Simulation of self-x algorithms

Dr.-Ing. Ingo Gaspard
Deutsche Telekom AG
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!**
10 different simulation environments in E3-WP3 → categorization of partners’ simulators according to functionalities studied

- Common assumptions and KPI’s for simulation

<table>
<thead>
<tr>
<th></th>
<th>Class A Network &amp; System Level Simulator</th>
<th>Class B System Level Simulator</th>
<th>Class C System Level Simulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categorisation</td>
<td>Protocol &amp; Dynamic system behaviour</td>
<td>Dynamic system behaviour, Snap-shot based</td>
<td>Snap-shot/Quasi-static based</td>
</tr>
<tr>
<td>Examples of functionalities addressed</td>
<td>JRRM, self-x</td>
<td>JRRM, DSM, self-x</td>
<td>Self-x</td>
</tr>
<tr>
<td>Simulated time scale</td>
<td>Up to several hours</td>
<td>order of minutes</td>
<td>Order of seconds</td>
</tr>
<tr>
<td>Basic features</td>
<td>Modelling of protocols, dynamic user behaviour</td>
<td>Semi-dynamic change of user behaviour</td>
<td>Quasi-static positions of users</td>
</tr>
<tr>
<td>Cell/System configuration</td>
<td>Multi-cell, multi-RATs</td>
<td>Multi-cell, multi-RATs or single RAT</td>
<td>Multi-cell, single RAT</td>
</tr>
<tr>
<td>Main outputs</td>
<td>- Network throughput</td>
<td>- System throughput</td>
<td>- System throughput</td>
</tr>
<tr>
<td></td>
<td>- Service outage</td>
<td>- User TP (DL, UL)</td>
<td>- User distribution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Call/packet blocking/ dropping rate</td>
<td>- SIR distribution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Spectrum utilization</td>
<td></td>
</tr>
</tbody>
</table>
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 Detection
  - Trigger
  - Input parameter
    - NCL of all cells in NCL
  - Control parameters
    - Power settings
    - Antenna parameters
    - ...
  - Initialization of a compensation network
  - COC (Rule based, genetic algorithm)
  - Reconfiguration of compensating cells
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
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
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).
⇒ An outdoor MS@MBS is always outside of any building.
⇒ An indoor MS@HBS is always inside the femtocell.
- 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

Gain in SNIR
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

Higher QoS levels assignment

DSNPM

Context

Profiles and Policies

Optimization Process

Behavior Configuration

Learning

B3G Wireless Network Segment

Video Streaming

Browsing

Sessions percentage (%)

Higher QoS levels assignment

Mean Optimization Delay

Simulation time - Context

Successful context matching probability

Mean Optimization Delay
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.
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

(a) Average Dissatisfaction

(b) Average Spectral Efficiency
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