SON in 4G Mobile Networks

Self-Optimization Techniques for Intelligent Base Stations

Bell Labs Stuttgart

Ulrich Barth

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Self- organizing Radio Access Networks
Motivation

Current situation for radio access network management

- Deployment and maintenance become more and more complex and cost extensive
  - Trend to smaller cells, multi-band operation, heterogeneous mobile networks
  - High manual intervention for configuration, capacity upgrade or in failure cases required
- High effort required for optimisation of system performance
  - Deep system expertise required
  - High effort necessary for measurement campaigns (drive tests)
- Different tools for planning, configuration, measurement/KPI acquisition and optimisation involved

increasing effort for network management and optimisation

➔ new concepts for simplified network operation required

Self- organizing Radio Access Networks
Requirements

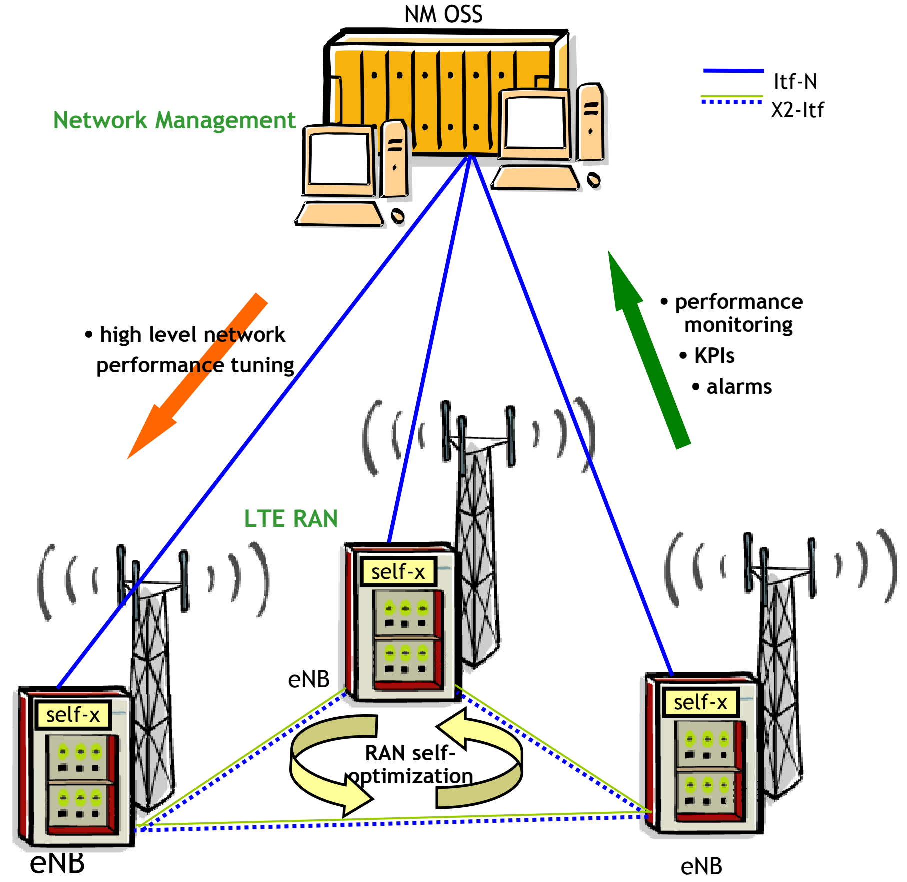
Management of radio access networks has to be self-organized in future

- Automated configuration, optimization and fault management:
  - towards real plug-and-play self-configuration
  - continuous up to autonomous self-optimization
  - fast self-healing mechanisms
- Paradigm change:
  - to put network optimization know how into intelligent self-x algorithms
  - to focus network management on high level monitoring and performance tuning
- High performance self-x algorithms required:
  - fast convergence
  - stable operation
  - tuneable according to operator requirements
  - managing mutual dependencies between self-x use cases

Self-X Architecture

Vision of fully distributed self-management

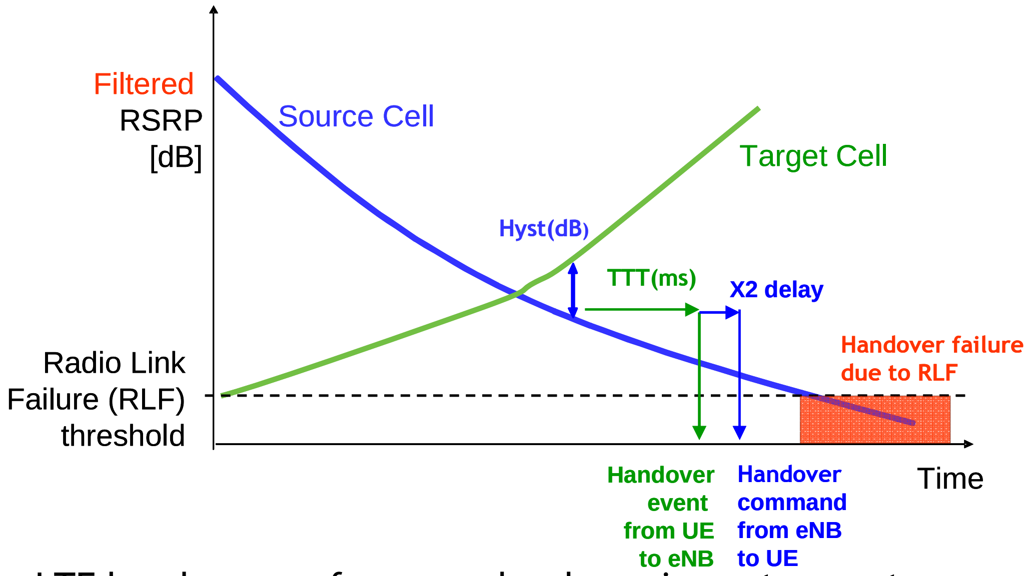
- "NEM less" network management
- Fully autonomous, distributed RAN optimisation
- Self-x functions in UE and eNB
  - measurements, UE location info
  - alarms, status reports, KPIs
  - distributed self-x algorithms
- Network management in NM OSS focussed on
  - network planning
  - alarm and performance monitoring
  - high level performance tuning

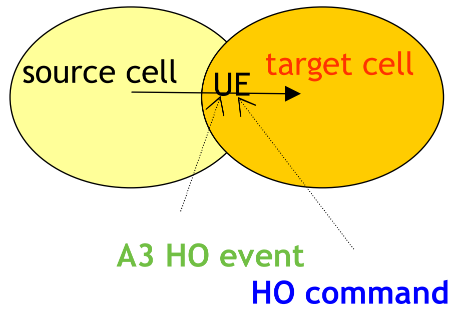


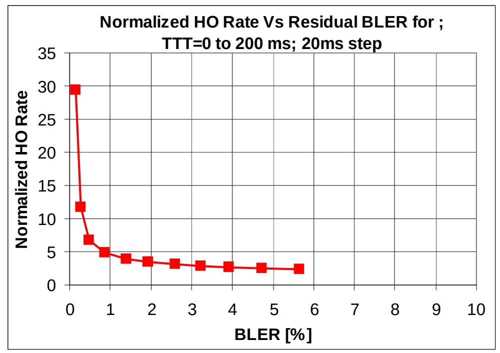
OSS: Operation Support System
NEM: Network Element Manager

Mobility Robustness (Handover Optimization)

Configuration Parameters for Handover in LTE







BLER: block error rate of HO command → RLF

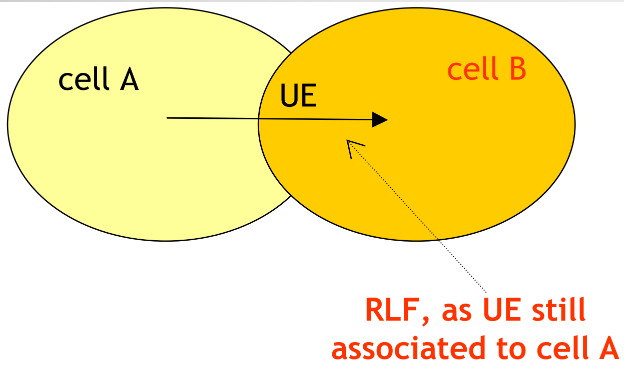
Normalized HO rate: without slow/fast fading

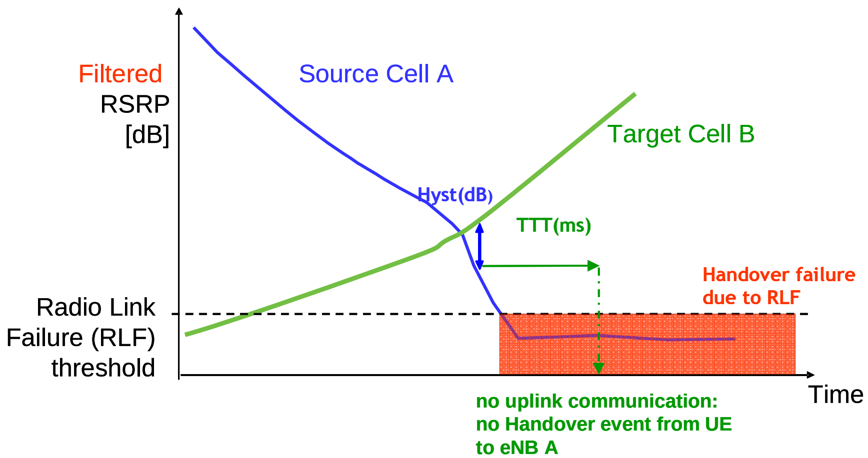
LTE handover performance has large impact on system performance

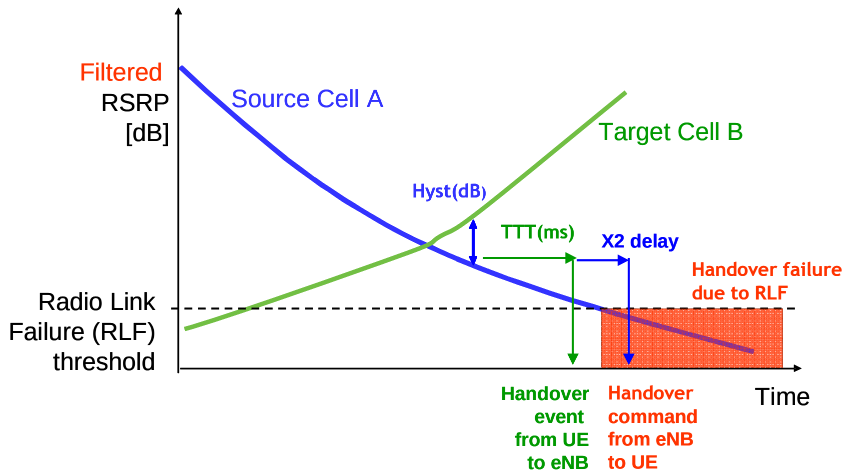
- Configuration parameters
  - Filtered RSRP values
  - Handover Margin, i.e. hysteresis between source and target
  - Time to trigger (TTT)
  - Cell Individual Offset (CIO), add on handover margin
- Target
  - High handover success rate

SON algo:
find best trade-off between minimum BLER and minimum HO rate (ping pong)

SON definition: too late Handover



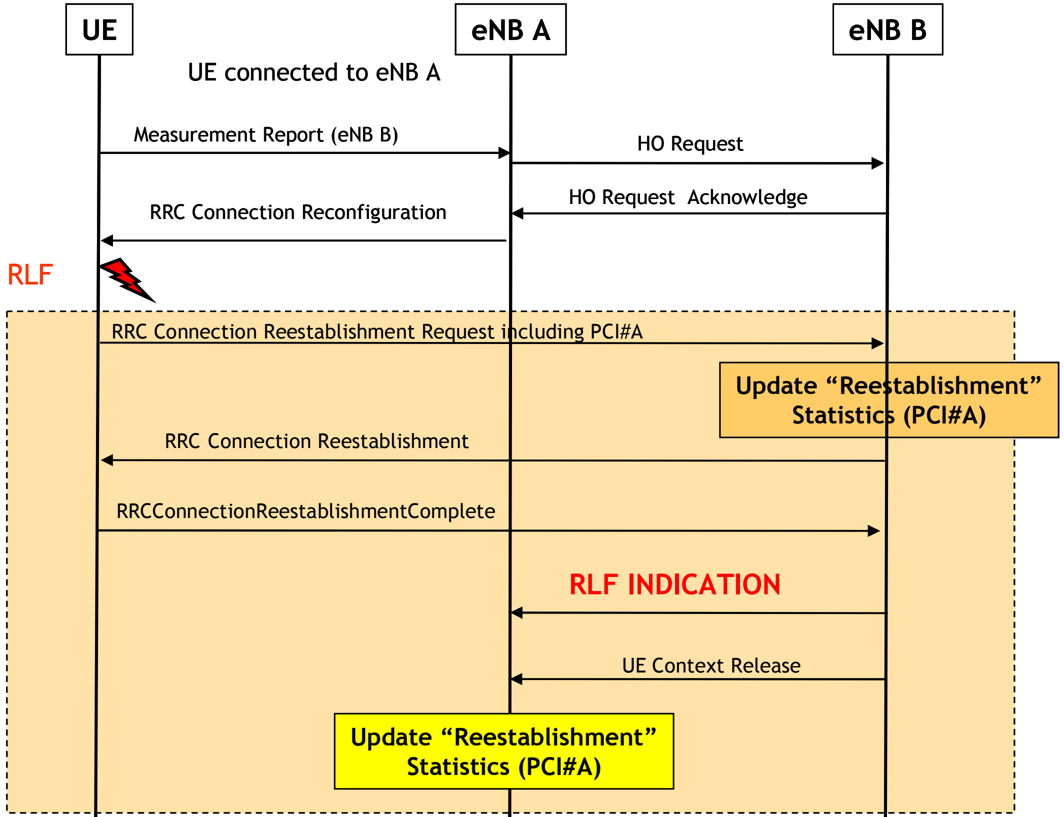




Alternative 1: a failure occurs in the source cell before the HO was initiated

Alternative 2: a failure occurs in the source cell during the HO procedure

Messages and algorithm for “too late” handover



SON Algorithm

- sufficient measurements for decision of HO problem ?
- analysis of measurements and other data (own eNB and other eNB)
- modify HO parameters
    - for all UE speed classes
    - mobility state dependent
- start new measurement cycle

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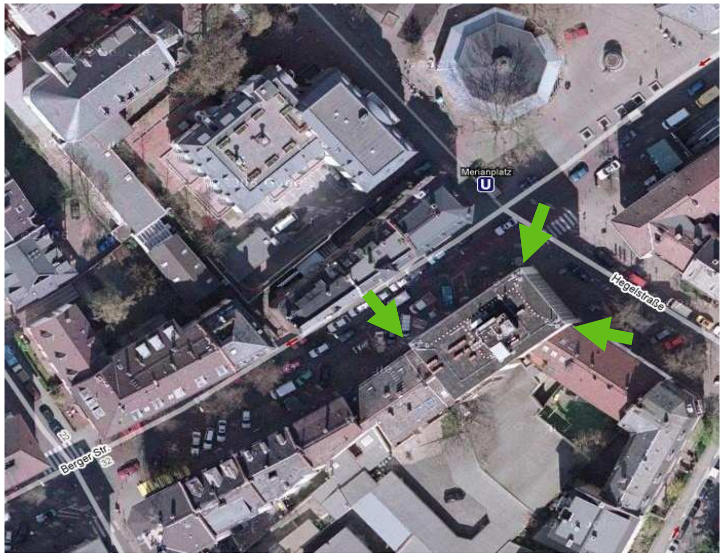
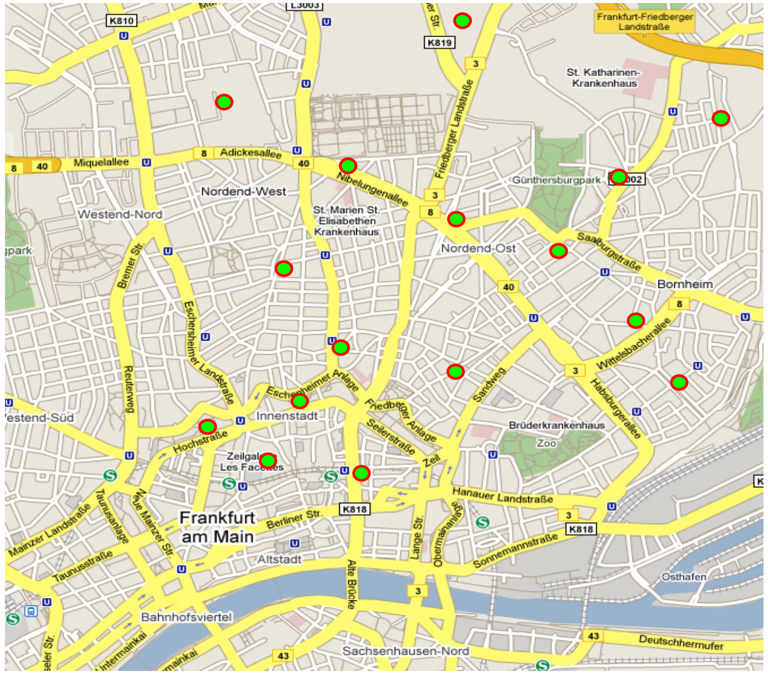
SON based HO optimization

Characteristics of simulation scenario “Frankfurt”

Available ray-tracing data

- Input data characteristics:
  - 16 real world antenna locations in the city of Frankfurt
  - Tri-sectorized configuration (i.e. 48 cells)
  - individual antenna type information, heights and beam directions
  - topographic map of region (4000m × 4000m)
- Output data characteristics:
  - Integer type pathloss data per 10m × 10m grid point per antenna
  - Range: -88dB to -214dB





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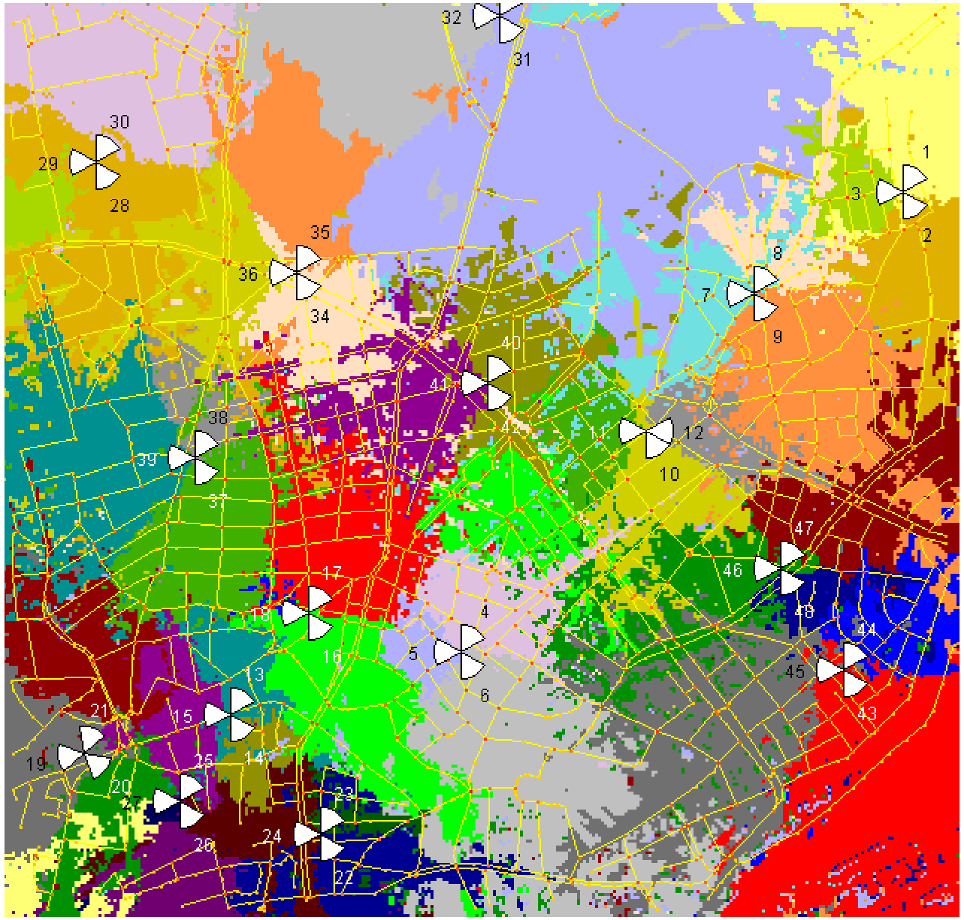
Algorithm test in simulation



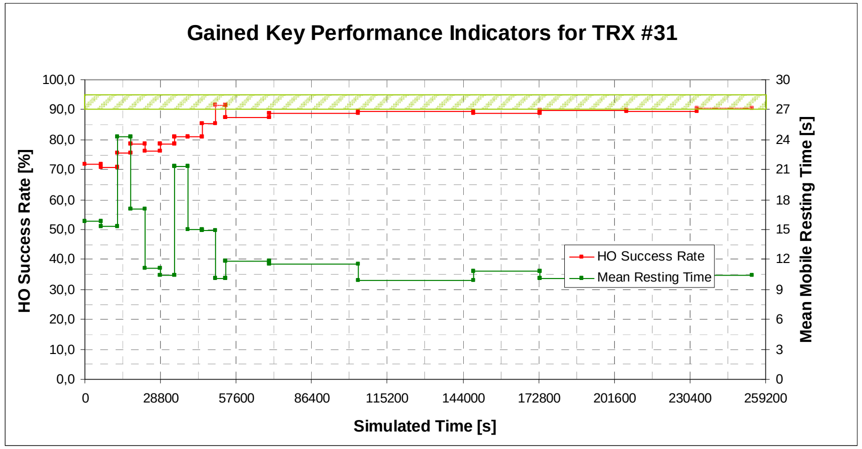
- Event based simulation of HO events, one algorithm instance per simulated cell
- Interference level: 50% load
- mobile speed: 3, 30, 120 km/h
  - 16 mobiles active per speed
  - moving along given roads
  - at crossroads, mobiles choose randomly next road
- same initial mobility parameters at simulation start

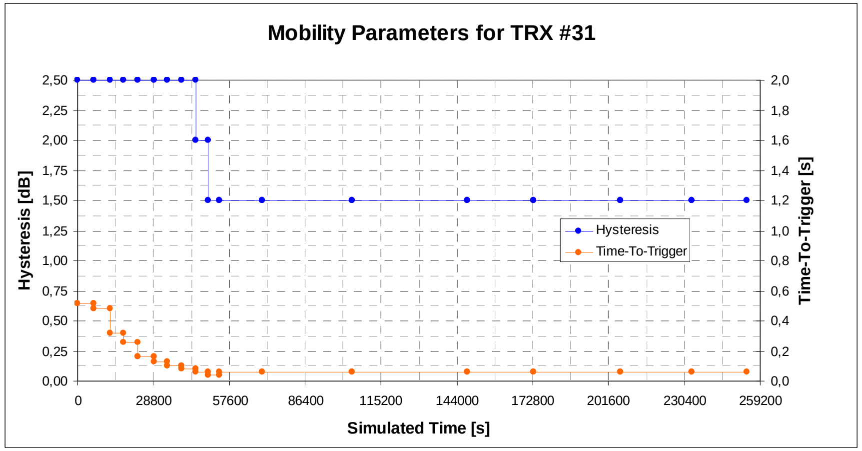
SON based HO optimization

HO success rate window controller

Simulation results

(Simulated network operation: 3 days = 259200 s)





- A quick convergence of the cell global parameters can be observed for frequently visited cells (i.e. on many HO events)
- Choosing initial HO parameters above optimal settings causes a HO success rate below given limit
- The algorithm instance tunes the parameters towards earlier decision for HO, achieving an improvement of the cell total HO success rate

Coverage and Capacity Optimisation

Antenna Tilt Optimization

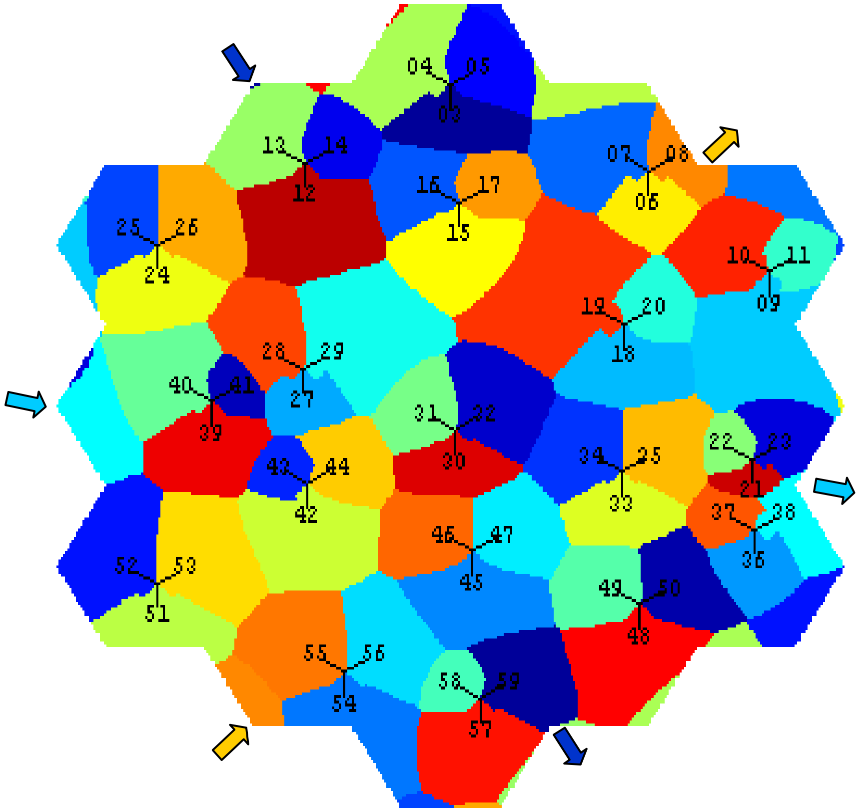
Optimization goals:

- sector coverage
- sector capacity
- based on downlink performance metric bits/sec/Hz

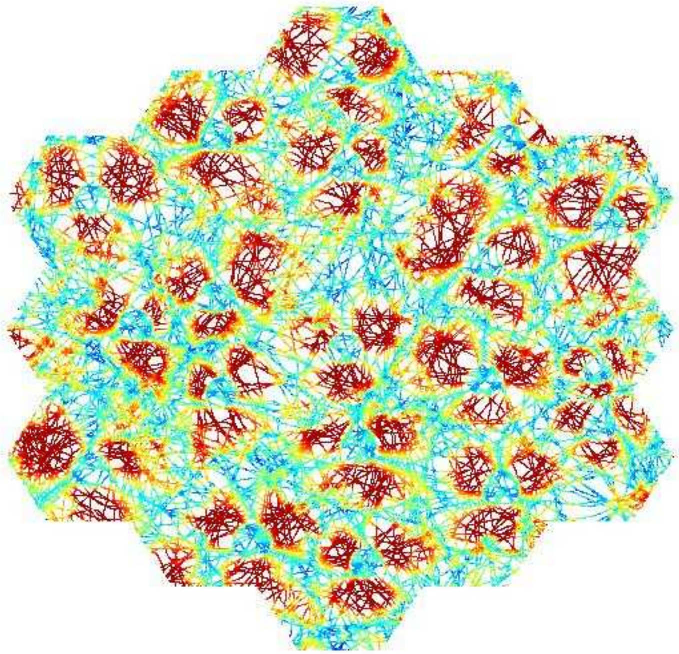
Approach:

- Distributed optimization:
  - optimization of single cells together with closest neighbors
    → targeting global optimum
  - by adjusting the antenna tilt for each sector individually
  - distributed approach, co-operating eNB and neighbours

Antenna Tilt Optimization
Best Serving Sectors, Displaced Site Locations



after optimization



- sites are displaced but playground borders are kept fixed, with wrap around
- slow fading with area correlated shadowing is invisible in best server plots due to the equal attenuation of all sectors at a certain point, independent of the direction of the signal

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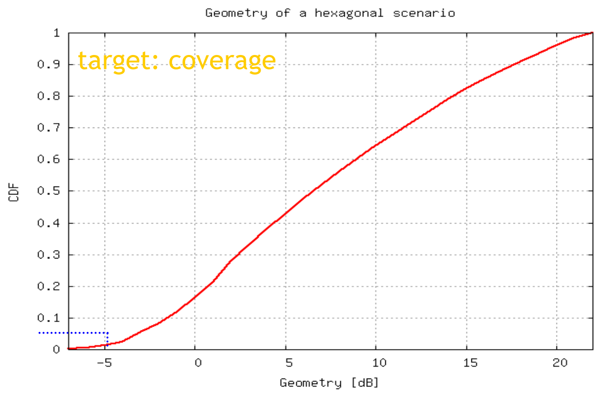
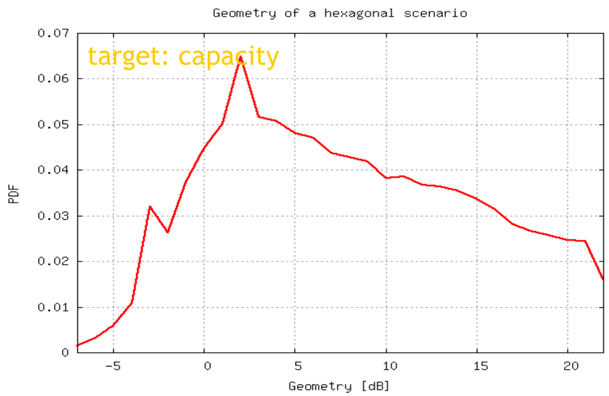
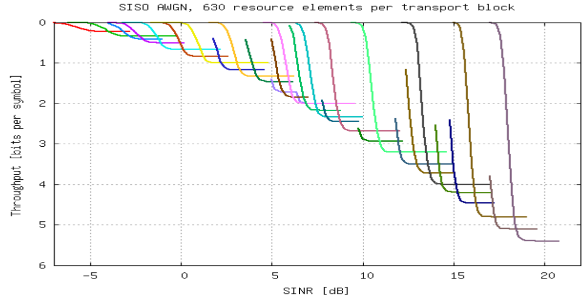
Antenna Tilt Optimization
Metrics

Cell wide optimization approach







M: performance metric
G: Geometry
B: bandwidth
p(G): probability
T_{tf}: throughput per MCS
W: weighting factor

coverage metric:

$$M_1 = B \cdot T_{tf}(G_{5-percentile})$$

capacity metric:

$$M_2 = B\int_{G_{\min}}^{G^{\max}} p(G)\cdot T_{tf}(G)dG$$

next charts:

concrete simulation studies: operator tunable weighting parameter W = 0.91

➔ weighted coverage/capacity metric:

$$M = W \cdot B \cdot T_{tf}(G_{5-percentile}) + (1-W)\cdot B\int_{G_{\min}}^{G^{\max}} p(G)\cdot T_{tf}(G)dG \qquad (1)$$

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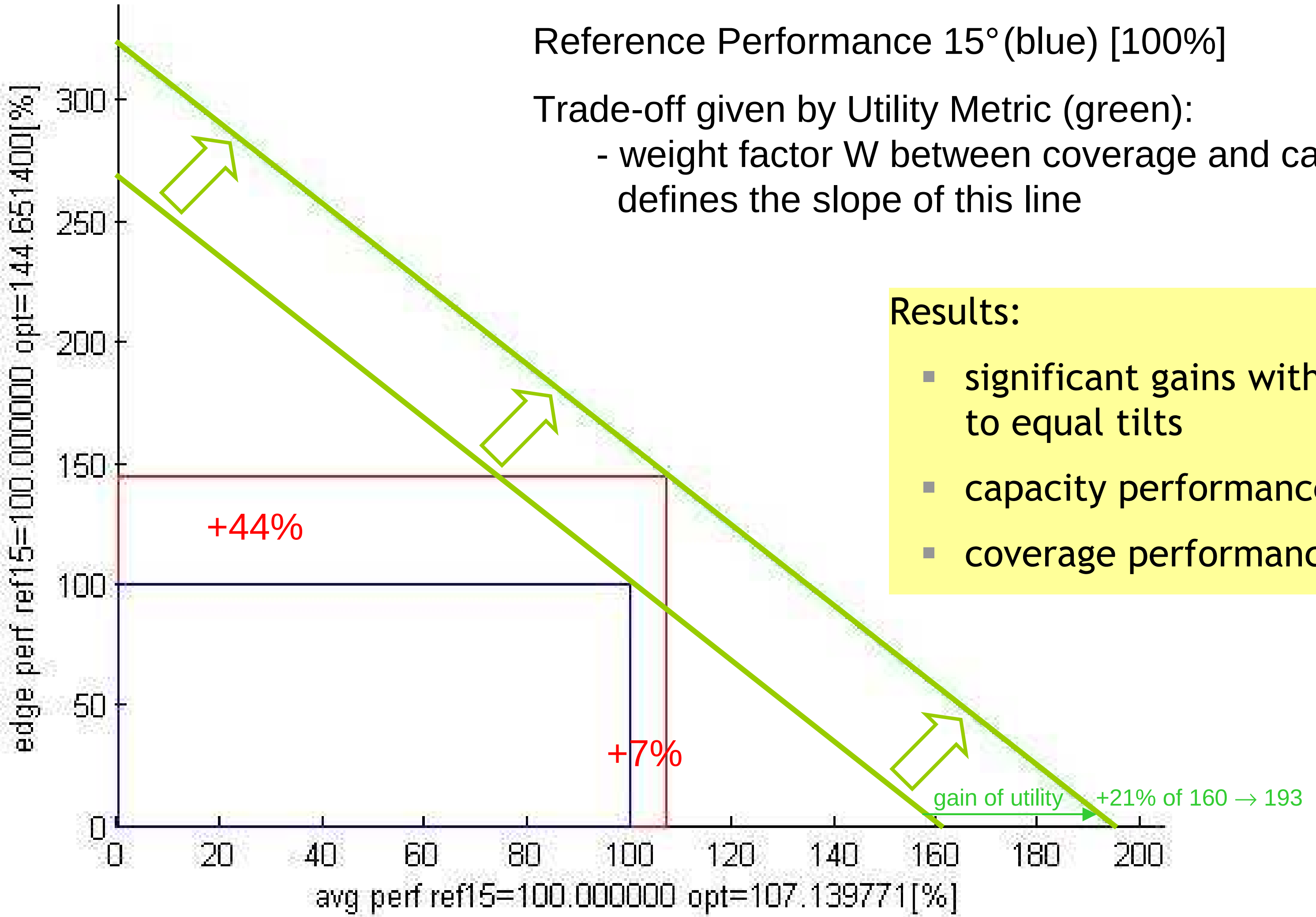
Antenna Tilt Optimization

Performance Gains of Sector Average Performance and Sector Edge Perf.

Optimized Performance (red) [%]

Reference Performance 15° (blue) [100%]

Trade-off given by Utility Metric (green):
- weight factor W between coverage and capacity defines the slope of this line



Results:

- significant gains with respect to equal tilts
- capacity performance +7%
- coverage performance +44%

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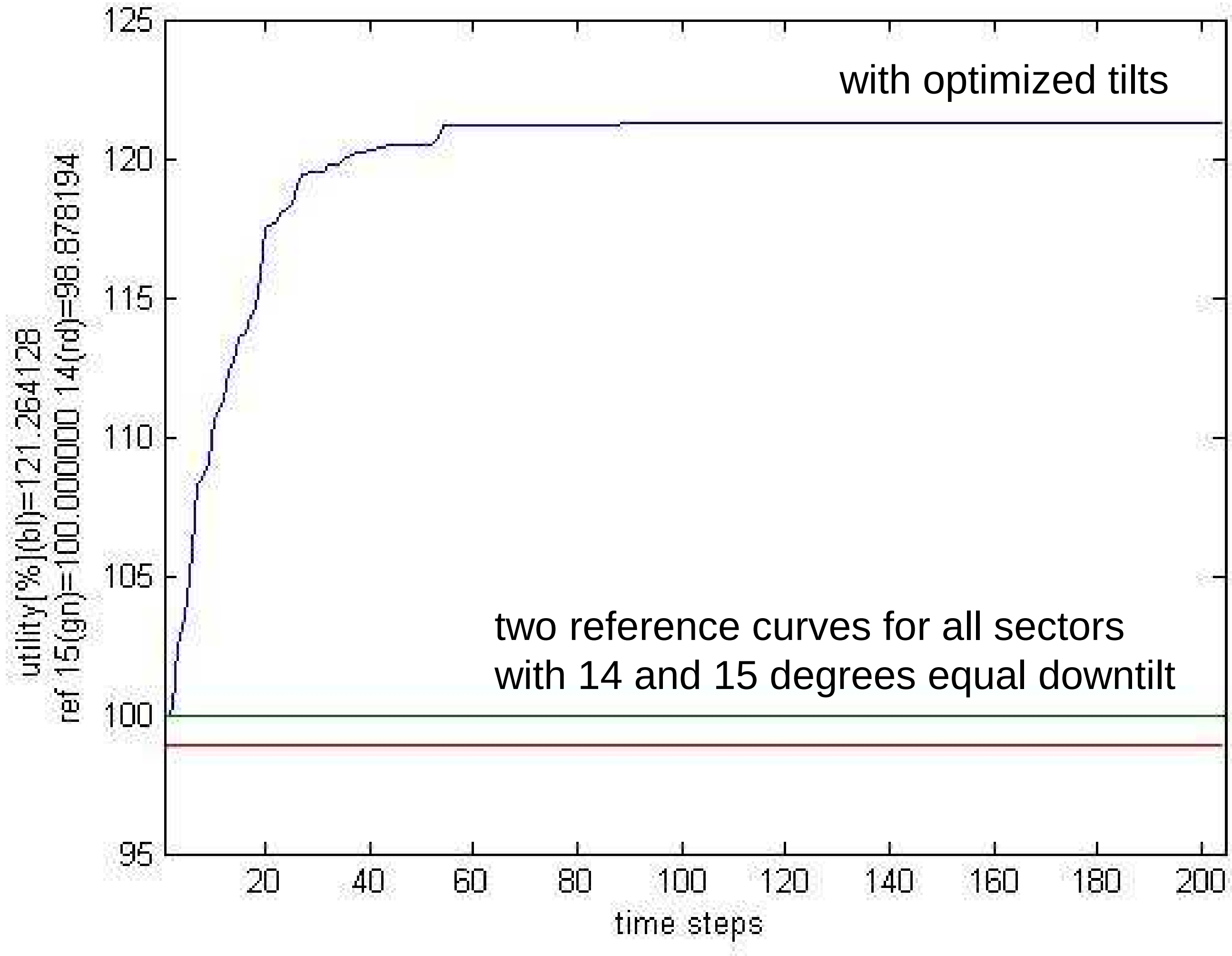
Antenna Tilt Optimization
Convergence Speed and Gains of Performance Metric



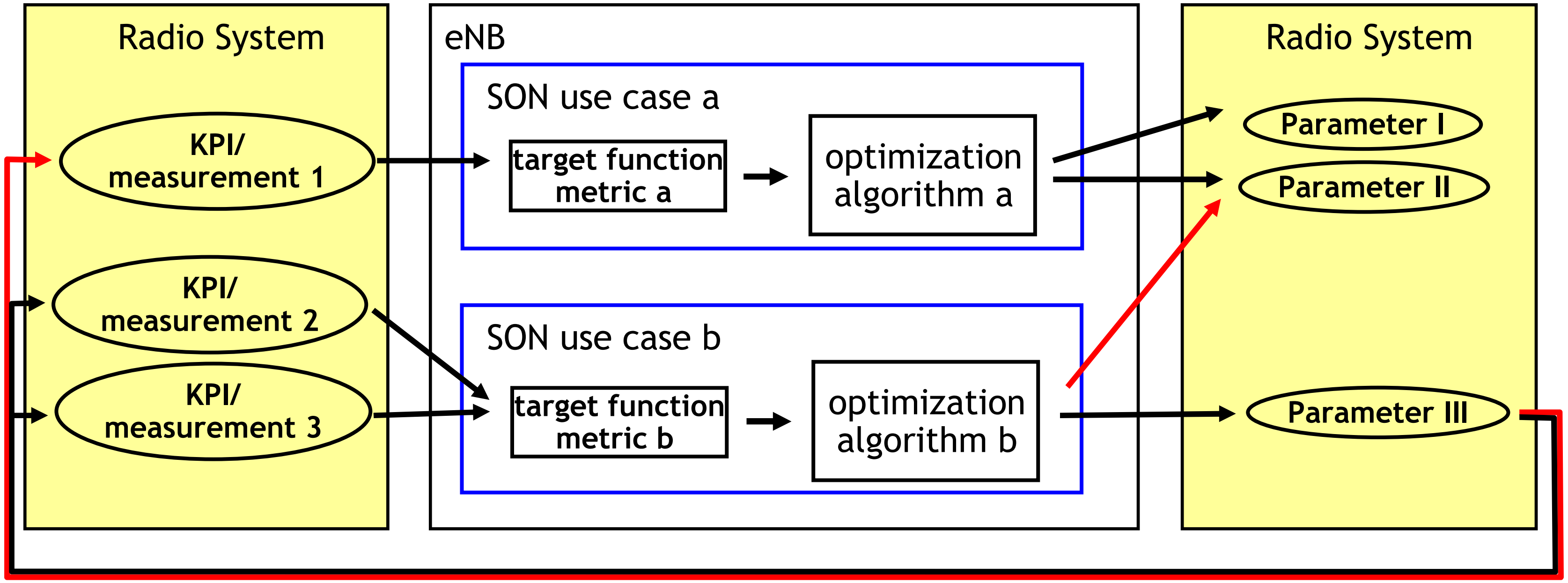
one cyle through all sectors equals 57 steps

Results:

- promising, playground wide improvement
- non-oscillating
- fast convergence

SON challenges

Mutual interactions of SON optimization algorithms



Mutual impact on optimization target:
One metric is influenced by parameters of different SON algorithms

Interference Coordination <-> Load balancing

Coupling by same control parameter:
One parameter is modified by different SON algorithms

Handover <-> Load balancing

- different coupling mechanisms, different coupling strength

⇒ solution required to manage SON use case interworking !

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