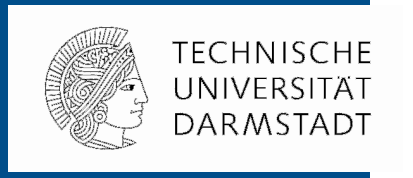
Radio Resource Allocation based on Power-Bandwidth Characteristics for Self-optimising Cellular Mobile Radio Networks



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Motivation

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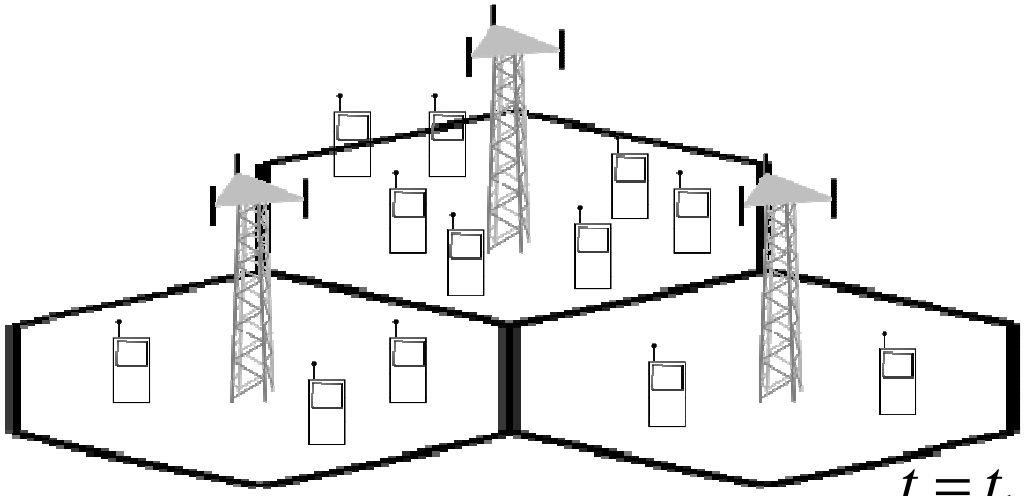
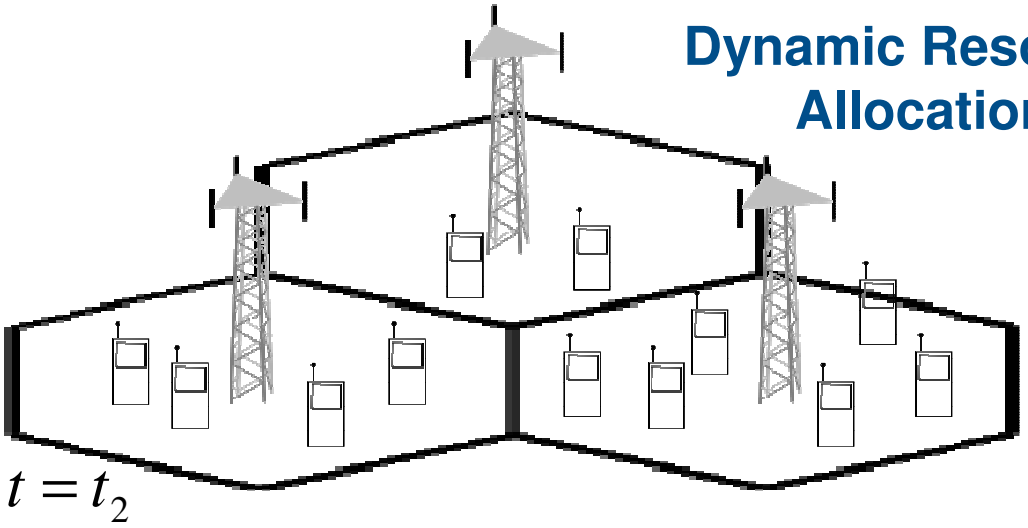
- Fluctuating resource demand of the cells
  - Rush hour traffic
  - Change in user behaviour
  - Change in environment





Dynamic Resource Allocation

- Self-organizing networks (SONs)
  - Fast, reliable, autonomous algorithms

Outline

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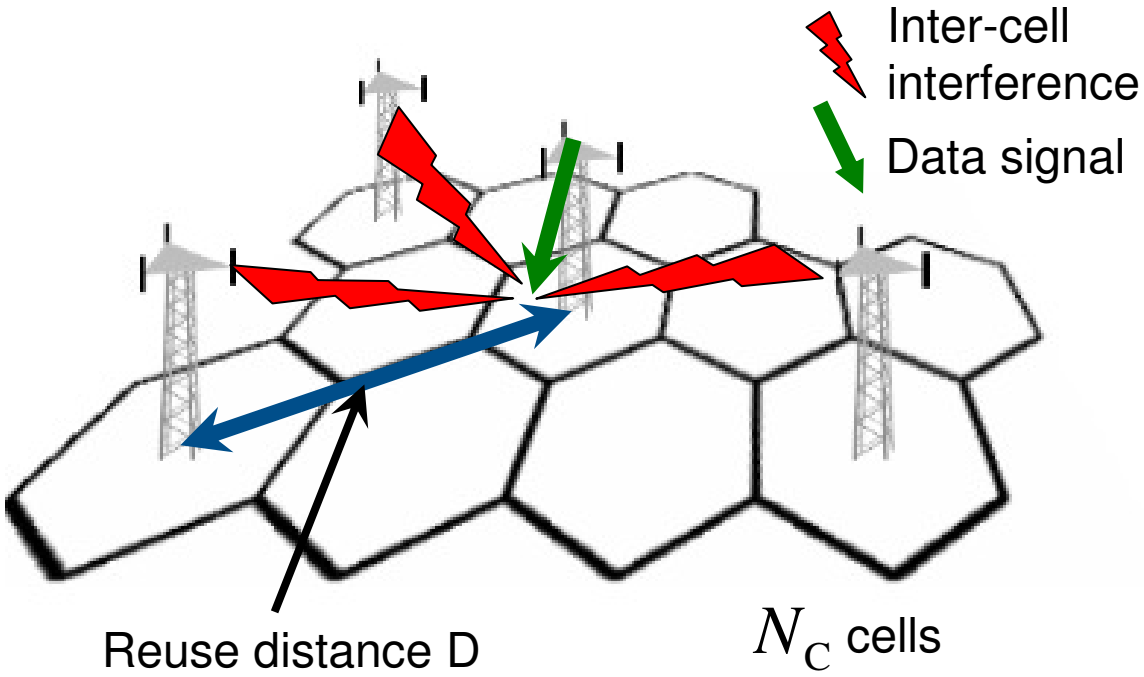
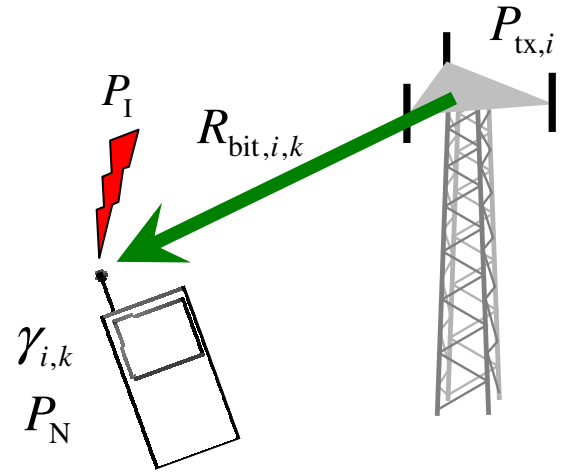
- System Model
- Power-Bandwidth Characteristics
- Resource Allocation
  - Cell Bandwidth Allocation
  - Transmit Power Allocation
- Simulation Results
  - Comparison

System Model



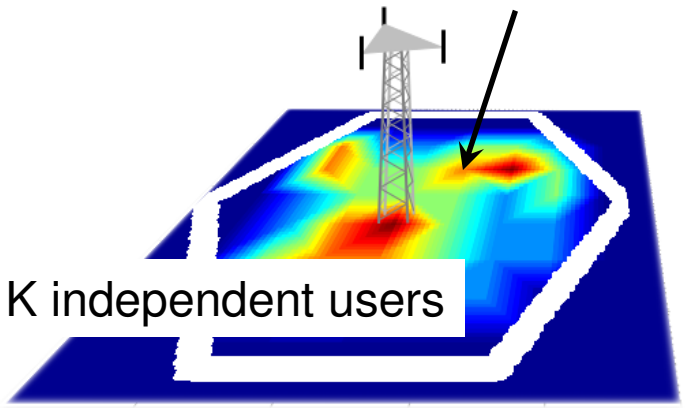


- Adaptive modulation is used
- QoS parameter: user bit rate

$P_{tx,i}$	Transmit power of cell i
$R_{bit,i,k}$	Required bit rate of user k of cell i
P_I	Inter-cell interference power
P_N	Noise power
$\gamma_{i,k}$	SINR of user k of cell i

Power-Bandwidth Characteristics

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



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

$$\hookrightarrow f_{\gamma}(\gamma)$$

$$\hookrightarrow f_{\tilde{B}_k}\left(\tilde{B}_k, P_{\mathrm{tx}}, \overline{P}_{\mathrm{I}}\right)$$

PDF of the bandwidth required by user k

$$\tilde{B}_k = \frac{R_{\mathrm{bit},k}}{\log_2(1+\gamma_k)}$$

Bandwidth required by user k

$$\tilde{B}_{\mathrm{cell}} = \sum_{k=1}^{K} \tilde{B}_k$$

Bandwidth required by the whole cell

Power-Bandwidth Characteristics

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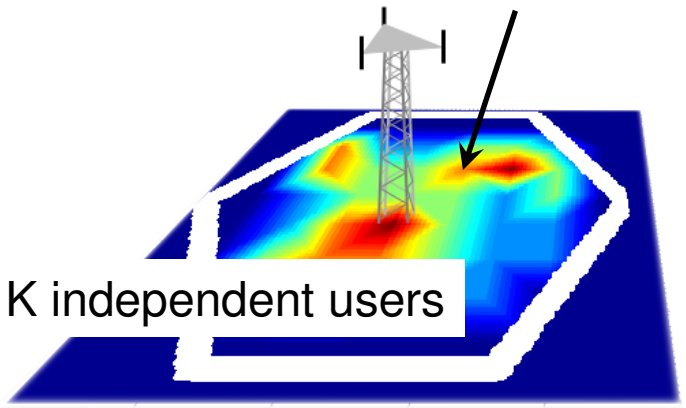

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Bandwidth required by the whole cell

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$$\hookrightarrow f_{\gamma}(\gamma)$$

PDF of the bandwidth required by user k

$$\hookrightarrow f_{\tilde{B}_k}\left(\tilde{B}_k, P_{\text{tx}}, \overline{P}_{\text{I}}\right)$$

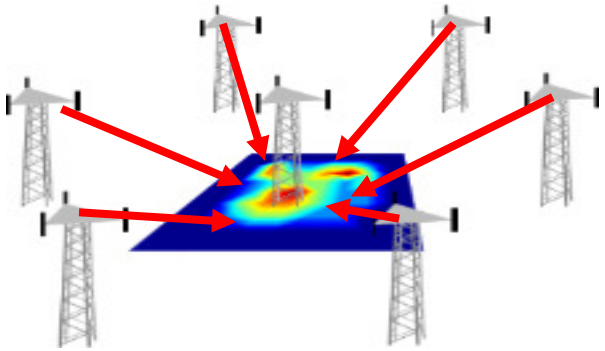
Central Limit Theorem

PDF of the bandwidth required by the cell

$$f_{\tilde{B}_{\text{cell}}}(\tilde{B}_{\text{cell}}, P_{\text{tx}}, \overline{P}_{\text{I}}) \sim N(\mu_{\text{cell}}, \sigma^2_{\text{cell}})$$

$$\Rightarrow F(B_{\text{cell}}, P_{\text{tx}}, \overline{P}_{\text{I}})$$

Average Interference, Power Ratio



Average interference

$$\overline{P}_{\mathrm{I},i} = \iint \sum_{j} \frac{P_{\mathrm{tx},j}}{a_{i,j}(r,\varphi)} \cdot f_{r,\varphi}(r,\varphi)\, r\, d\varphi\, dr$$

attenuation

user distribution

Power ratio

$$\Gamma_i = \frac{P_{\mathrm{tx},i}}{\overline{P}_{\mathrm{I},i} + P_{\mathrm{N}}}$$

$$\overline{\mathbf{P}}_{\mathrm{I}} = \mathbf{G} \cdot \mathbf{P}_{\mathrm{tx}}$$

Coupling matrix

Power-Bandwidth Characteristic

$$F(B_{\mathrm{cell}}, P_{\mathrm{tx}}, \overline{P}_{\mathrm{I}}) \Rightarrow F(B_{\mathrm{cell}}, \Gamma)$$

Cell Outage Probability

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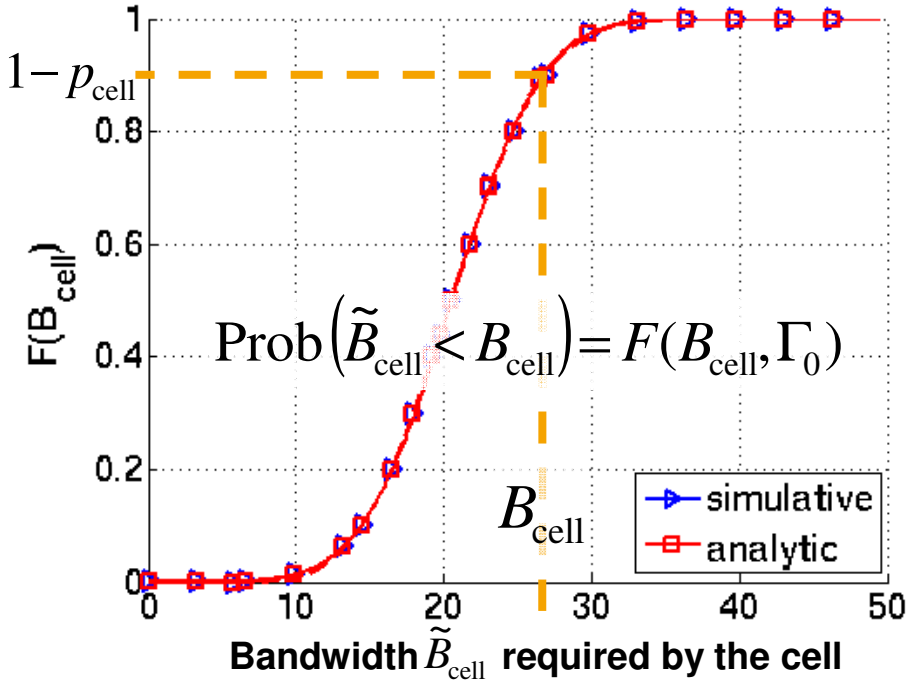
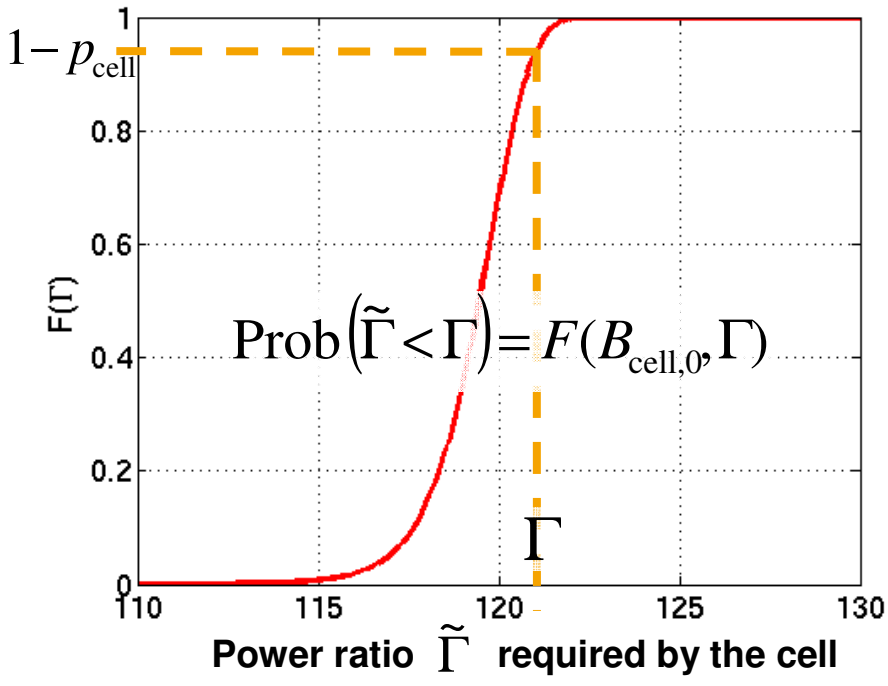
- CDF of the resources required by the cell: probability that sufficient resources are allocated





- Cell outage probability: probability that allocated resources are not sufficient

$$p_{\text{cell}} = 1 - F(B_{\text{cell}}, \Gamma)$$

Resource Allocation

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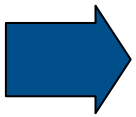
- Power-Bandwidth Characteristics
  - Model a cell w.r.t. to usage of transmit power and cell bandwidth
  - Contain information on user distribution, environment, interference
  - Provide quality indicator for resource assignment by means of cell outage probability



Application in resource allocation

Resource Allocation

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- Power-Bandwidth Characteristics
  - Model a cell w.r.t. to usage of transmit power and cell bandwidth
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Bandwidth allocation

$$\min_{B_{\text{cell},i}} \max_{i} \left\{ p_{\text{cell},i} \right\}$$

$$s.t. \quad 0 \le B_{\text{cell},i} \le B_{\text{sys}}$$

$$\sum_{\substack{n \in \{i_1,\ldots,i_r\} \\ \forall \{i_1,\ldots,i_r\} \in G}} B_{\text{cell},n} \le B_{\text{sys}}$$

$$i = 1 \ldots N_{\text{C}}$$

$$p_{\text{cell},i} = 1 - F(B_{\text{cell},i}, \Gamma_i)$$

Power allocation

$$\min_{\Gamma_i} \max_{i} \left\{ p_{\text{cell},i} \right\}$$

$$s.t. \quad \rho\left(\text{diag}(\boldsymbol{\Gamma}) \cdot \mathbf{G}\right) < 1$$

B_{sys} : total system bandwidth

$\rho(\mathbf{X})$: spectral radius of matrix X

Simulation Scenarios

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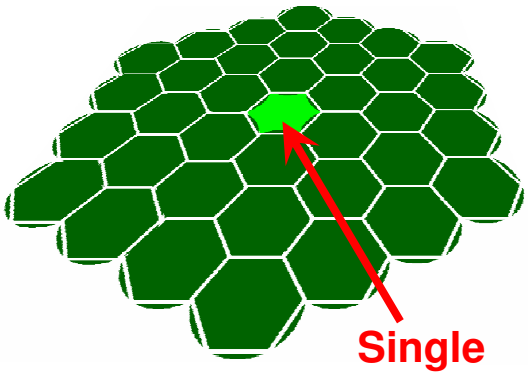
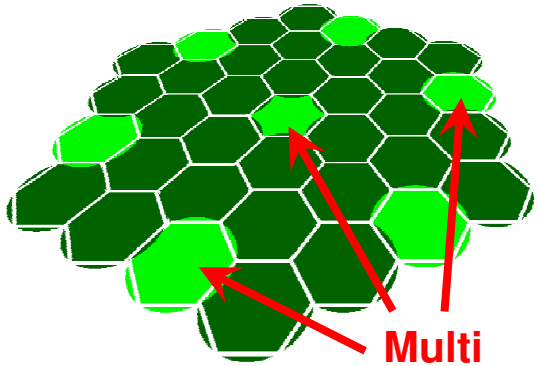
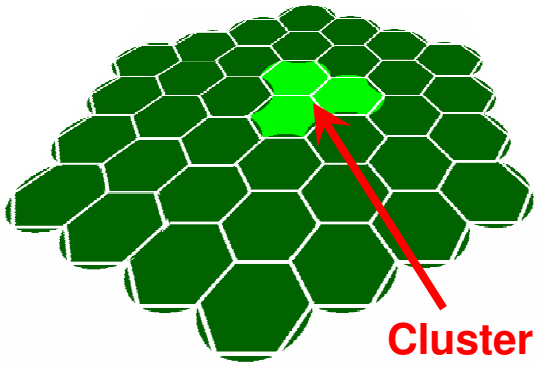
- Three hotspot scenarios
  - Number of users in hotspot cell N_{hs}
  - Number of users in normal cell N_0
- Wrap around technique
  - No boundary effects

- Performance comparison of bandwidth allocation and power allocation
  - Bandwidth allocation: no frequency reuse within frequency reuse distance, fixed transmit power
  - Power allocation: fixed frequency planning, homogeneous bandwidth allocation







Simulation Parameters

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Cell radius R	250 m
User distribution	uniform
Propagation model	3GPP SCM Urban Macro
Shadow fading variance	8 dB
No frequency reuse within	3 times the cell radius R
Hotspot reuse factor	12
Total system bandwidth	10 MHz
Scheduling	Fair throughput
Data rate per user	100 kbit/s

Simulation Results

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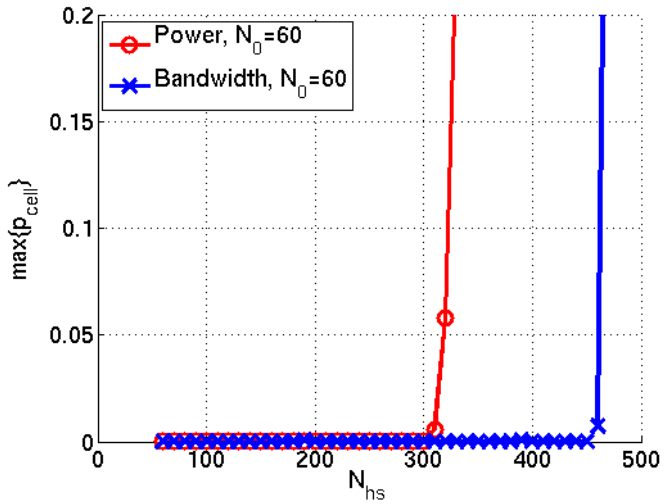
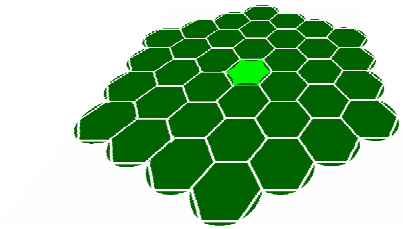
Single hotspot



- Adaptation to resource demand
- Capacity increases
  - linear with bandwidth
  - nonlinear (log2) with power



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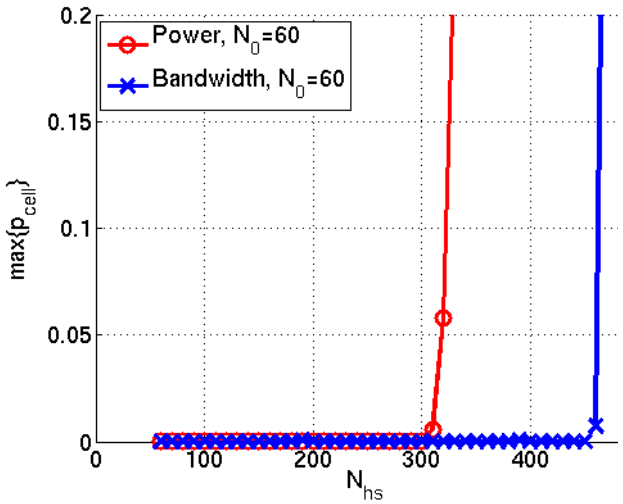

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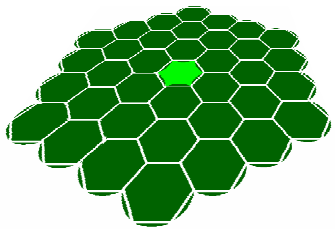
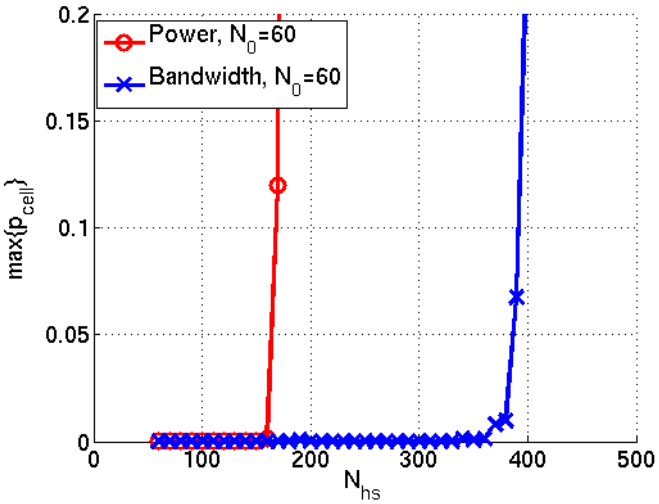
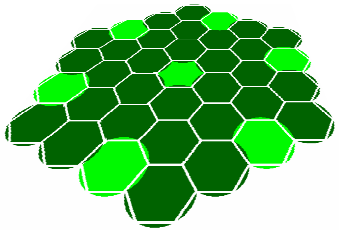


Multi hotspot



- Independent hotspots for bandwidth allocation
- Dependent hotspots for power allocation



Simulation Results

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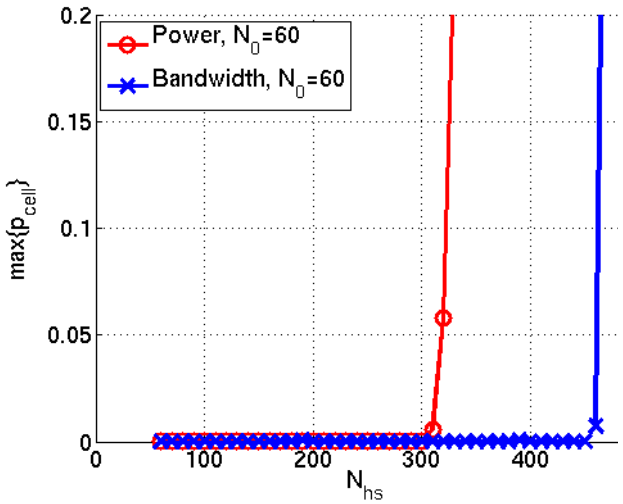

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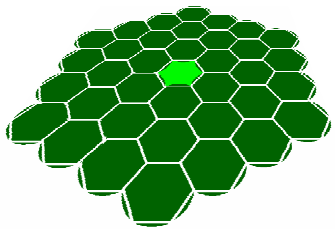

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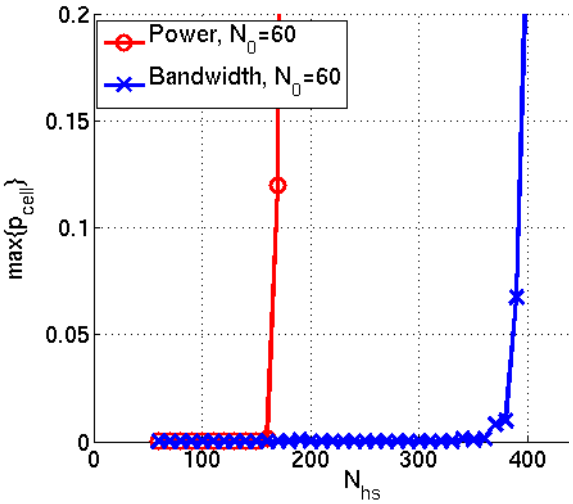

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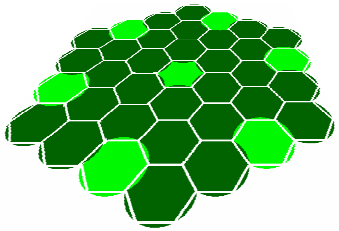
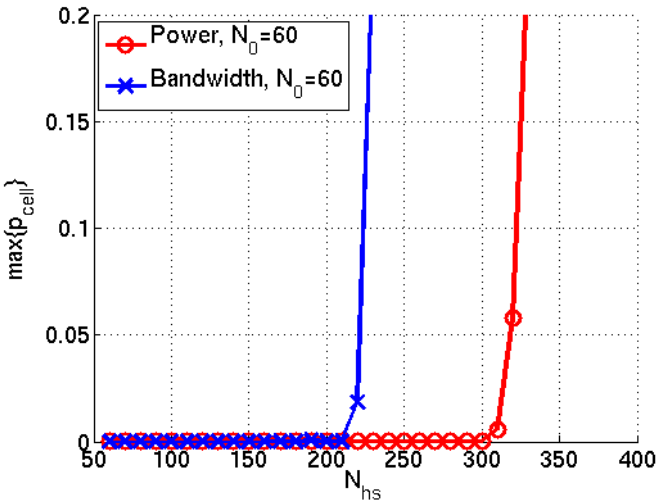
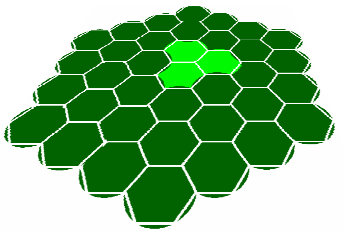


Cluster hotspot



- Dependent hotspots for bandwidth allocation
- Independent hotspots for power allocation



Conclusion

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- Power-Bandwidth Characteristics
  - Assessment of the resource requirements of the cells
  - Quality measure for resource allocation
- Two resource allocation algorithms
  - Bandwidth allocation
  - Transmit power allocation
- Dynamic resource allocation
  - Adaptation to varying resource demands
  - Performance gains
    - bandwidth allocation for distributed hotspots scenarios
    - transmit power allocation in concentrated hotspots scenarios
  - Application in self-organising optimisation