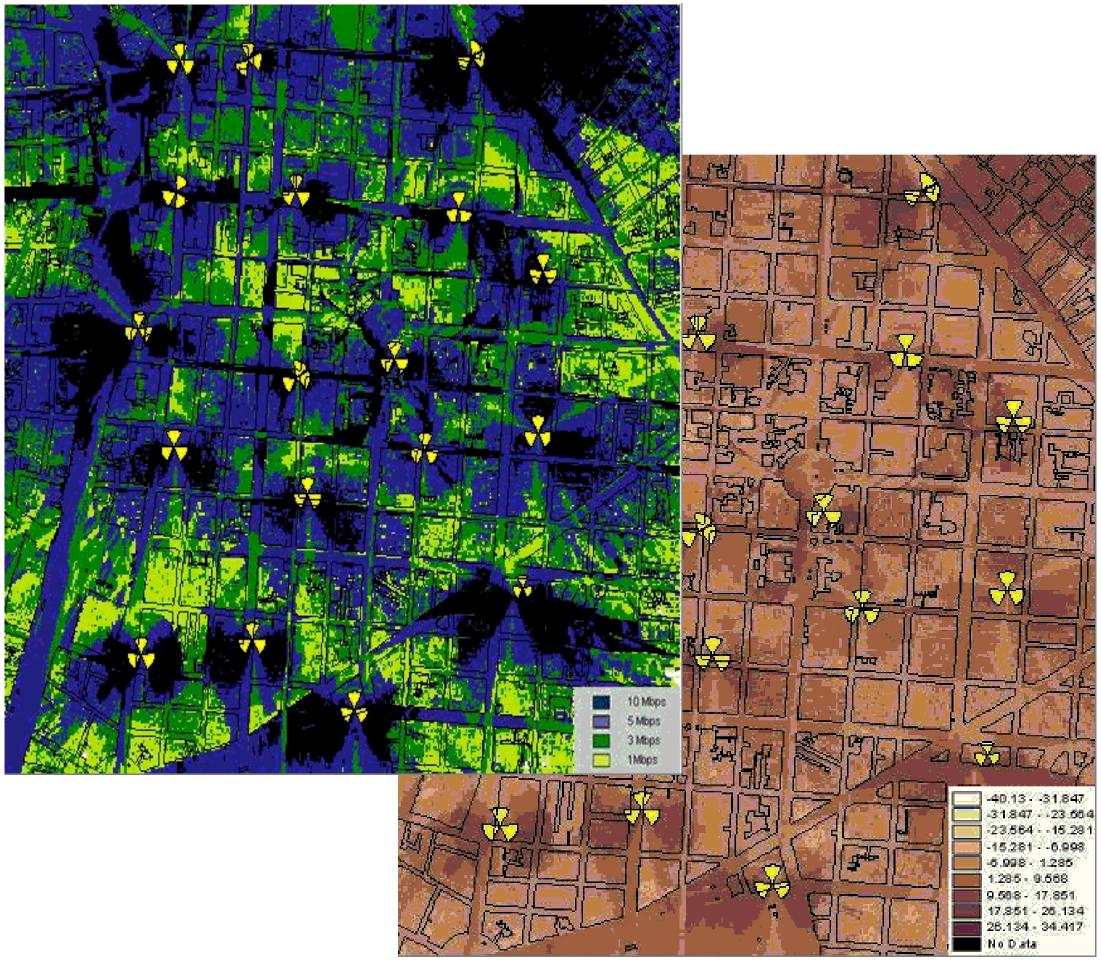


- Each BS – MS link can be characterized by a channel model.
- Multiple channel models based on WINNER II channel models are implemented.

- The following rules are assumed for the selection of the channel model:
  - ⇒ If two HBS have a distance less than 20m, both HBS are within the same building (indoor channel). Otherwise the femtocells are located in different buildings (indoor-outdoor-indoor channel).
  - ⇒ If an indoor MS@MBS have a distance to a HBS less than 6m, the MS is located in the same building like the HBS (indoor channel). Otherwise the MS is located in another building (indoor-outdoor-indoor channel). It is possible that an indoor MS@MBS is located in a building with multiple HBS.
  - ⇒ An outdoor MS@MBS is always outside of any building.
  - ⇒ An indoor MS@HBS is always inside the femtocell.

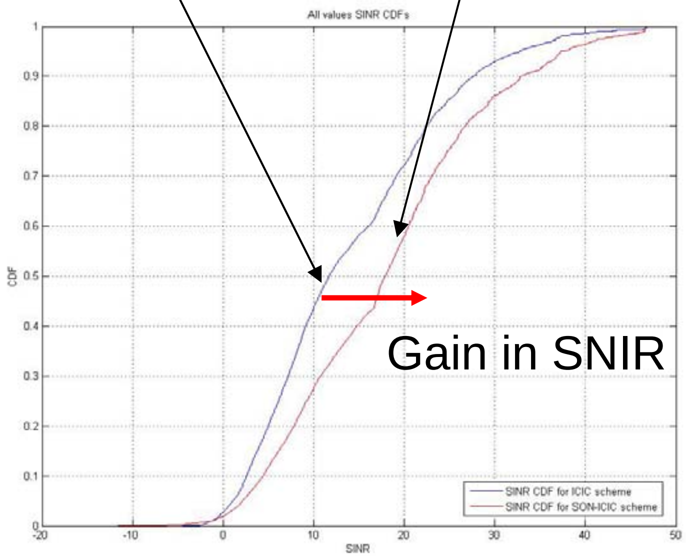
ICIC

- **Inter-cell Interference Co-ordination (ICIC) based on real network scenario**



ICIC: fixed reuse of resources for cell-edge users

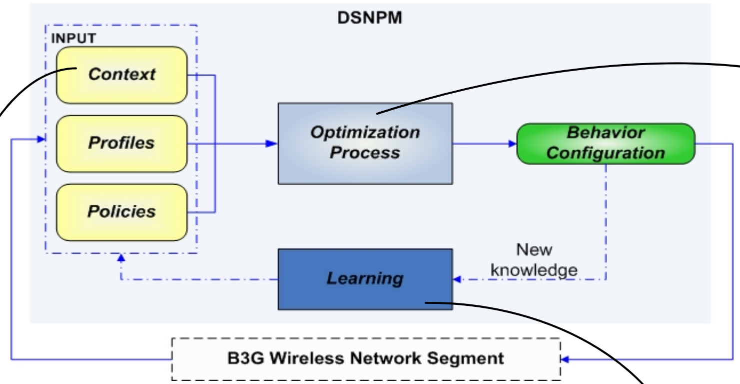
SON-ICIC: adaptation of cell-edge resources to traffic

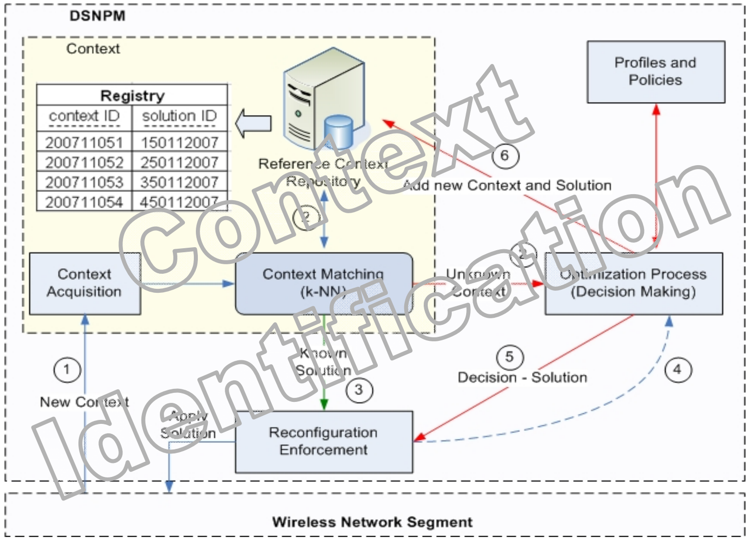


Knowledge based reconfiguration

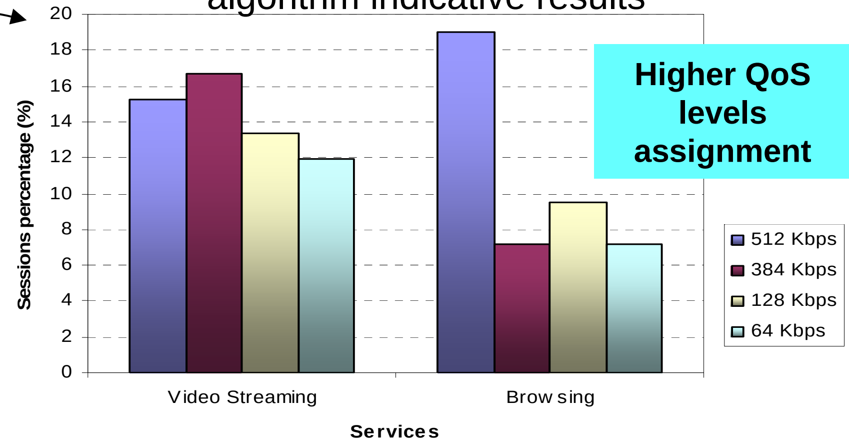
Self-x selection of algorithms and first evaluation results

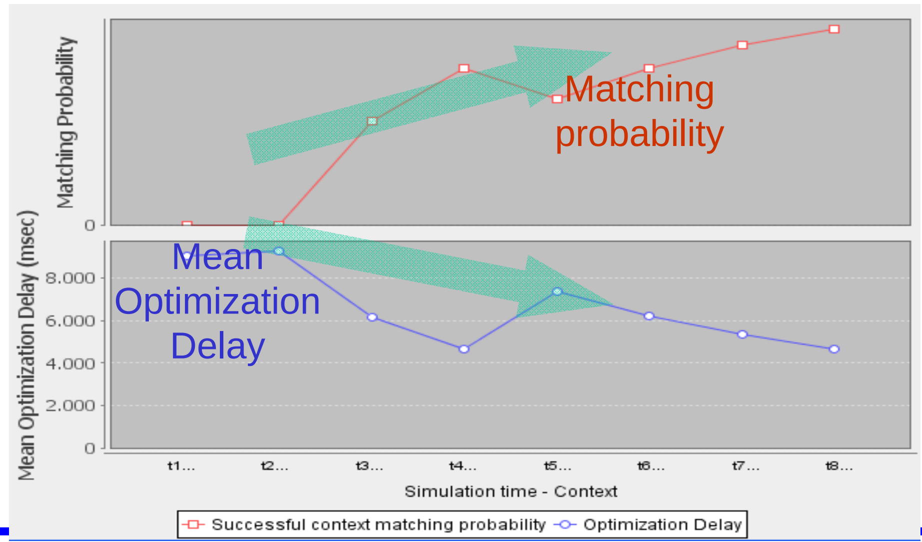
Have we addressed the context before?





Dynamic Sub-carrier Allocation (DSA) algorithm indicative results



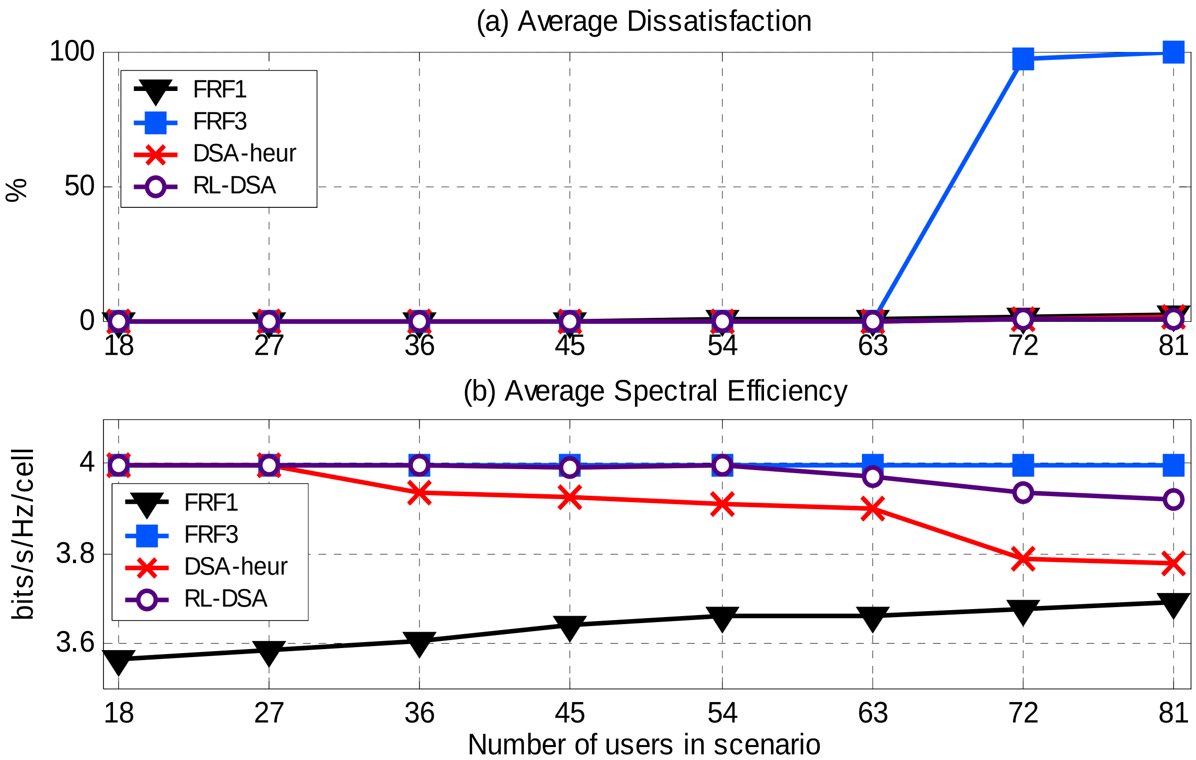


E^3 DSM

- Dynamic spectrum management (DSM) to achieve an efficient utilisation of the scarce and valuable spectrum resources:
  - ⇒ Maximise spectrum reuse amongst users, cells, radio access networks (RAN's) and systems
  - ⇒ Ensuring that mutual interference between them remains at acceptable levels at the same time
- Optimization methodologies covered in E3:
  - ⇒ Machine learning,
  - ⇒ Genetic algorithms,
  - ⇒ Simulated annealing,
  - ⇒ Heuristics, etc.

Dynamic spectrum mangement - example

- Multicell OFDMA
- Fixed spectrum assignment strategies compared with DSA algorithms
- Heuristic Algorithms and Reinforcement Learning (RL) Algorithms are proposed
- DSA algorithms improve spectral efficiency, user's QoS and spatial spectrum usage.
- First static results show that RL is suitable for DSA



Conclusions and outlook

- Increasing processing power and flexibility leads to enhanced radio resource management concepts

- Optimized operability and optimized usage of resources of radio access technologies is in focus of future systems

- Requirements and concepts for self-x were developed and are under investigation by means of simulation of algorithms

- Derivation of recommendations for advanced RRM including performance analysis of different algorithms

- Simulation of further operator use cases - HO parameter optimization & load balancing - : "Rule-based algorithms for self-x functionalities in radio access networks", Rosenberger, M. et al., ICT Mobile Summit Santander