Interference in Radio Resource Management: A Comparison of Coordinated and Uncoordinated Approaches

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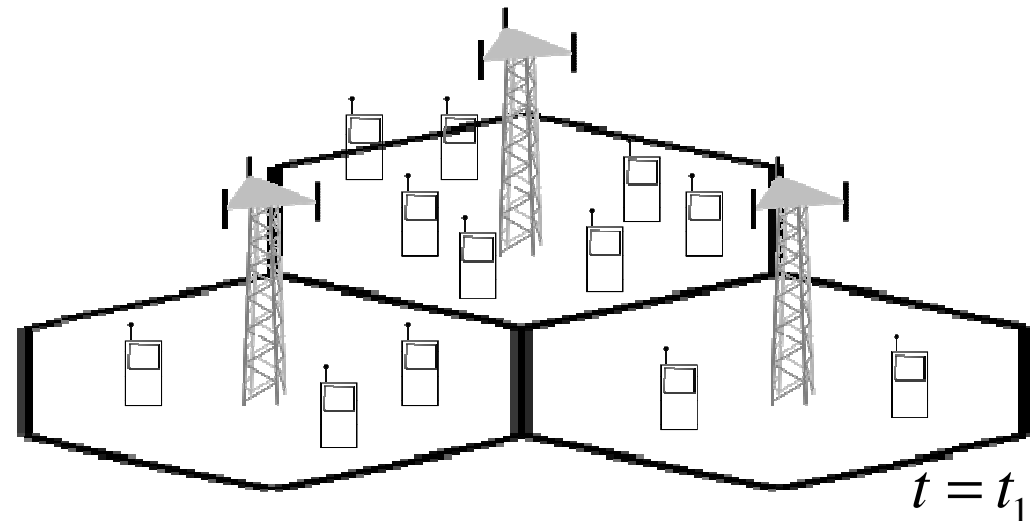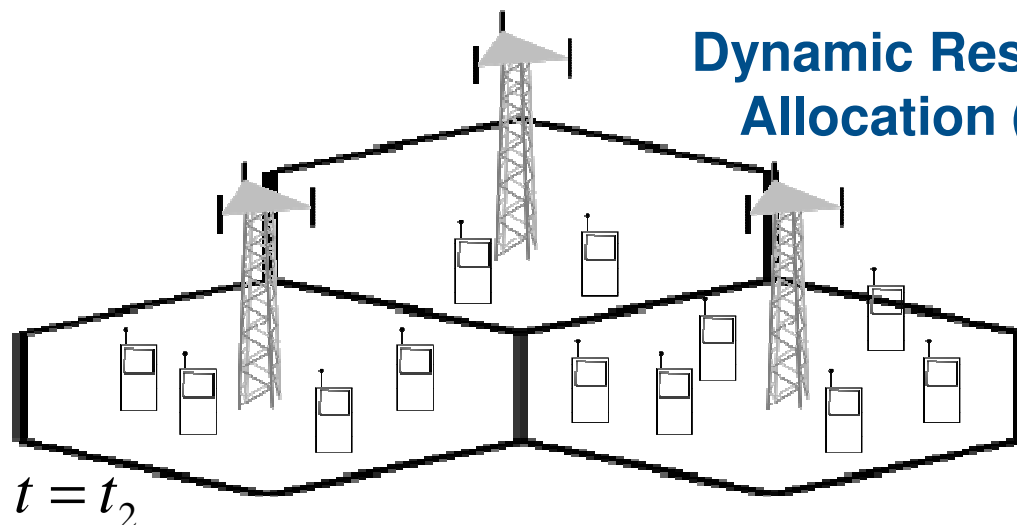
Deutsche Telekom Laboratories
Darmstadt, Germany

Motivation

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

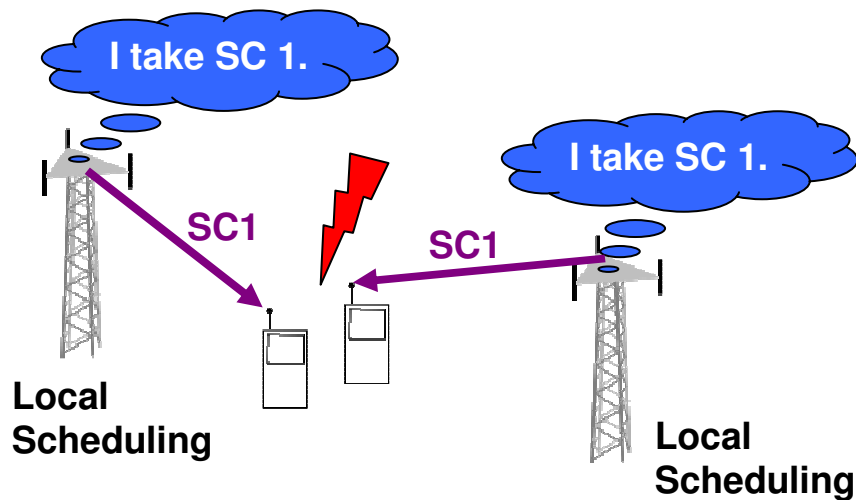**Dynamic Resource Allocation (RA)**

$$t = t_1$$

$$t = t_2$$

- Coordination in RA
  - Effect on Interference
  - Effect on Performance

Coordination in Resource Allocation

Uncoordinated:

I take SC 1.

I take SC 1.

SC1

SC1

Local Scheduling

Local Scheduling

+ : **easy implementation**
- : **Collisions, QoS?**

Coordinated:

Can I take SC 1?

OK, I take SC 2

SC1

SC2

Inter-BS communication

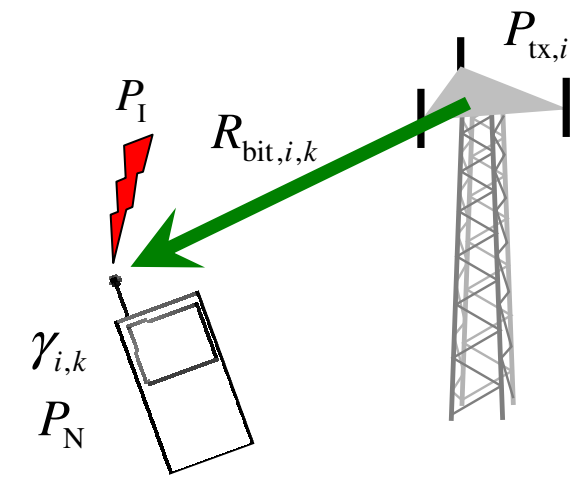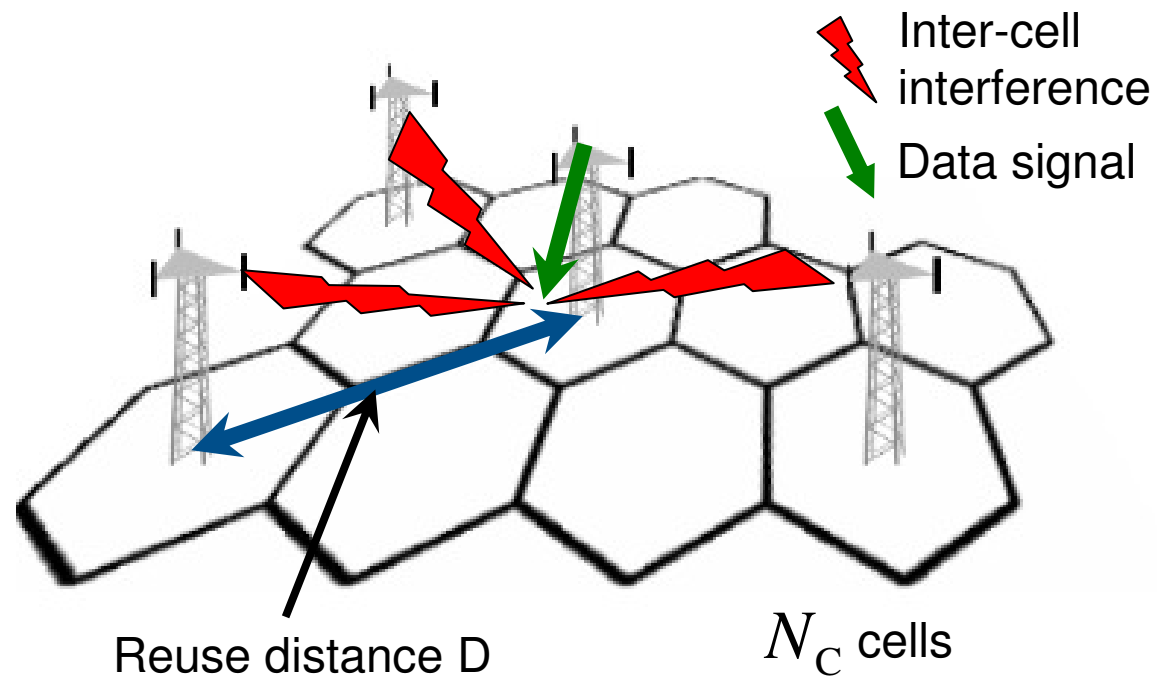+ : **Collisions can be avoided QoS**
- : **Overhead? Implementation?**

Outline

- **System Model**
- Resource Allocation
  - Coordinated Approaches
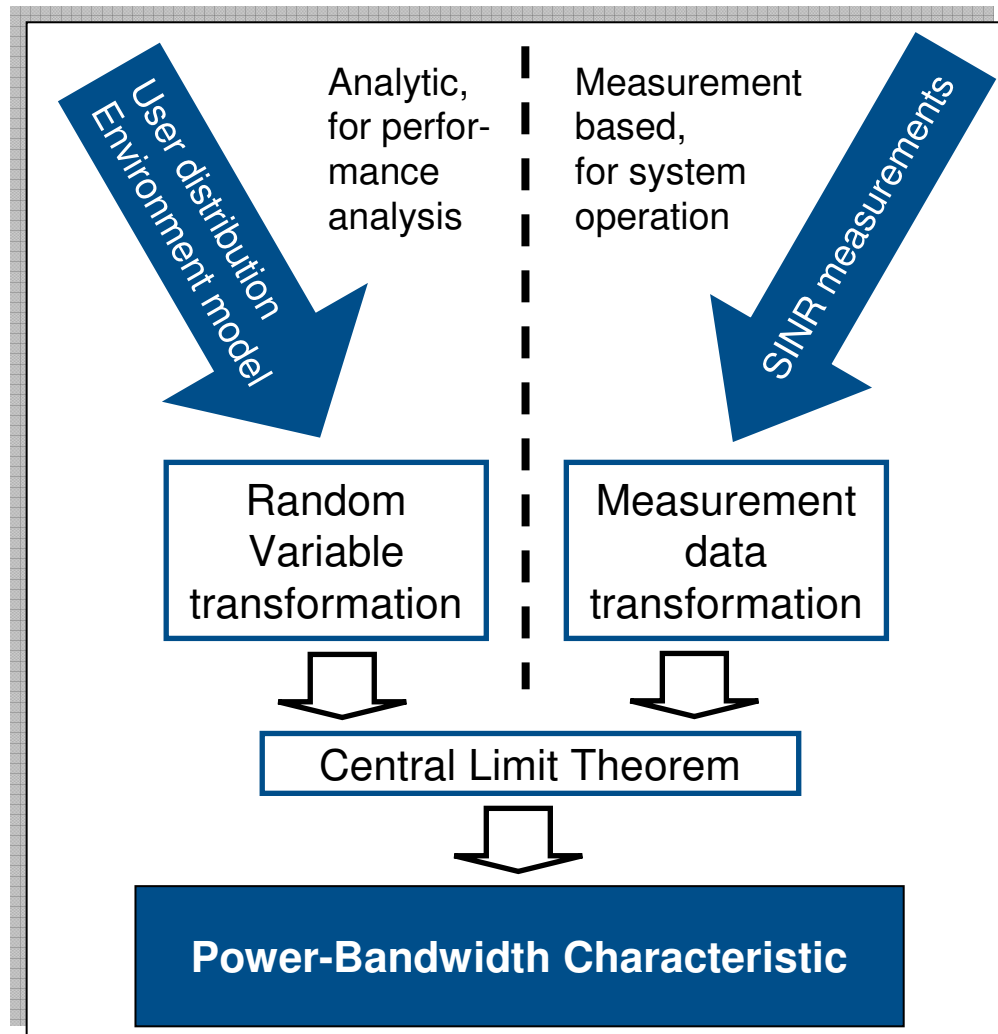 - Uncoordinated Approaches
- Performance Evaluation

System Model

Inter-cell interference

Data signal

Reuse distance D

N_C cells

- OFDMA, downlink
- Adaptive modulation is used

$P_{\mathrm{tx},i}$

P_I

$R_{\mathrm{bit},i,k}$

$\gamma_{i,k}$

P_N

$P_{\mathrm{tx},i}$	Transmit power of cell i
$R_{\mathrm{bit},i,k}$	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

- Model the interdependence of transmit power, cell bandwidth and QoS

- Contain information on user distribution, environment, inter-cell interference

- Analytic derivation available

- Measurement based derivation available, determined from standard system measurements (attenuation, SINR)

User distribution Environment model

Analytic, for performance analysis

Measurement based, for system operation

SINR measurements

Random Variable transformation

Measurement data transformation

Central Limit Theorem

Power-Bandwidth Characteristic

Power-Bandwidth Characteristics

Cell Bandwidth

B_{cell}

$\times 10^4$

Γ

Power ratio

$F(B_{cell}, \Gamma)$

QoS metric

Probability that a certain assignment of transmit power and cell bandwidth is sufficient with respect to user QoS requirements

$$\Gamma = \frac{P_{tx}}{P_I + P_N}$$

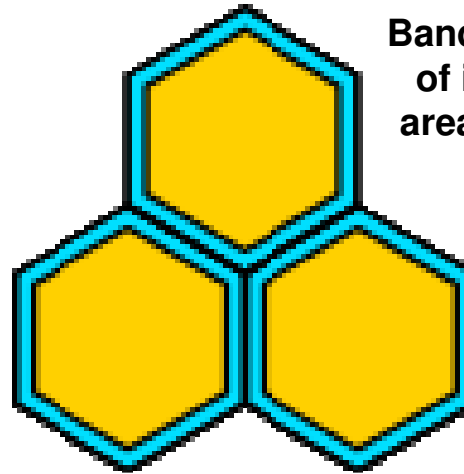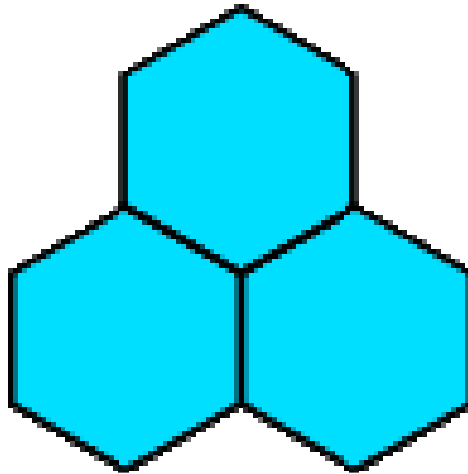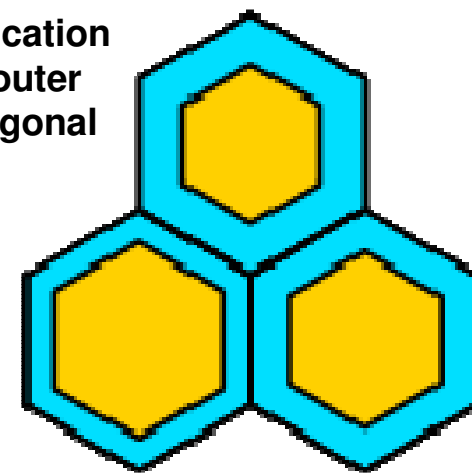P_{tx} : Transmit power

P_I : Avg. interference power

P_N : Noise power

Outline

- System Model
- **Resource Allocation**
  - Coordinated Approaches
  - Uncoordinated Approaches
- Performance Evaluation

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Fractional Reuse Modes

**Bandwidth allocation
of inner and outer
area are orthogonal**

No fractional reuse
- One area per cell
- Same bandwidth and transmit power for the whole cell

Fixed fractional reuse
- Two areas per cell
- Different bandwidths and transmit powers for the two areas possible
- Constant size of the two areas

Variable fractional reuse
- Two areas per cell
- Different bandwidths and transmit powers for the two areas possible
- Variable size of the two areas

Resource Allocation Techniques
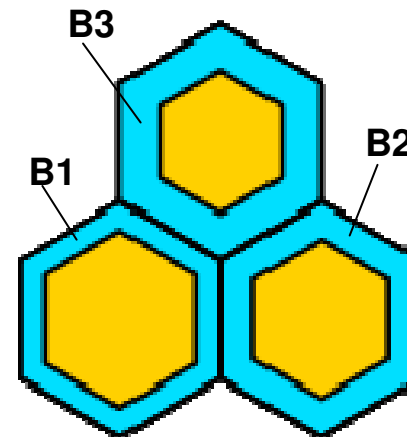
- **Uncoordinated** bandwidth allocation
  - Fixed power allocation
  - Bandwidth allocation to maximise capacity
  - Reuse one
  - Random subcarrier selection

- **Coordinated** bandwidth allocation
  - Fixed power allocation
  - Bandwidth allocation to maximise capacity
  - Reuse one
  - Coordinated subcarrier selection: adjacent cells or outer areas cannot use the same subcarriers

- Transmit power allocation
  - Fixed bandwidth allocation
    - Reuse one in no fractional reuse mode
    - **Coordinated** fixed bandwidth allocation in fractional reuse mode
  - Power allocation to maximise capacity

Coordinated bandwidth allocation: B1, B2, B3 are non overlapping sets of subcarriers
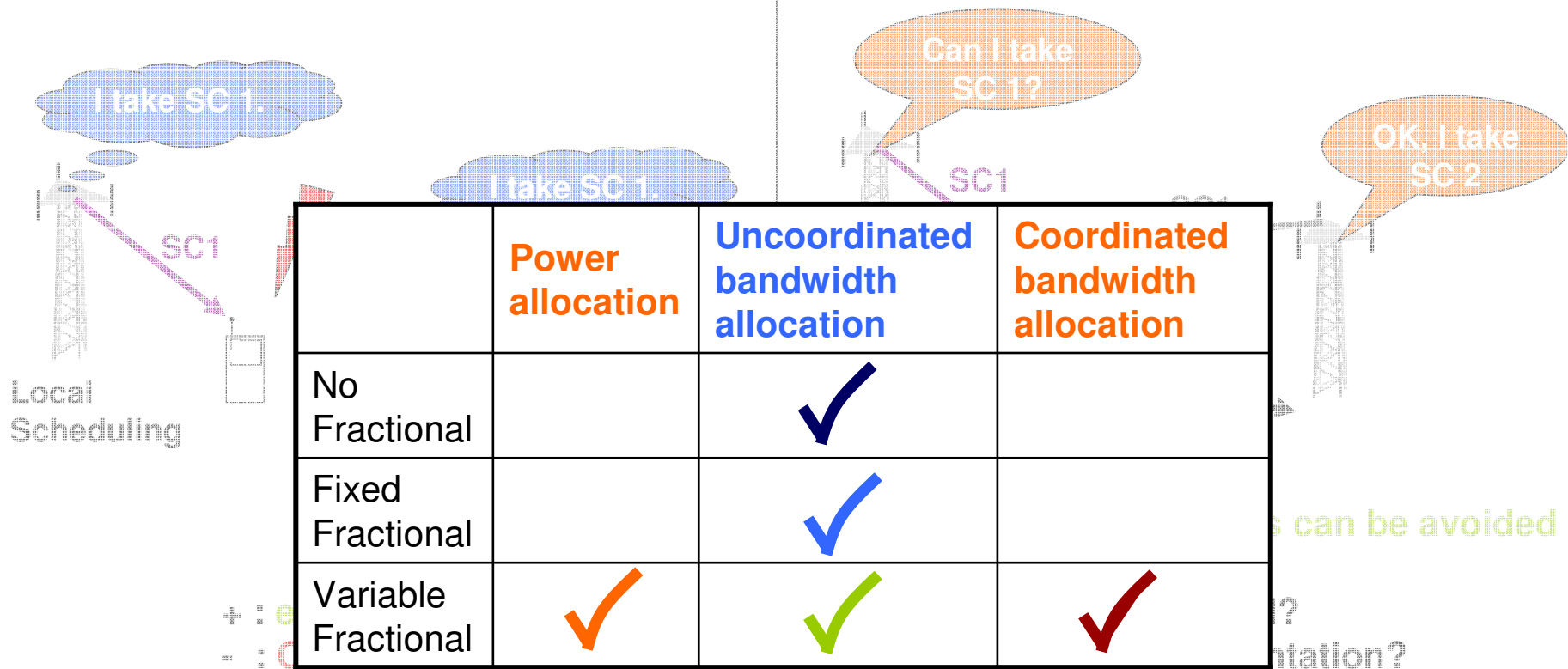
RRM Approaches

Resource allocation techniques

Fractional reuse modes	Power allocation	Uncoordinated bandwidth allocation	Coordinated bandwidth allocation
No Fractional	✓	✓	✓
Fixed Fractional	✓	✓	✓
Variable Fractional	✓	✓	✓

Coordination in Resource Allocation

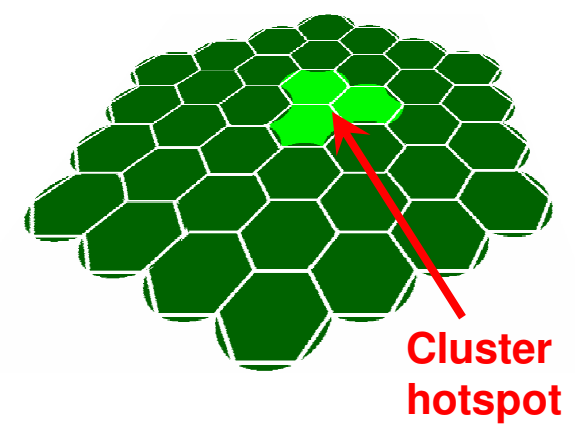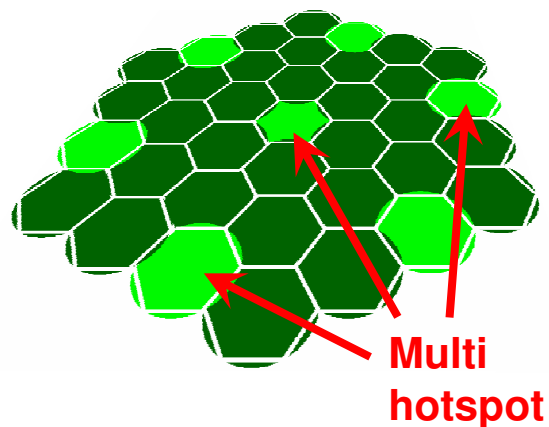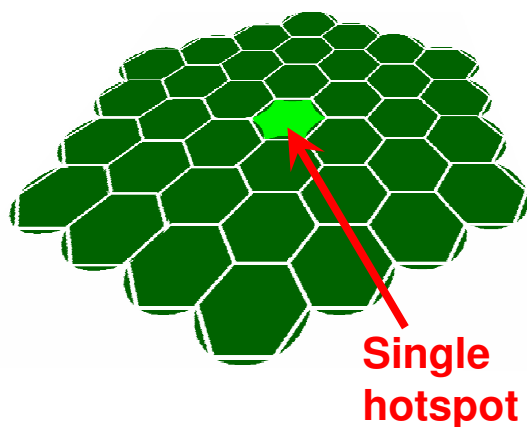|	**Power allocation**	**Uncoordinated bandwidth allocation**	**Coordinated bandwidth allocation**
No Fractional		✔	
Fixed Fractional		✔	
Variable Fractional	✔	✔	✔

Outline

- System Model
- Resource Allocation
  - Coordinated Approaches
  - Uncoordinated Approaches
- **Performance Evaluation**
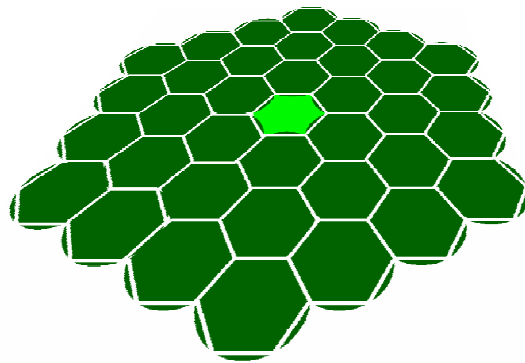
Simulation Scenarios

- 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
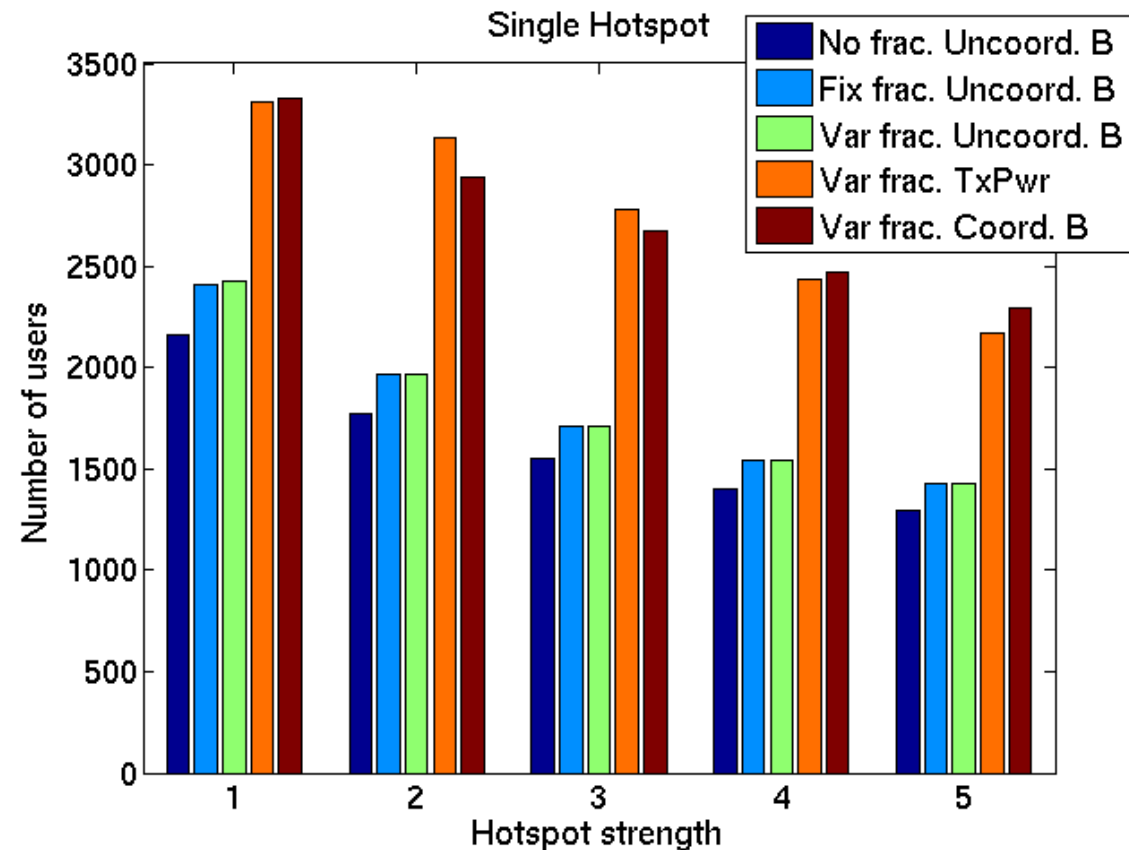
Single hotspot

Multi hotspot

Cluster hotspot

Simulation Parameters

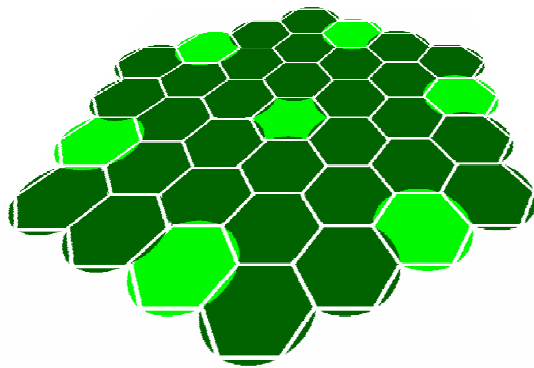|	
Cell radius R	250 m
User distribution	uniform
Propagation model	3GPP SCM Urban Macro
Shadow fading variance	8 dB
Hotspot strength factor $= N_{hs}/N_0$	1, 2, 3, 4, 5
Total system bandwidth	10 MHz
Scheduling	Fair throughput
Data rate per user	100 kbit/s
Inner area size for fixed fractional reuse mode (selected according to best average performance)	30 % of total cell area

Performance Results Single Hotspot Scenario

- Performance gain due to coordination
- Highest performance achieved with bandwidth allocation
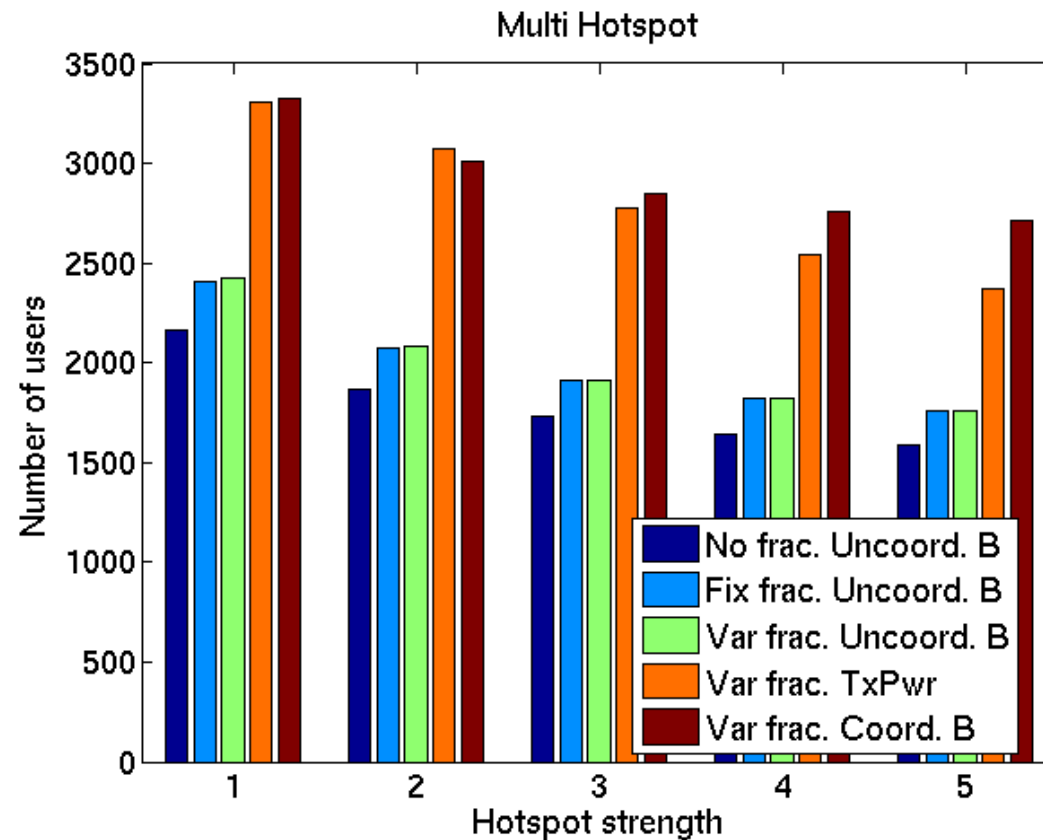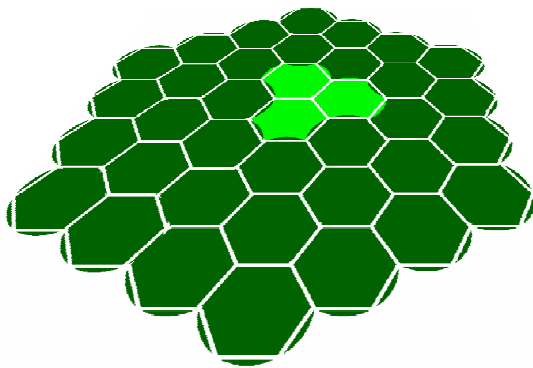 - log2-relation of capacity and power
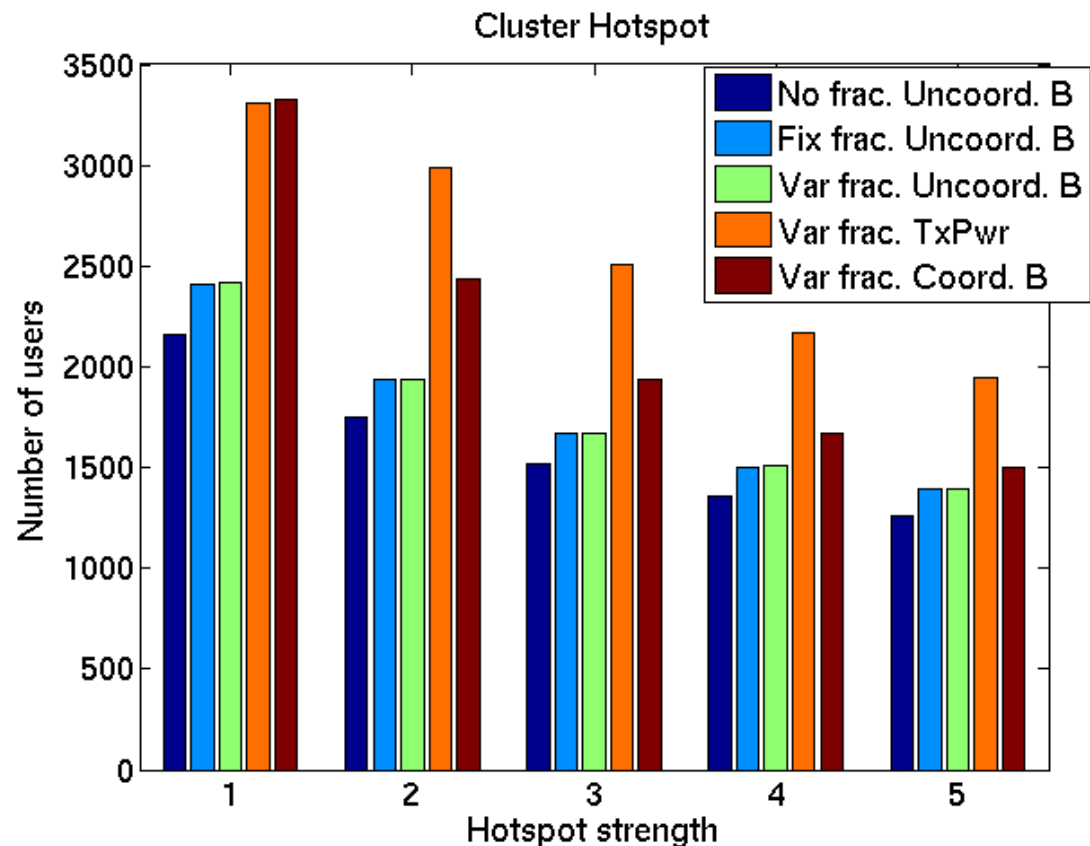
Performance Results Multi Hotspot Scenario

- Performance gain due to coordination
- Independent hotspots for bandwidth allocation
- Dependent hotspots for power allocation

Performance Results Cluster Hotspot Scenario

- Performance gain due to coordination
- Dependent hotspots for bandwidth allocation
- Independent hotspots for power allocation

Performance Comparison