Evaluation of Self-x Approaches for Mobile Radio Networks using Cell Level Simulations

Philipp P. Hasselbach, Anja Klein

Communications Engineering Lab
Technische Universität Darmstadt, Germany

Matthias Siebert

Deutsche Telekom/T-Systems Enterprise Services GmbH
Darmstadt, Germany

This work was partly funded by Deutsche Telekom AG and is part of the corporate project SORAN (self-optimizing radio access networks).

Why Self-organising Systems?

Increasing network complexity

- Future mobile radio networks trends
  - Multiple Radio Access Technologies
  - Increasing variety of services
  - High data rates
- Increased operational effort, complexity, cost
- Automatic network planning, operation, optimisation required

Self-organising functionality

- Ensuring manageability
- Reduction of operational effort
- Increase of resource efficiency

Self-organising Functionality

TECHNISCHE UNIVERSITÄT DARMSTADT

Self-x

- **Self-planning**
  - network planning
  - automated
- **Self-configuration**
  - initial operating parameters
  - download/ cognitive/ interactive
  - automated
- **Self-optimisation**
  - parameter adjustment
  - adaptation to changes
  - automated
- **Self-healing**
  - reaction to failures
  - automated

Self-organising Functionality

TECHNISCHE UNIVERSITÄT DARMSTADT

Self-x

- **Self-planning**
- network planning
- automated

- **Self-configuration**
- initial operating parameters
- download/ cognitive/ interactive
- automated

- **Self-optimisation**
- parameter adjustment
- adaptation to changes
- automated

- **Self-healing**
- reaction to failures
- automated

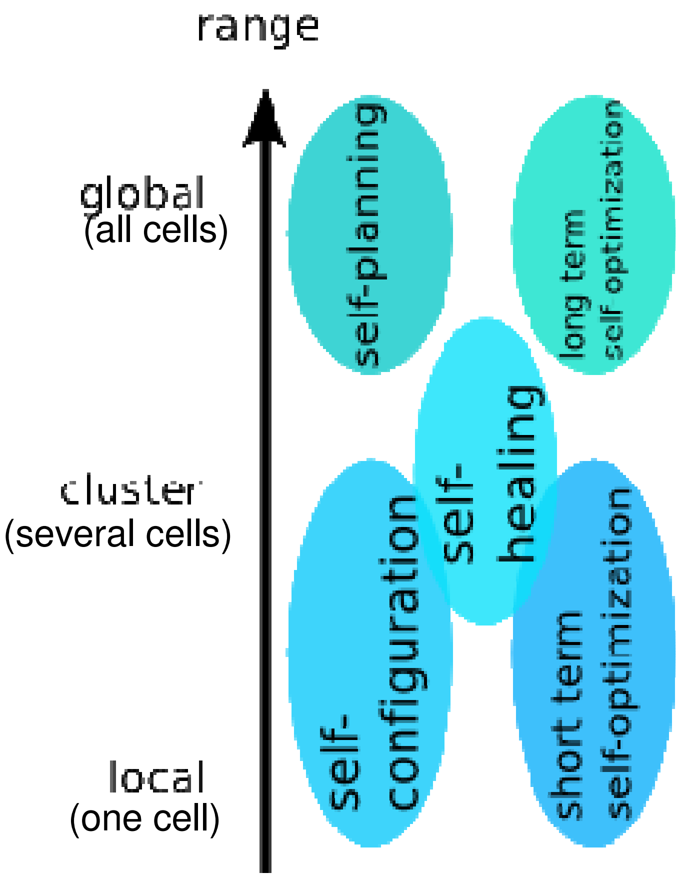
Outline

TECHNISCHE UNIVERSITÄT DARMSTADT

- **Simulation Fundamentals**
- Bandwidth Demand Model and Cell Outage Probability
- Key Data of the Simulative Approach and Simulation Example

Spatial Classification of Self-x

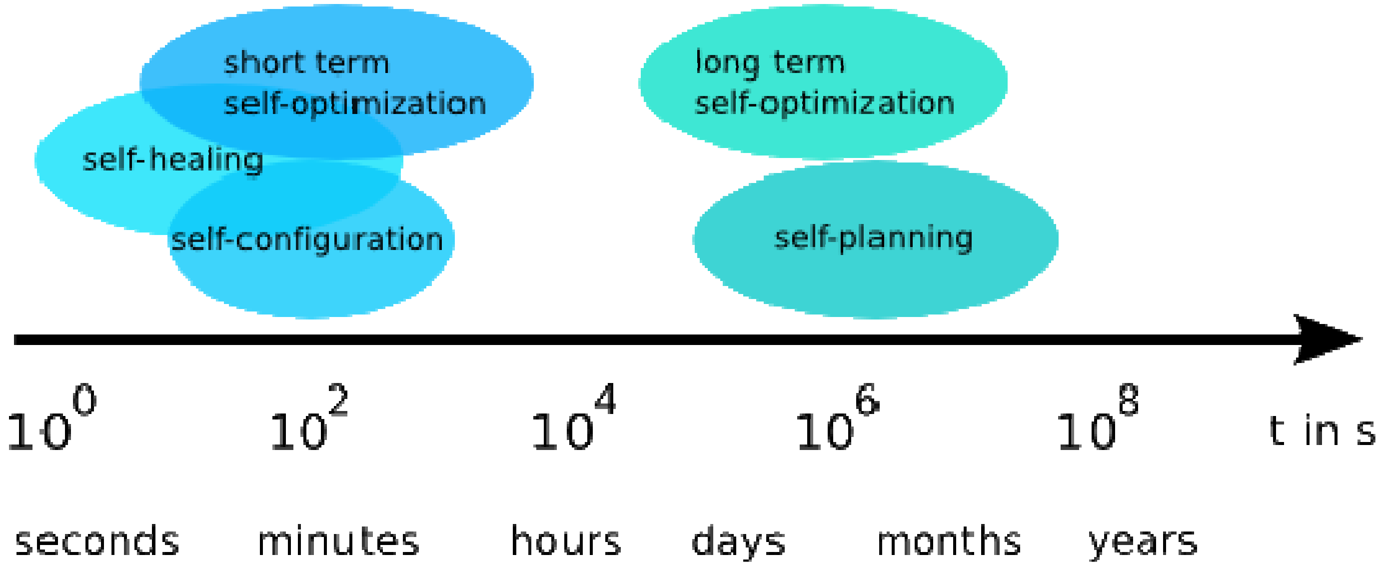
TECHNISCHE UNIVERSITÄT DARMSTADT



- Cells are in the focus
  - Several, interdependent cells
- Simulation at cell-level

Temporal Classification of Self-x

TECHNISCHE UNIVERSITÄT DARMSTADT

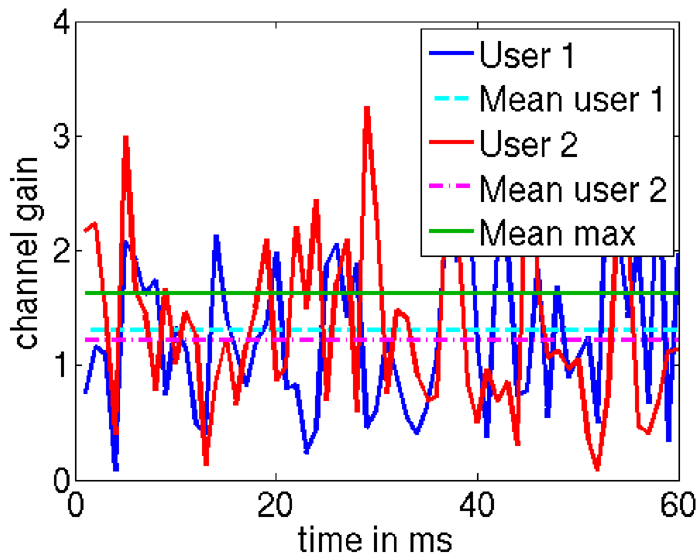


- Large timescales
  - Duration of minutes, hours, days
  - Time steps of seconds, minutes, hours
- Fast fading averaged out

Scheduler Assumption, QoS

TECHNISCHE UNIVERSITÄT DARMSTADT

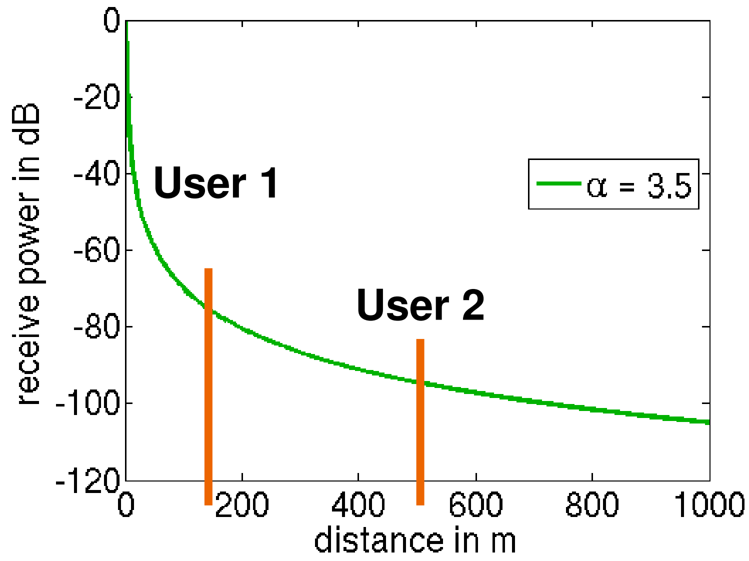
- Scheduling increases average SINR
  - Example: max SINR
  - Decrease in required resources
- Sufficient QoS achievable if sufficient resources available
  - w.r.t. delay, maximum/minimum/average data rate, data rate jitter,…

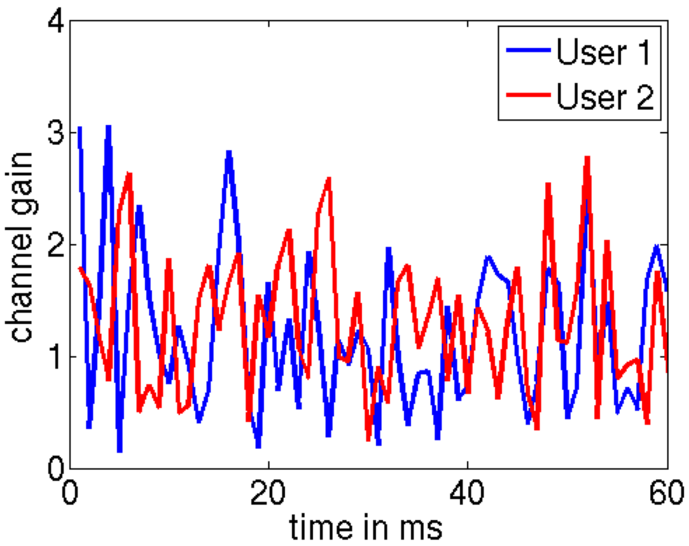


- Focus on determining and evaluating resource situation
  - Resource demand/resource supply of the cells
- QoS is expressed in terms of average user data rate
  - Further QoS parameters achievable according to scheduler assumption

Bandwidth Averaging

- Cell bandwidth demand = sum of user bandwidth demands
  - All users of one cell considered jointly
- User bandwidth demands depend on service type, channel and user position
  - Fluctuations in user bandwidth demand





- Simulation at cell-level: Bandwidth averaging over all users
  - Influence of service type, fast fading, and user position mitigated
  - Bandwidth demand fluctuations mitigated

Outline

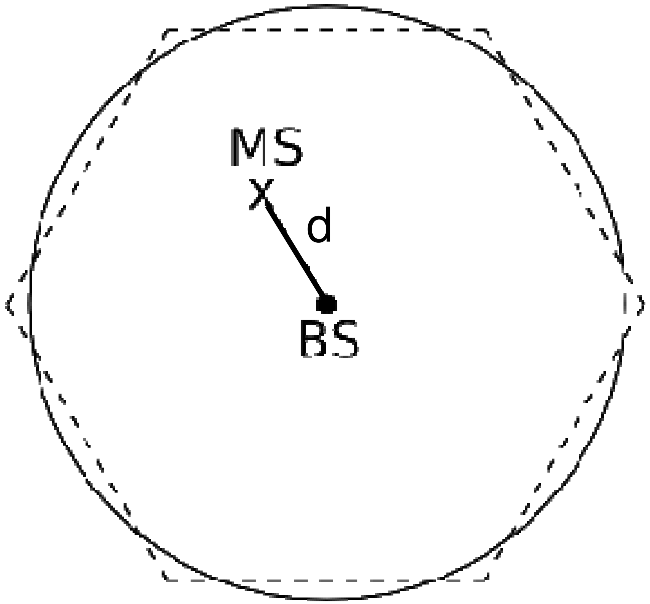
TECHNISCHE UNIVERSITÄT DARMSTADT

- Simulation Fundamentals
- **Bandwidth Demand Model and Cell Outage Probability**
- Key Data of the Simulative Approach and Simulation Example

User Bandwidth Demand PDF

TECHNISCHE UNIVERSITÄT DARMSTADT

- Single cell scenario



User position PDF

$$f_{r,\varphi}(r,\varphi)$$

$$\rightarrow f_d(d)$$

$$\rightarrow f_{PL}(PL)$$

$$\rightarrow f_{SINR}(SINR)$$

$$\rightarrow f_B(B)$$

Bandwidth demand PDF of a single user

η : user data rate
B : user bandwidth
γ : receiver SINR

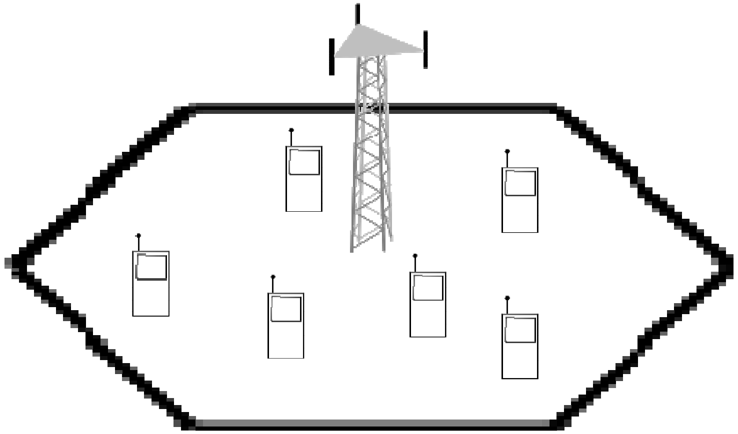
- Bandwidth demand of a single user

$$B = \frac{\eta}{\log_2(1+\gamma)}, \quad \gamma = \frac{1}{d^{\alpha}} \cdot \frac{P_{\mathrm{tx}}}{P_{\mathrm{N}} + P_{\mathrm{I}}}$$

Cell Bandwidth Demand PDF

TECHNISCHE UNIVERSITÄT DARMSTADT

- K independent users



- η_i : data rate requirement of user i
- B_i : bandwidth demand of user i
- Cell bandwidth demand for FDMA

$$B_{\text{cell}} = \sum_{i=1}^{K} B_i$$

For data rates of comparable order:

Central Limit Theorem

$$\Rightarrow f_{B_{\text{cell}}}(B_{\text{cell}}) \sim N(\mu_{\text{cell}}, \sigma^2_{\text{cell}})$$

$$\mu_{\text{cell}} = \sum_{i=1}^{K} \mu_i \ , \quad \sigma^2_{\text{cell}} = \sum_{i=1}^{K} \sigma_i^2$$

$$f_{B_i}(B_i) \Rightarrow \mu_i, \sigma_i^2$$

Bandwidth Demand: Examples

TECHNISCHE UNIVERSITÄT DARMSTADT

Cell radius $R = 250$ m, $\alpha = 4$

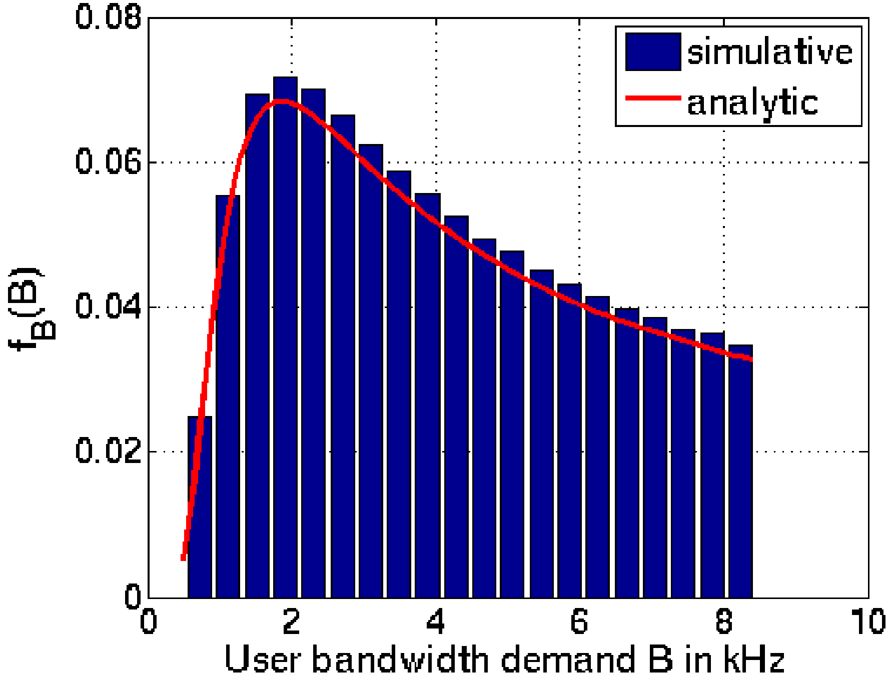
$P_{\mathrm{tx}} = -70$ dBm/Hz

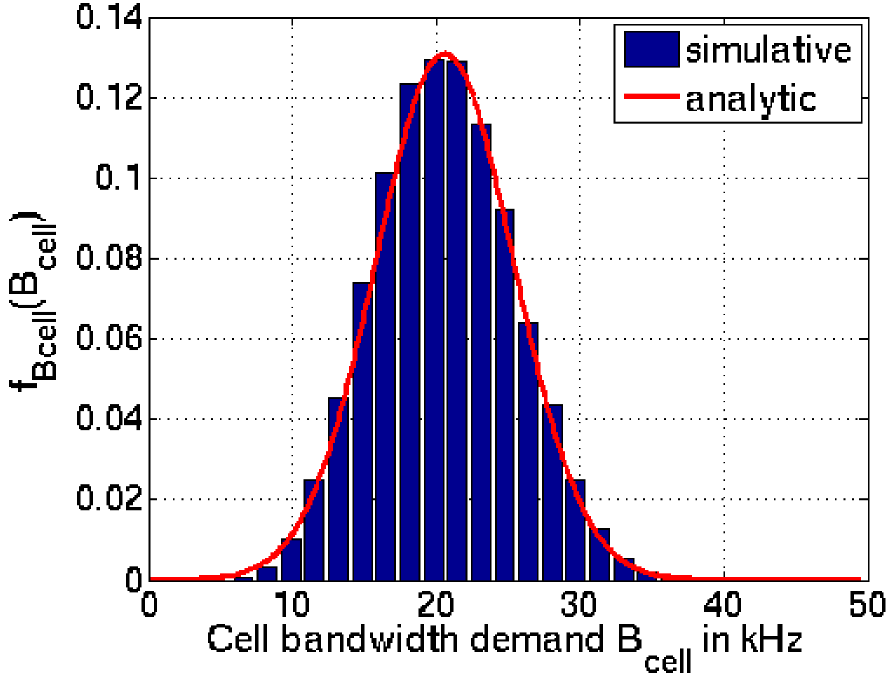
$P_{\mathrm{N}} + P_{\mathrm{I}} = -167$ dBm/Hz

$K = 5$, Uniform user distribution

$\eta_i = 10$ kbit/s , $i = 1 \ldots K$

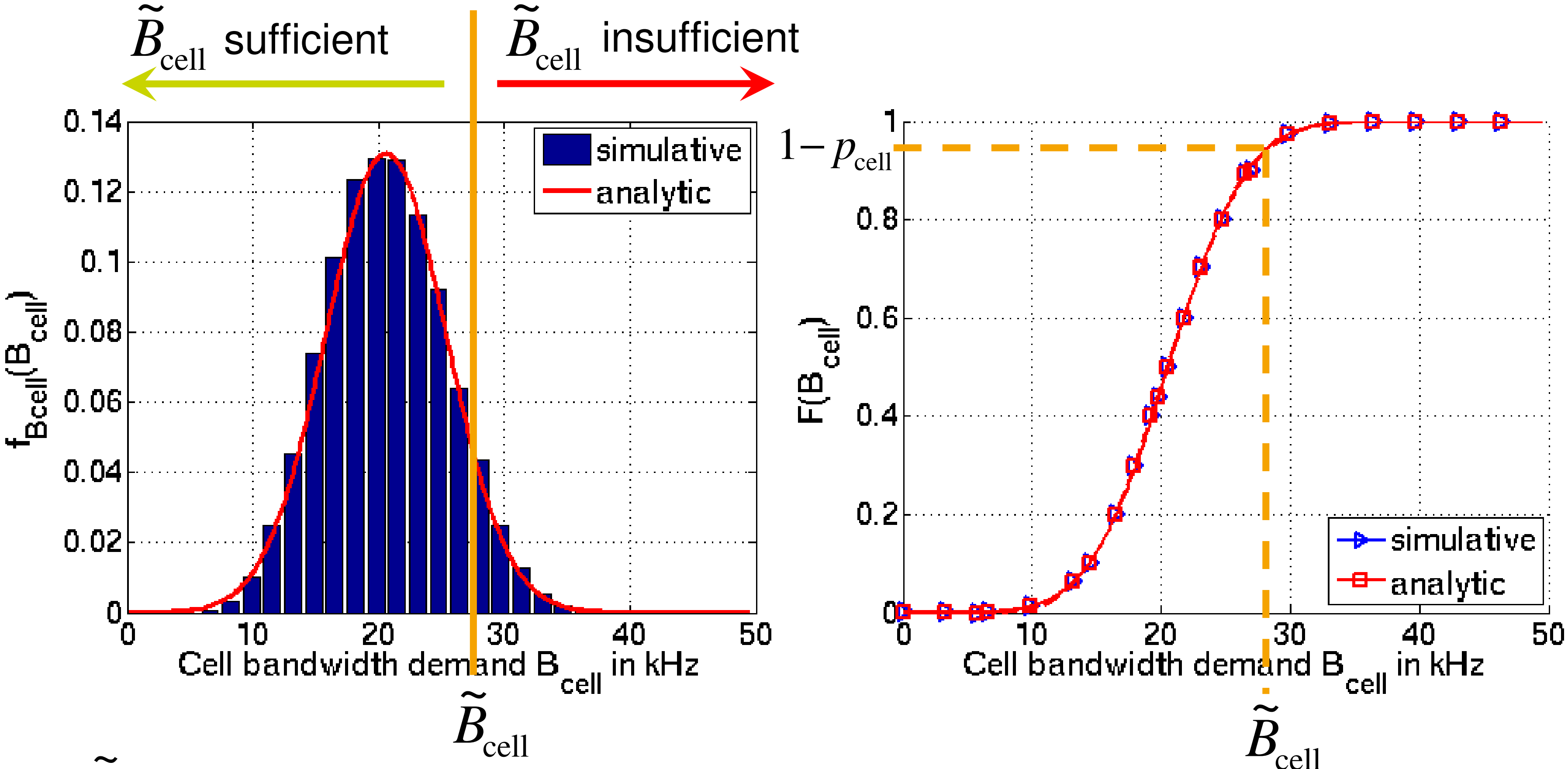
$\eta_{\mathrm{unit}} = 1$ bit/s





Cell Outage Probability

TECHNISCHE UNIVERSITÄT DARMSTADT



- $\tilde{B}_{cell}$: assigned cell bandwidth
- p_{cell} : cell outage probability

$$p_{cell} = 1 - F(\tilde{B}_{cell})$$

Outline

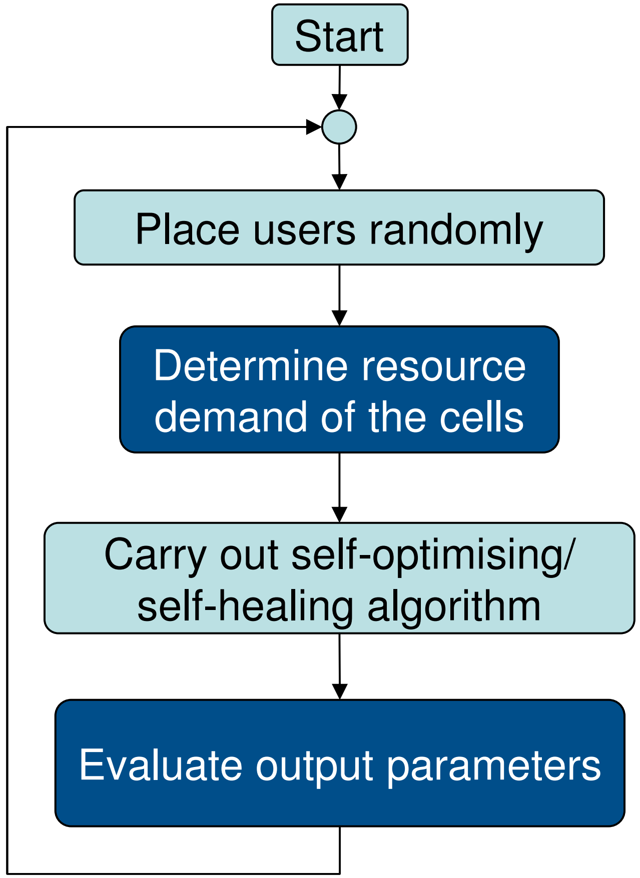
TECHNISCHE UNIVERSITÄT DARMSTADT

- Simulation Fundamentals
- Bandwidth Demand Model and Cell Outage Probability
- **Key Data of the Simulative Approach and Simulation Example**

Simulation Parameters and Flowchart

TECHNISCHE UNIVERSITÄT DARMSTADT

- Input data
  - User distribution
  - Service distributions
  - Traffic models
  - Propagation models
- Output data
  - Allocated cell bandwidth
  - Resource availability
  - Capacity, throughput
  - Outage probability

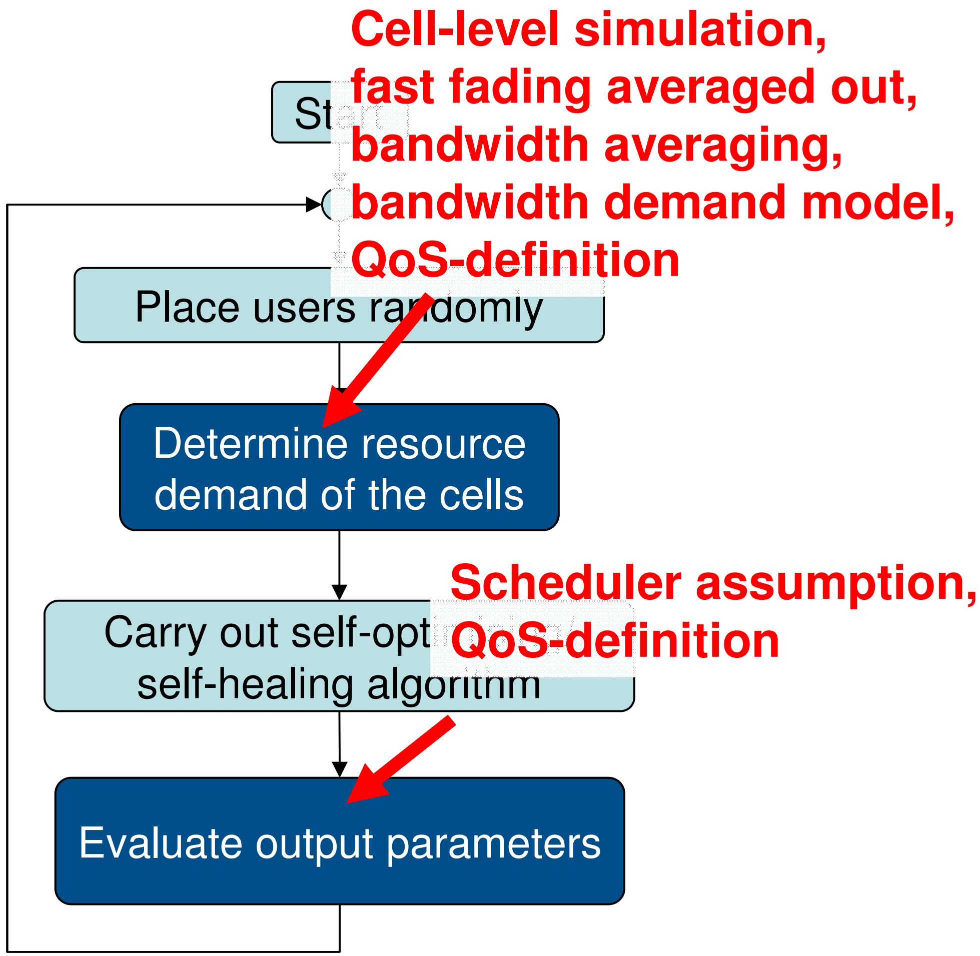


Simulation Parameters and Flowchart

TECHNISCHE UNIVERSITÄT DARMSTADT

- Input data
  - User distribution
  - Service distributions
  - Traffic models
  - Propagation models

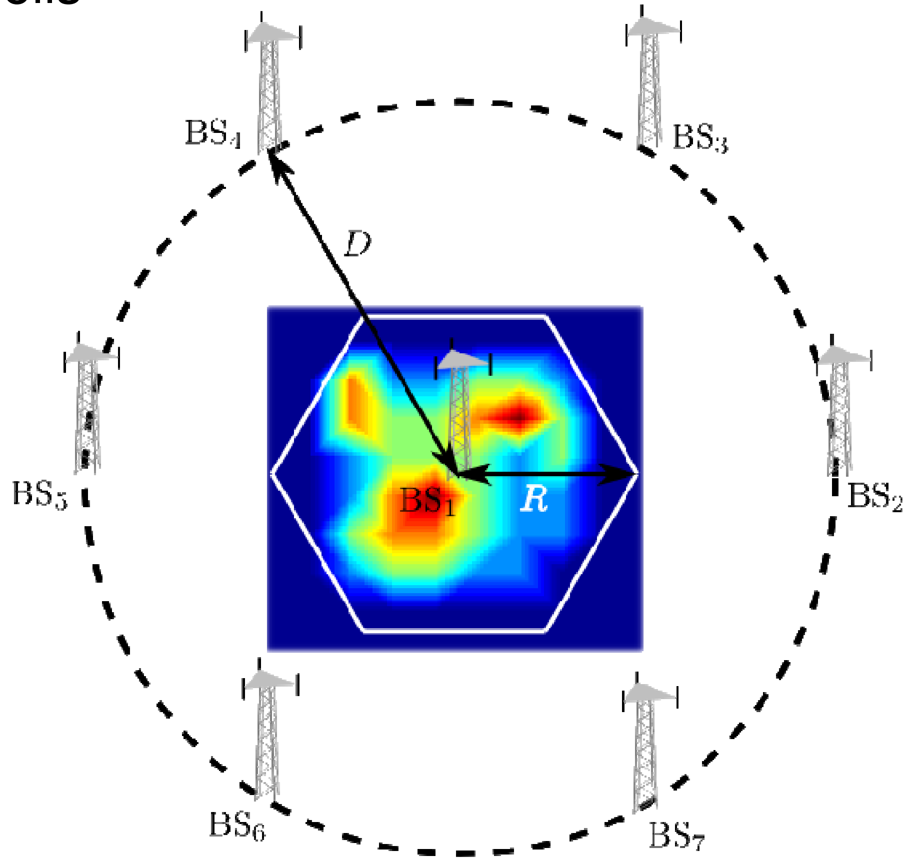
- Output data
  - Allocated cell bandwidth
  - Resource availability
  - Capacity, throughput
  - Outage probability



TECHNISCHE UNIVERSITÄT DARMSTADT

Simulation Example: Scenario

- Evaluation of resource assignment algorithm for joint assignment of transmit power and bandwidth to cells
- Cell outage probability $p_{\text{cell}}^{(\text{BS1})}$ of centre cell evaluated
- Six closest interferers regarded
- User density
  - Red: high
  - Blue: low
- Voice service



Simulation Example: Parameters

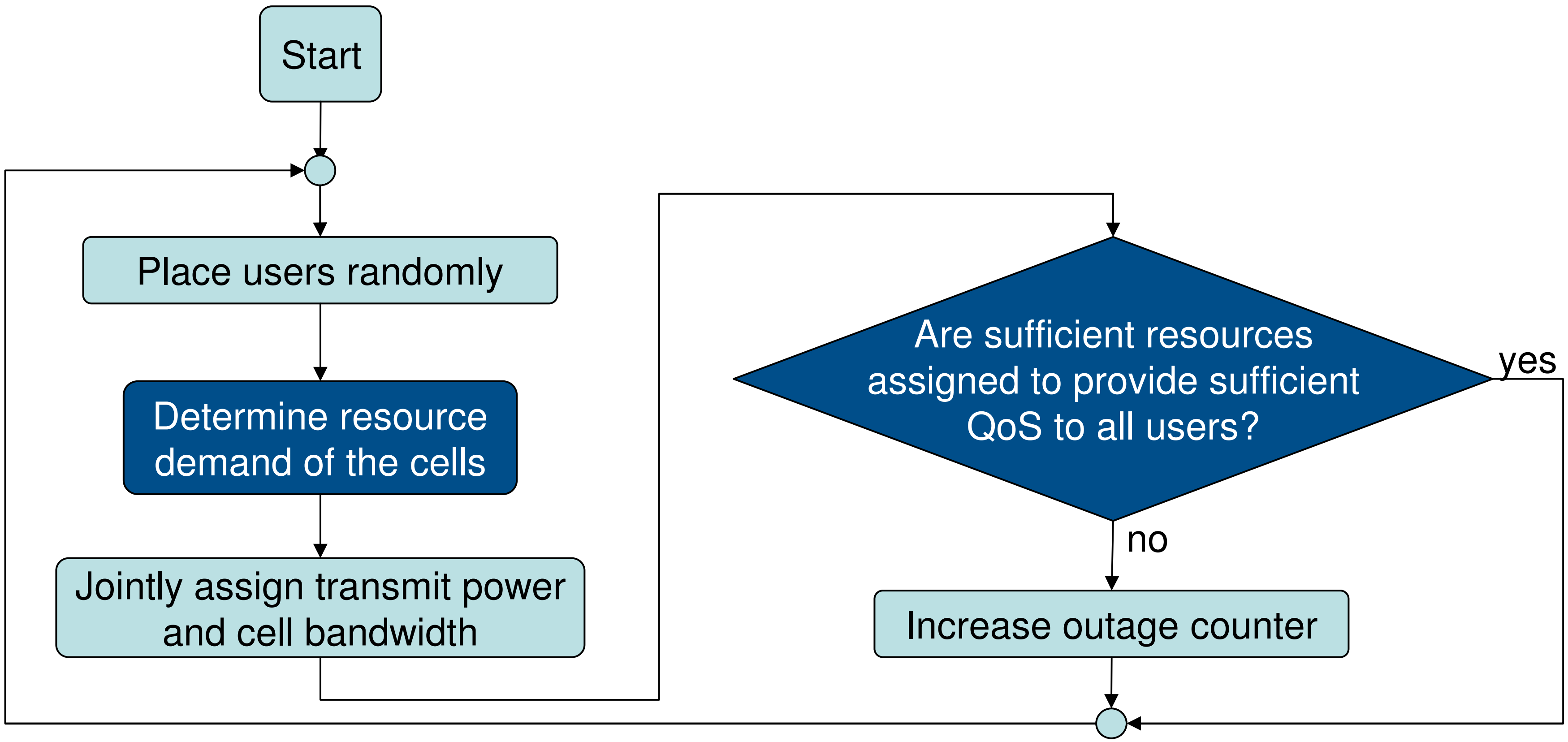
TECHNISCHE UNIVERSITÄT DARMSTADT

Cell radius R	250m
Height of MSs/BSs	1.5m/32m
Average number of active users K	50
Data rate (QoS) requirement per user	10kbit/s
Data rate unit	1bit/s
Propagation model	3GPP SCM Urban Macro
Pathloss exponent	3.5
Carrier frequency	1.9GHz
Lognormal shadow fading variance	8dB
Shadow fading correlation distance	40m
Noise power spectral density (PSD) P_{N}	-167dBm/Hz
Target cell outage probability $\tilde{p}_{\mathrm{cell}}$	0.05

TECHNISCHE UNIVERSITÄT DARMSTADT

Simulation Flowchart

- Goal: evaluation of resource assignment algorithm for joint assignment of transmit power and bandwidth to cells of mobile radio networks



Simulation Example: Results

TECHNISCHE UNIVERSITÄT DARMSTADT