Minimising Cell Transmit Power Towards Self-Organized Resource Allocation in OFDMA Femtocells

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Outline

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  - MSC, RB and power allocation
  - RB and power allocation, given MSC
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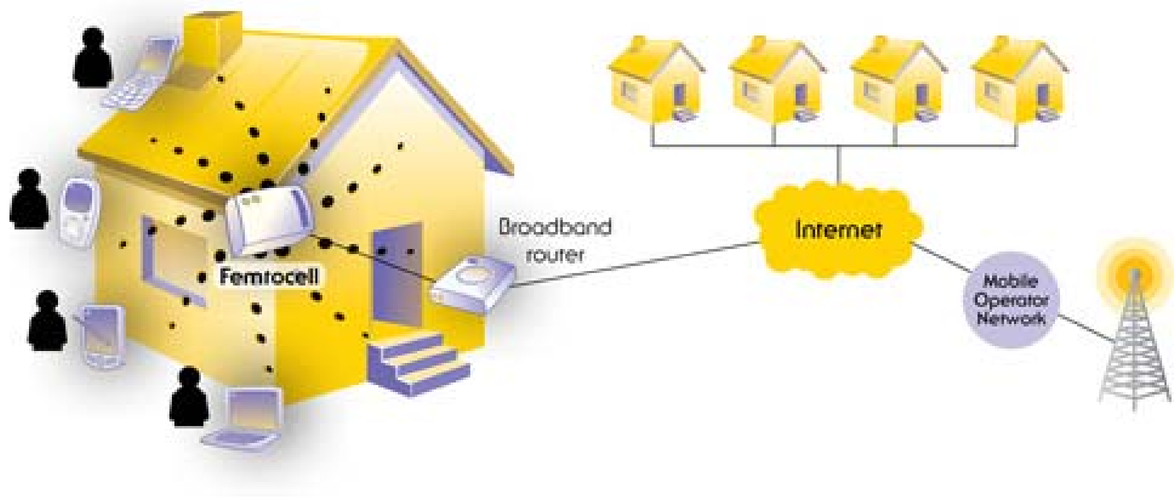
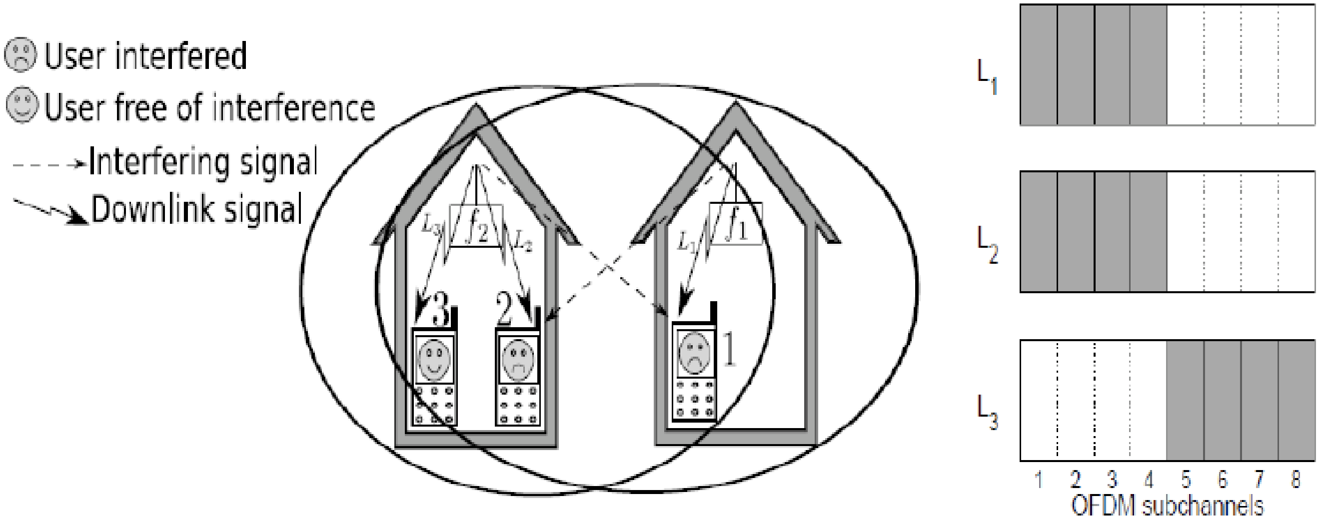
Femtocells

- Femtocells are low-power wireless access points that operate in licensed spectrum to connect standard mobile devices to a mobile operator's network using residential DSL or cable broadband connections [Source: Femto Forum].
  - Improve indoor coverage
  - Unload traffic from overburdened macrocells
  - Likely to be user-deployed → self-organization
  - Closed access, open access, hybrid access



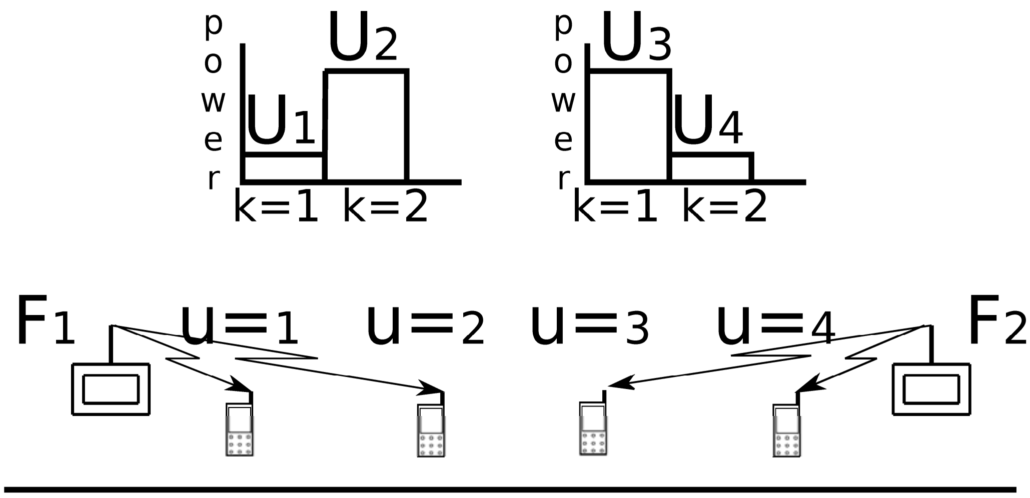
Self-Organized Resource Allocation

- Resource allocation strategies or rules that allow cells to independently perform assignments, while converging to a network-wide efficient resource allocation pattern



DL Transmit Power Minimization

- Minimizing DL transmit power per cell
  - Less power is allocated to users that have better locations or lower throughput demands.
  - A cell tends to use RBs that are less faded or interfered, where less power is needed to get a targeted SINR.
  - Mitigates interference to other cells



Resource Allocation Based on DL Power Minimization

- Each cell allocates MCS, RBs and power to users independently
- Target is to minimize DL transmit power

Transmit power needed by cell *m* to serve user *u* in RB *k* with MCS *r*

$$p_{m,u,k} = \gamma_{r_u} \cdot \frac{w_{u,k} + \sigma^2}{\Gamma_{m,u}}$$

- γ_{r_u} : target SINR
- $\Gamma_{m,u}$: channel gain
- $w_{u,k}$: interference power
- σ^2 : noise power

- Constraints:
  - No more than one UE per RB per cell
  - One MCS for each UE
  - UE throughput demand must be satisfied

Problem Formulation

- Joint MCS, RB and power allocation problem (RAP)

$$\min_{\chi_{u,k,r}} \sum_{u=1}^{U} \sum_{k=1}^{K} \sum_{r=1}^{R} P^{m}_{u,k,r} \cdot \chi_{u,k,r} \qquad (6a)$$

Transmit power of cell *m* to serve user *u* in RB *k* with MCS *r*

subject to:

$\sum_{u=1}^{U} \sum_{r=1}^{R} \chi_{u,k,r} \leq 1$	$\forall k$	(6b)	One UE per RB
$\sum_{r=1}^{R} \rho_{u,r} \leq 1$	$\forall u$	(6c)	One MCS per UE
$\chi_{u,k,r} \leq \rho_{u,r}$	$\forall u, k, r$	(6d)	
$\sum_{k=1}^{K} \sum_{r=1}^{R} \Theta \cdot \mathit{eff}_r \cdot \chi_{u,k,r} \geq TP^{req}_{u}$	$\forall u$	(6e)	UE throughput demand must be satisfied
$\rho_{u,r} \in \{0,1\}$	$\forall u, r$	(6f)	UE *u* uses MCS *r*
$\chi_{u,k,r} \in \{0,1\}$	$\forall u, k, r$	(6g)	UE *u* uses MCS *r* in RB *k*

RB and Power Allocation

- RB and power allocation problem (RPAP)
  - If the MCS of a user is fixed a priori, the joint MCS, RB and power allocation problem can be simplified to

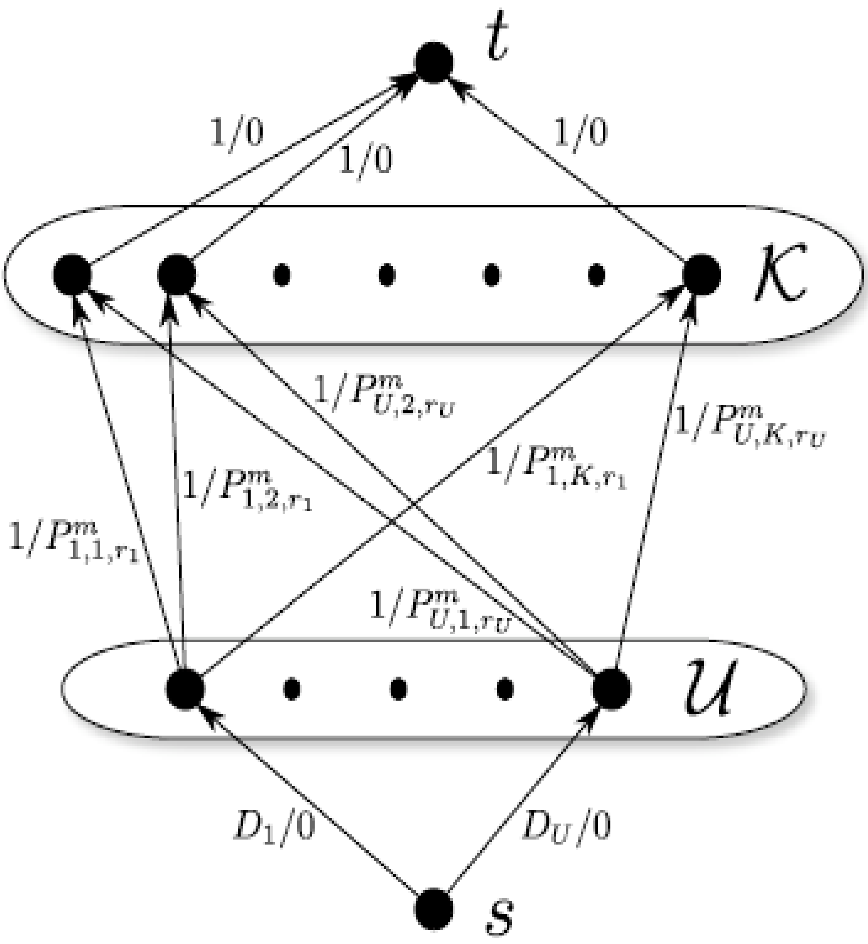
$$C_{\mathcal{S}} = \min_{\phi_{u,k}} \sum_{u=1}^{U} \sum_{k=1}^{K} P_{u,k,r_u}^{m} \cdot \phi_{u,k} \qquad (6a^*)$$

subject to:

$\sum_{u=1}^{U} \phi_{u,k} \leq 1$	$\forall k$	(6b*)	One UE per RB
$\sum_{k=1}^{K} \phi_{u,k} = D_u$	$\forall u$	(6e*)	UE *u* must have D_u RBs
$\phi_{u,k} \in \{0, 1\}$	$\forall u, k$	(6g*)	UE *u* uses RB *k*

Solving RPAP

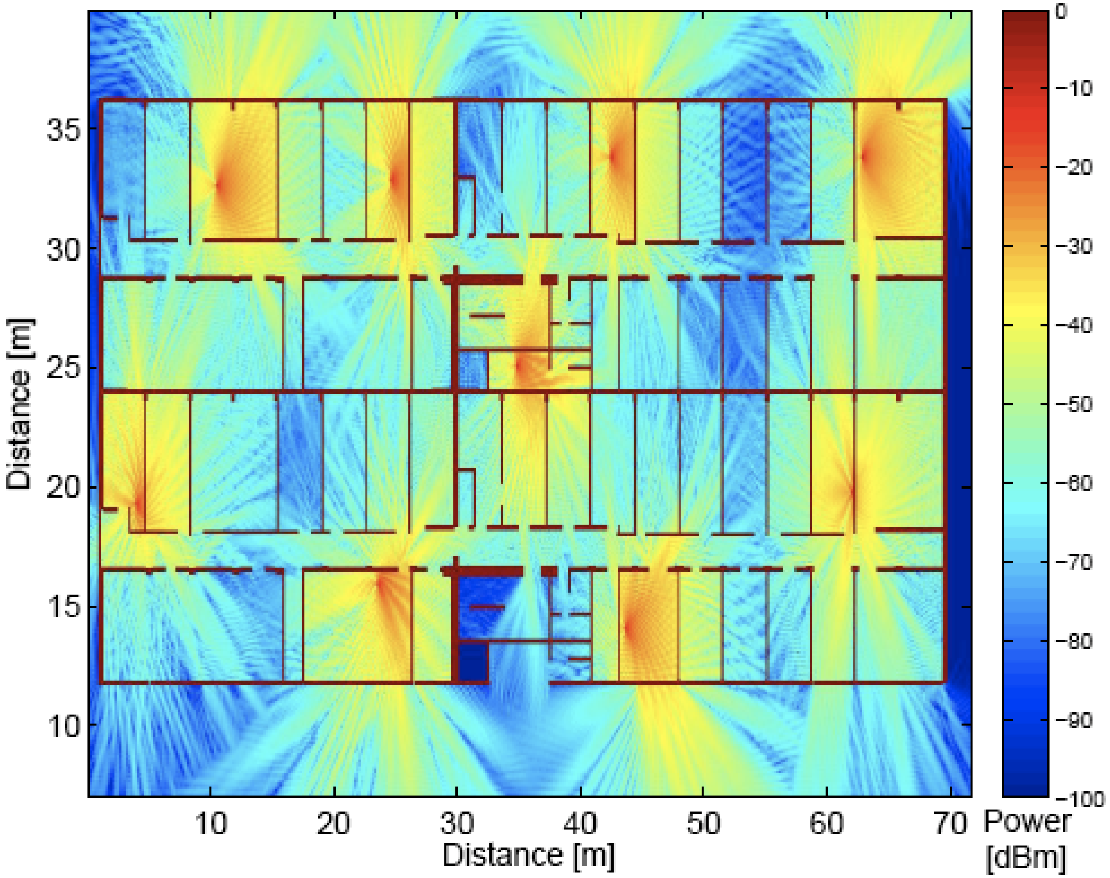
- The minimum-cost network-flow can be used to provide an optimal solution to RPAP.
- A network simplex approach is used to solve the minimum-cost network-flow.
- Running time: around 0.044ms



Label: capacity/cost

Simulation Setup

- Scenario: 9 femtocells, 8 RBs, and 8 UEs per femtocell



UEs are uniformly distributed within each femtocell coverage area.

Each UE connects to the network for an exponentially distributed time (mean = 90s).

When a UE disappears, a new one is generated in a randomly selected location.

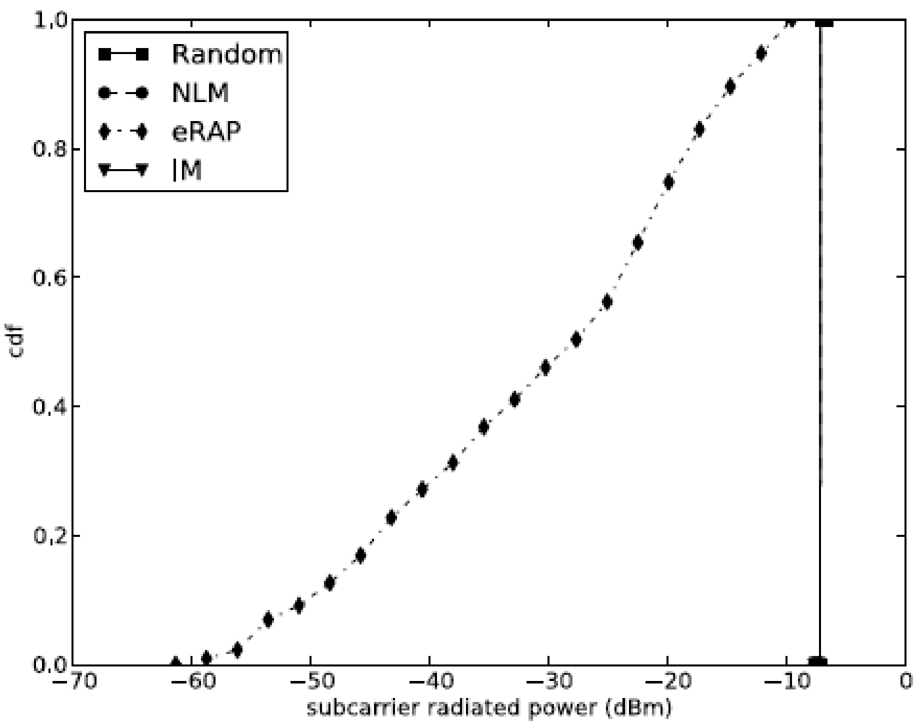
Simulation Setup

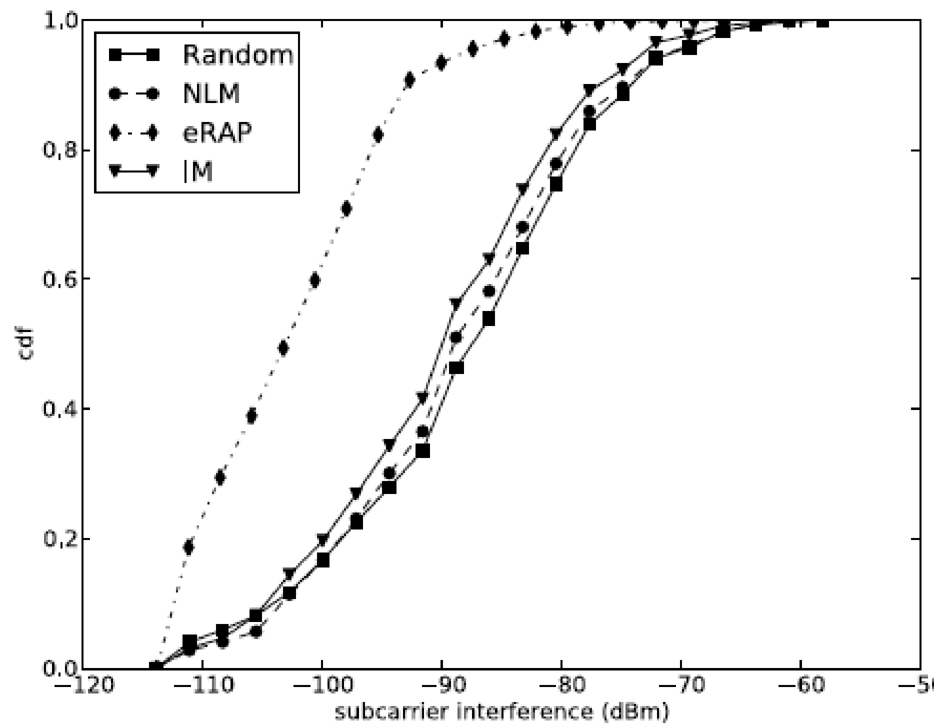
Parameter	Value	Parameter	Value
Simulation time	$10\,min$	Femto ant. gain	$0\,dBi$
Scenario size	$90 \times 90m$	Femto ant. pattern	Omni
# Femtos (F)	9	UE ant. gain	$0\,dB$
r_f	$15\,m$	UE body loss	$0\,dB$
Carrier frequency	$2.0\,GHz$	UE ant. pattern	Omni
Channel bandwidth	$5\,MHz$	UE noise figure	$9\,dB$
$T_{subframe}$	$5\,ms$	UE per femto. (U)	8
Subcarriers	512	μ_p	$90\,s$
Subchannels (K)	8	UE distribution	uniform
DL OFDM symbols	39	TP_u^{req}	$500\,kbps$
Femto TX power	$20\,dBm$	Traffic model	full buffer

- A UE is considered to be in outage, when it fails to keep transmitting at a throughput larger than its demand (500kbps) for 4 seconds.

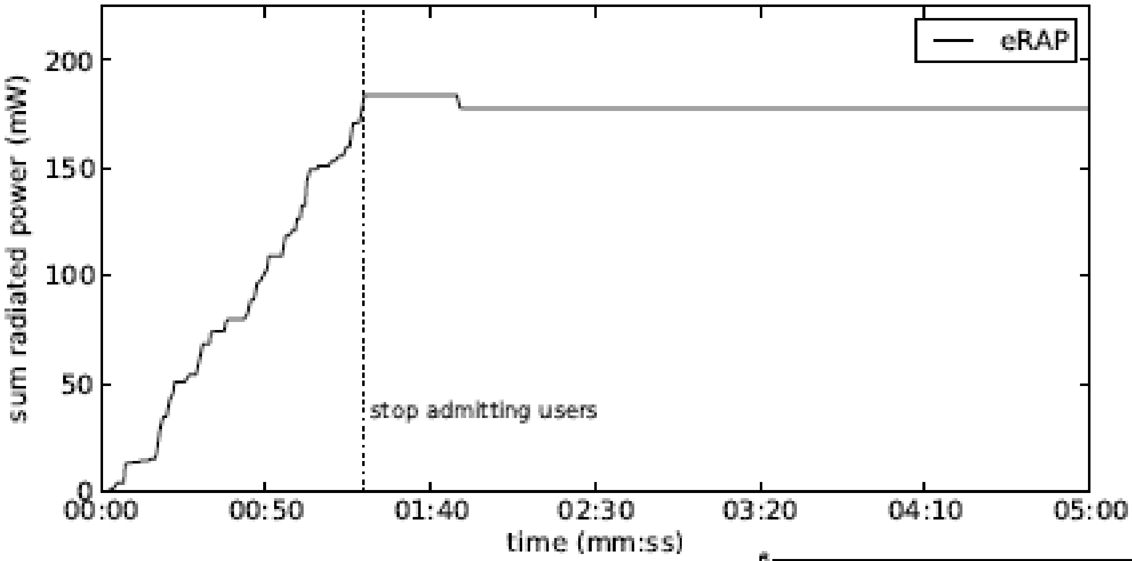
Results

- Transmit power and interference
  - Random: Uniform power distribution + random assignment
  - NLM: Uniform power distribution + Network Listening Mode
  - IM: Uniform power distribution + Interference Minimization

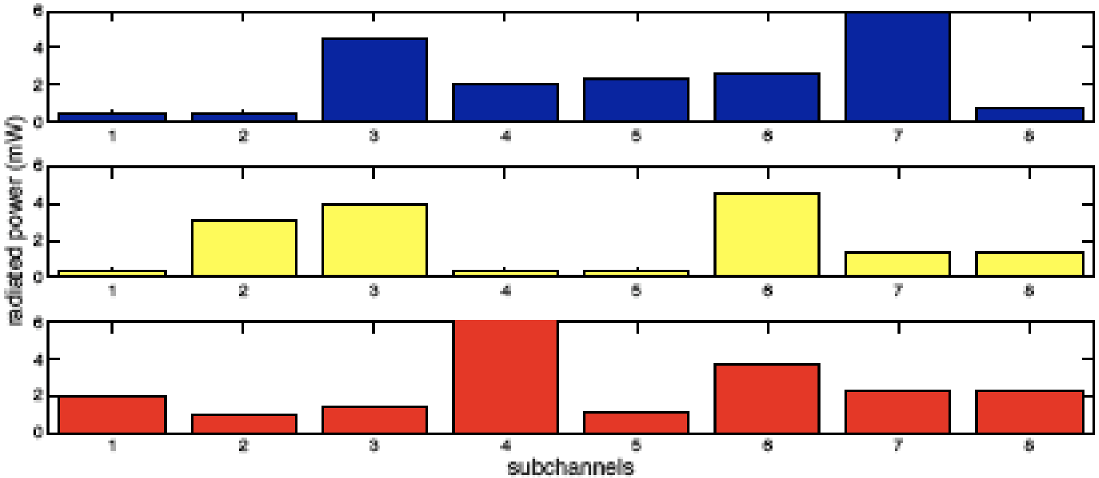




Stability and Interference Avoidance



The proposed scheme converges to an stable solution.



Network Performance

- Network performance in terms of number of outages, number of connected users, and throughput.

Table 7.5: System-level simulation results (9 femtocell scenario)

Cell load	Scheme	Rnd	MNL	IM	eRAP
4 users/femtocell 50 % load	Outage	25 (9.92 %)	6 (2.38 %)	1 (0.40 %)	1 (0.40 %)
	Users	31.93	35.02	35.54	35.79
	Mbps	15.84	17.49	17.76	17.87
6 users/femtocell 75 % load	Outage	67 (17.49 %)	56 (14.62 %)	25 (6.53 %)	3 (0.78 %)
	Users	46.46	47.78	51.13	53.78
	Mbps	22.96	23.75	25.46	26.62
8 users/femtocell 100 % load	Outage	121 (23.04 %)	118 (22.48 %)	96 (18.29 %)	17 (3.24 %)
	Users	55.49	55.69	59.64	69.21
	Mbps	27.47	27.54	29.47	33.49

Conclusion

- Minimizing DL transmit power independently at femtocells allows for a better spatial reuse.
- Allocating different power levels to different subcarriers is much more efficient than uniformly distributing power among them.
- Minimizing DL transmit power per cell mitigates inter-cell interference.
- The proposed joint MSC, RB and power allocation scheme is able to converge to stable resource assignments.

Thank You !

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