

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



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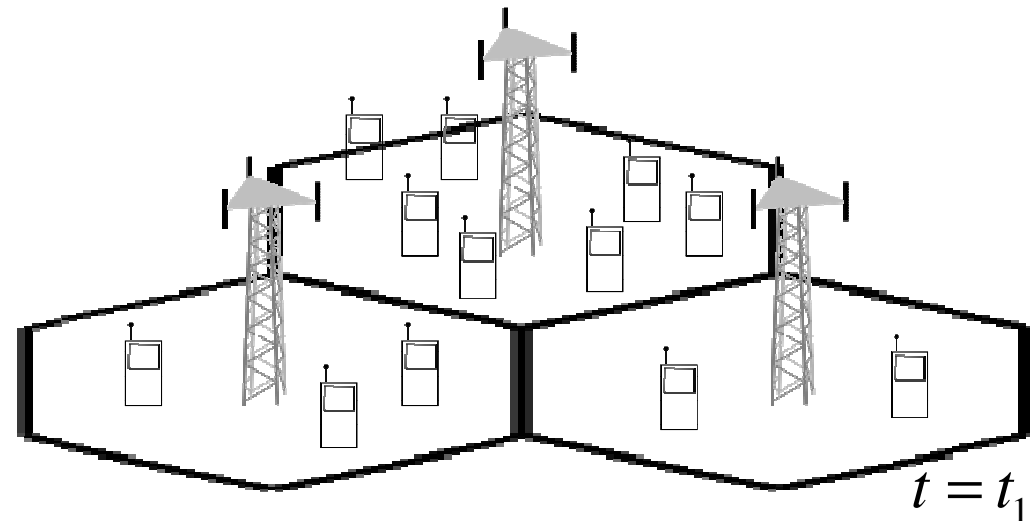
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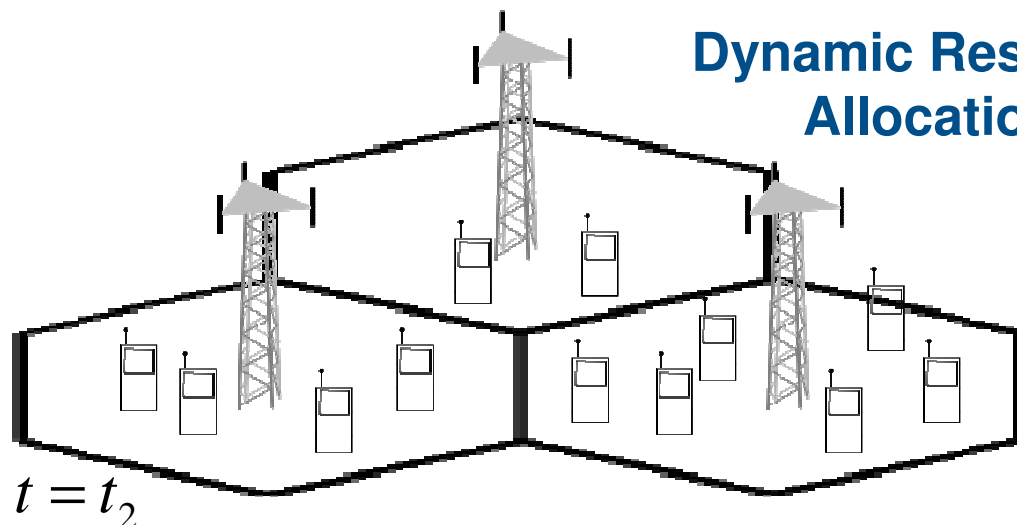
This work was partly funded by Deutsche Telekom AG and is part of the corporate project SORAN (self-optimizing radio access networks).

# Motivation

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



## Dynamic Resource Allocation

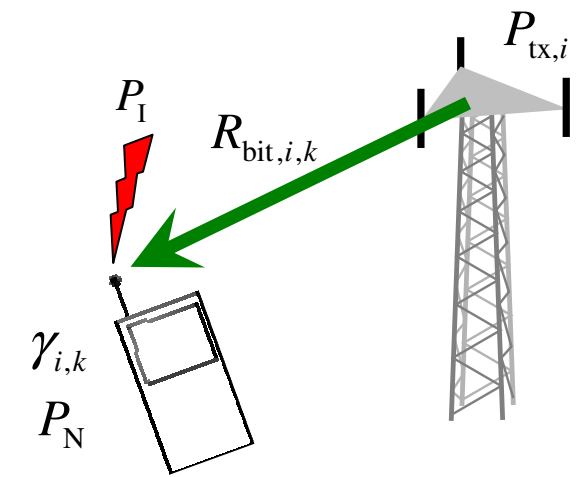
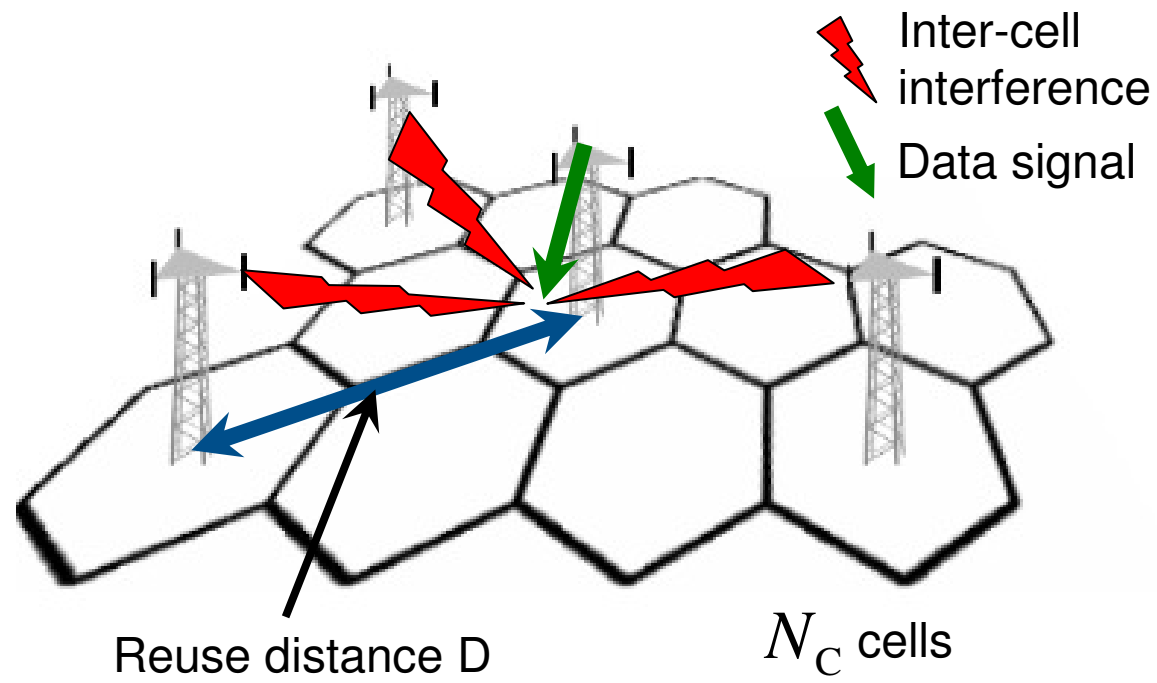


- Self-organizing networks (SONs)
  - Fast, reliable, autonomous algorithms

# Outline

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

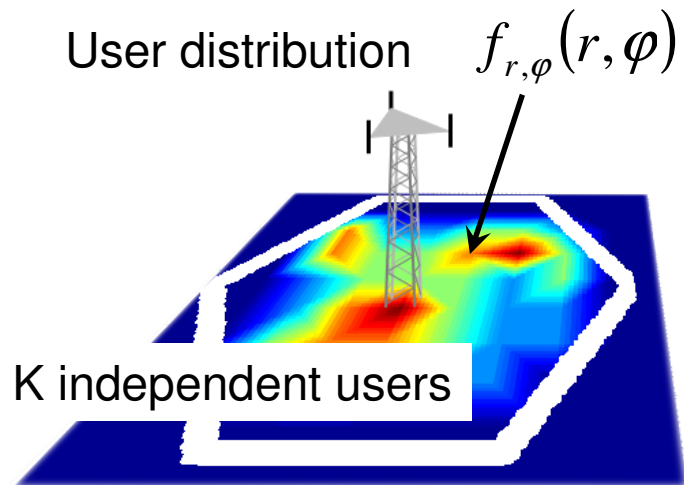
# System Model



- 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



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

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

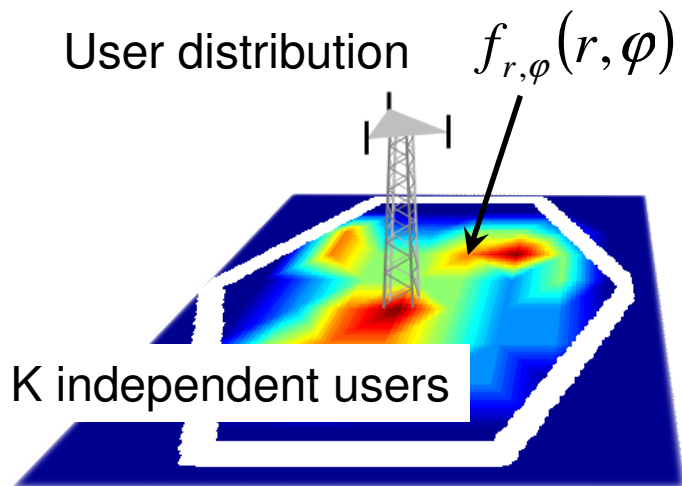
$$\hookrightarrow f_{\tilde{B}_k}(\tilde{B}_k, P_{\text{tx}}, \bar{P}_I)$$

PDF of the bandwidth  
required by user k

$$\tilde{B}_k = \frac{R_{\text{bit},k}}{\log_2(1 + \gamma_k)} \quad \text{Bandwidth required by user k}$$

$$\tilde{B}_{\text{cell}} = \sum_{k=1}^K \tilde{B}_k \quad \text{Bandwidth required by the whole cell}$$

# Power-Bandwidth Characteristics



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

$$\hookrightarrow f_\gamma(\gamma)$$

PDF of the bandwidth  
required by user k

$$\hookrightarrow f_{\tilde{B}_k}(\tilde{B}_k, P_{\text{tx}}, \bar{P}_I)$$

**Central Limit Theorem**

PDF of the bandwidth  
required by the cell

$$f_{\tilde{B}_{\text{cell}}}(\tilde{B}_{\text{cell}}, P_{\text{tx}}, \bar{P}_I) \sim N(\mu_{\text{cell}}, \sigma_{\text{cell}}^2)$$

$$\hookrightarrow F(B_{\text{cell}}, P_{\text{tx}}, \bar{P}_I)$$

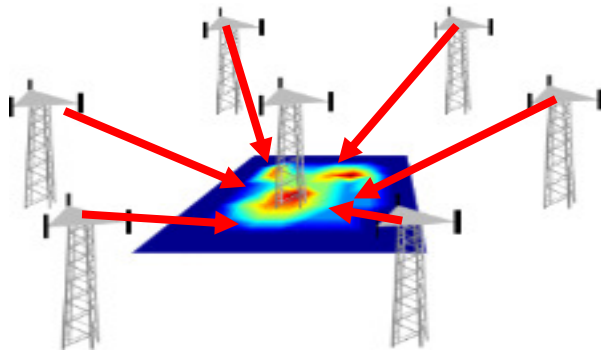
$$\tilde{B}_k = \frac{R_{\text{bit},k}}{\log_2(1 + \gamma_k)}$$

Bandwidth required  
by user k

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

Bandwidth required  
by the whole cell

# Average Interference, Power Ratio



Average interference

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

Power ratio

$$\Gamma_i = \frac{P_{tx,i}}{\bar{P}_{I,i} + P_N}$$

$$\bar{\mathbf{P}}_I = \mathbf{G} \cdot \mathbf{P}_{tx}$$

attenuation  
user distribution

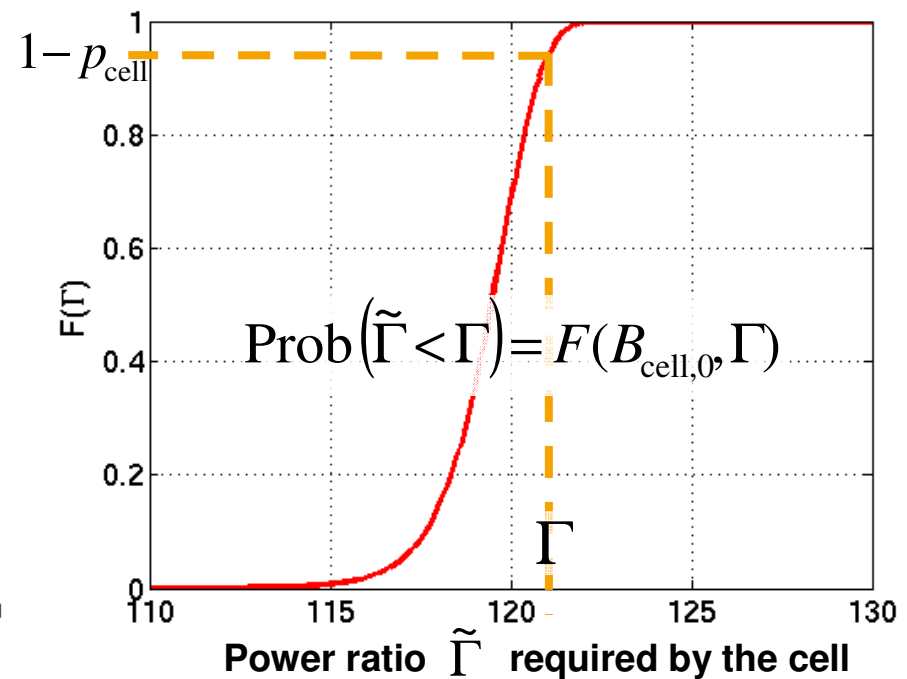
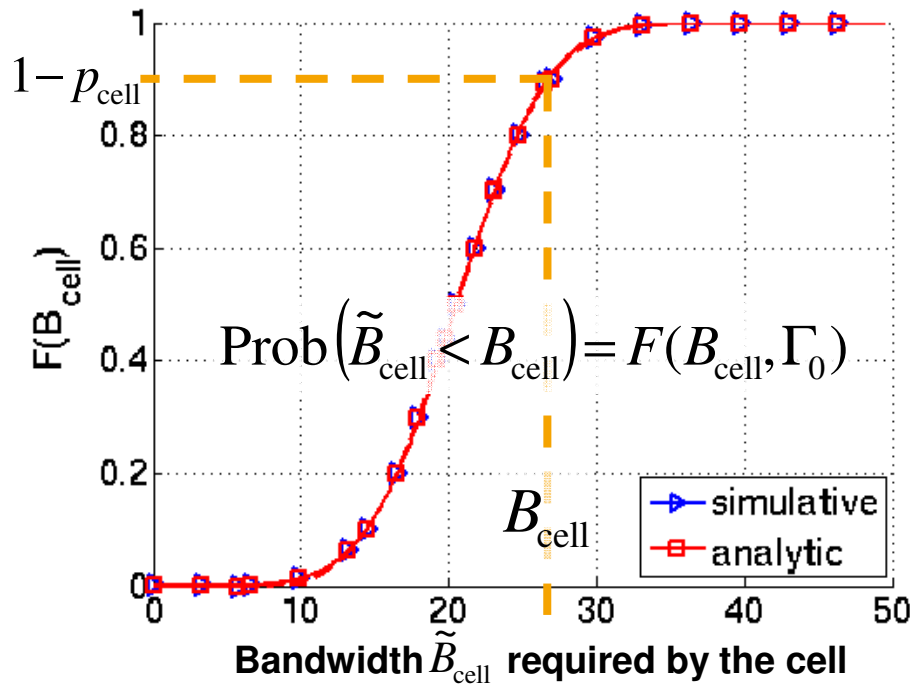
Coupling matrix

Power-Bandwidth Characteristic

$$F(B_{\text{cell}}, P_{tx}, \bar{P}_I) \quad \Rightarrow \quad F(B_{\text{cell}}, \Gamma)$$

# Cell Outage Probability

- 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

- 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

- 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

## Bandwidth allocation

$$\begin{aligned} & \min_{B_{\text{cell},i}} \max_i \{p_{\text{cell},i}\} \\ & \text{s.t. } 0 \leq B_{\text{cell},i} \leq B_{\text{sys}} \\ & \sum_{\substack{n \in \{i_1, \dots, i_r\} \\ \forall \{i_1, \dots, i_r\} \in G}} B_{\text{cell},n} \leq B_{\text{sys}} \end{aligned}$$

$B_{\text{sys}}$ : total system bandwidth

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

$$i = 1 \dots N_C$$

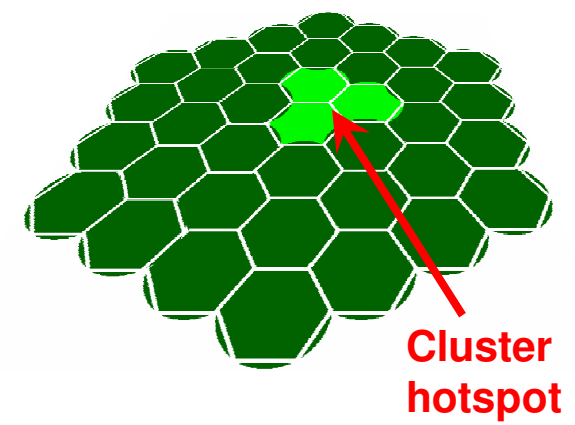
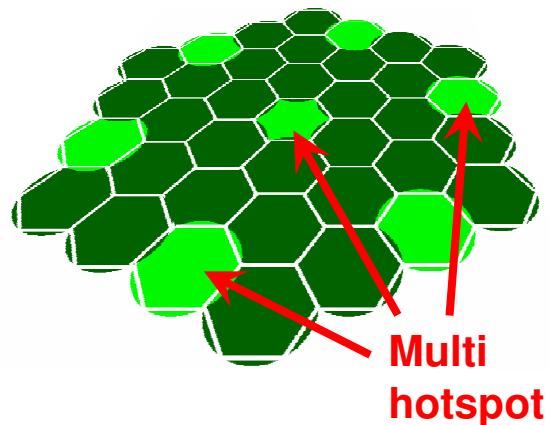
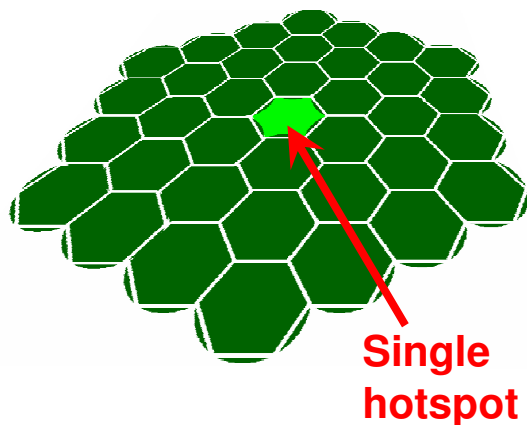
## Power allocation

$$\begin{aligned} & \min_{\Gamma_i} \max_i \{p_{\text{cell},i}\} \\ & \text{s.t. } \rho(\text{diag}(\mathbf{\Gamma}) \cdot \mathbf{G}) < 1 \end{aligned}$$

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

# Simulation Scenarios

- 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

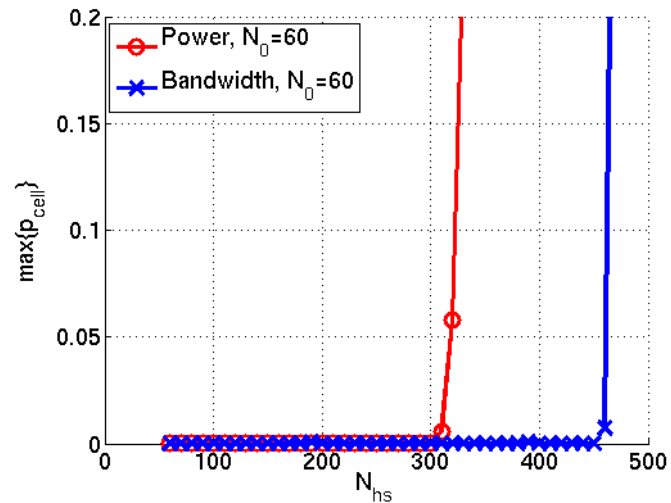


# Simulation Parameters

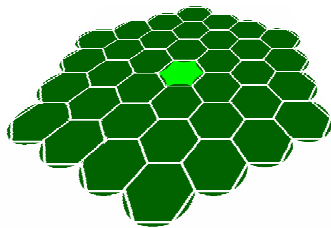
Cell radius R	250 m
User distribution	uniform
Propagation model	3GPP SCM Urban Macro
Shadow fading variance	8 dB
No frequency reuse within	3 times the cell radius R
Hotspot reuse factor	12
Total system bandwidth	10 MHz
Scheduling	Fair throughput
Data rate per user	100 kbit/s

# Simulation Results

## Single hotspot

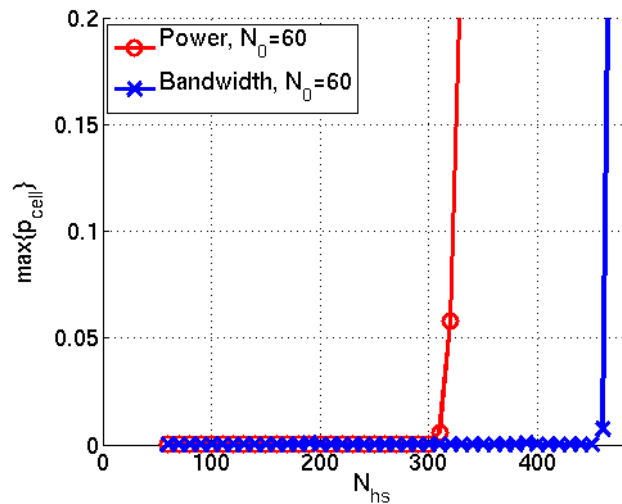


- Adaptation to resource demand
- Capacity increases
  - linear with bandwidth
  - nonlinear ( $\log_2$ ) with power

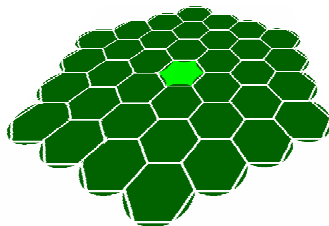


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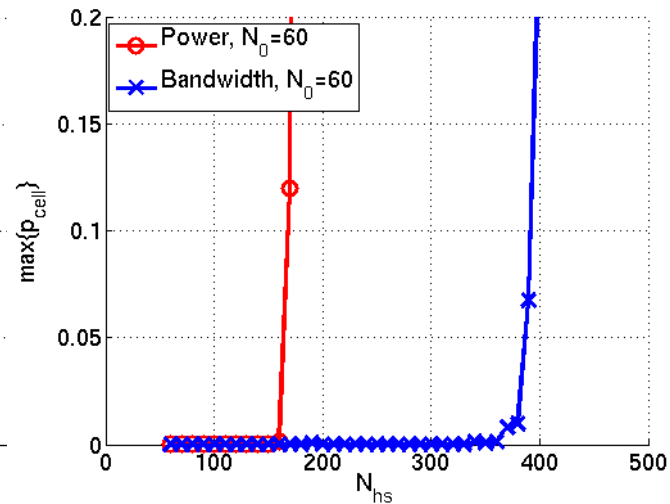
## Single hotspot



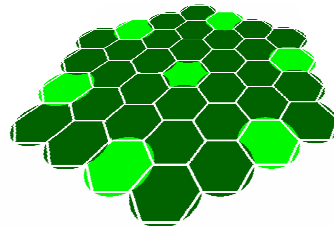
- Adaptation to resource demand
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## Multi hotspot

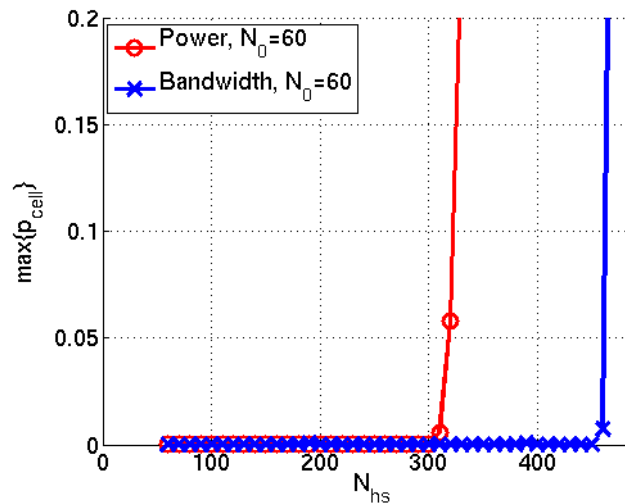


- Independent hotspots for bandwidth allocation
- Dependent hotspots for power allocation

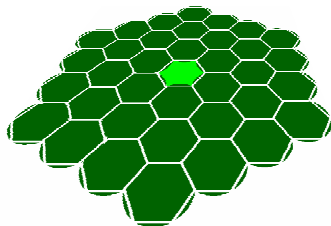


# Simulation Results

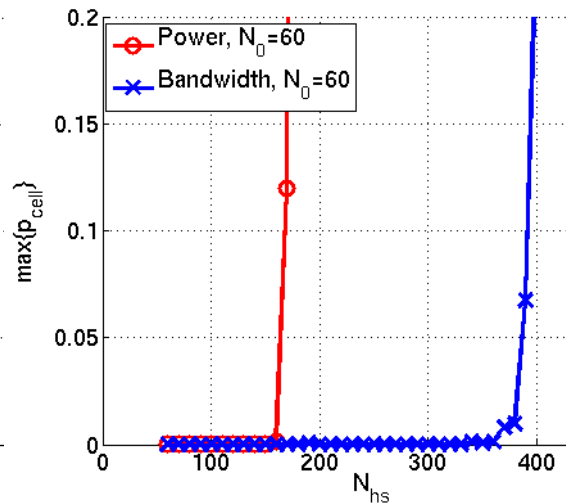
## Single hotspot



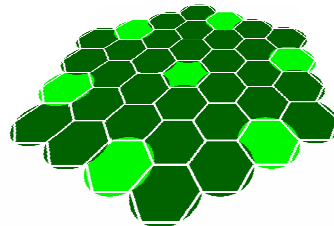
- Adaptation to resource demand
- Capacity increases
  - linear with bandwidth
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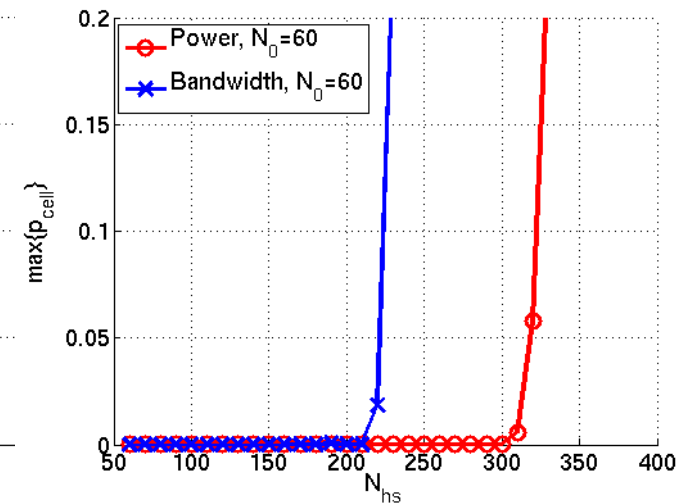
## Multi hotspot



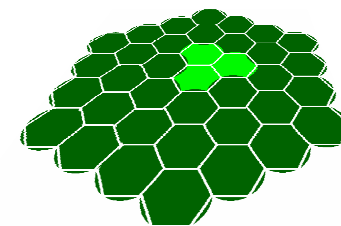
- Independent hotspots for bandwidth allocation
- Dependent hotspots for power allocation



## Cluster hotspot



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



# Conclusion

- 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