University of Bedfordshire

CWIND Centre for Wireless Network Design

Self-organisation of the Sub-channel Assignment in OFDMA Femtocells: Advantages and Drawbacks of Different Channel Monitoring Techniques

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24th June 2009 – Femtocells World Summit

Agenda

- Introduction
  - OFDMA
  - Interference in femtocell deployments
- Self-organisation
  - Spectrum allocation
  - Self-organisation techniques
- Proposed approach: Broadcast message
- Proposed approach: Measurement report
- Dynamic System Level Simulation& Performance evaluation

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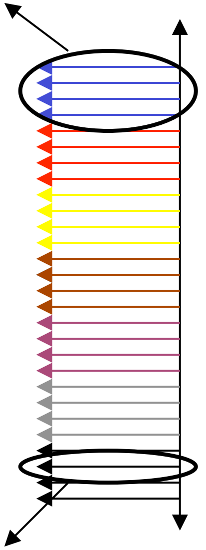
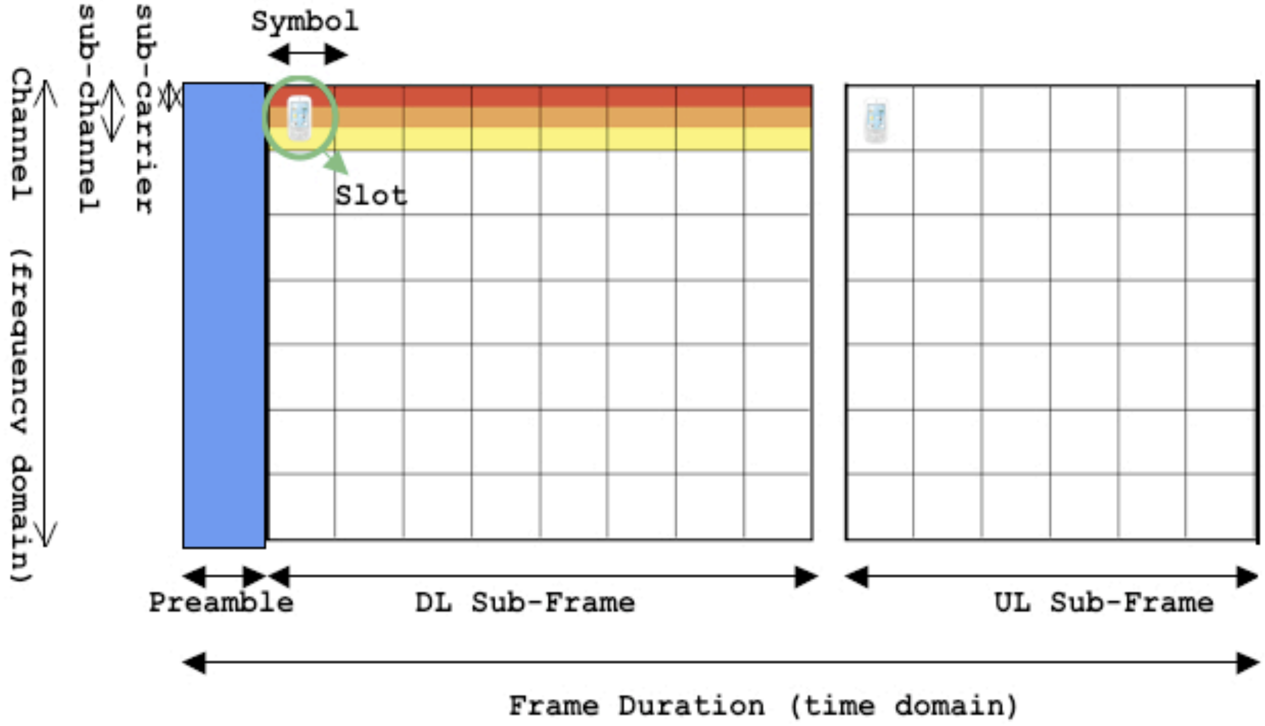
Introduction

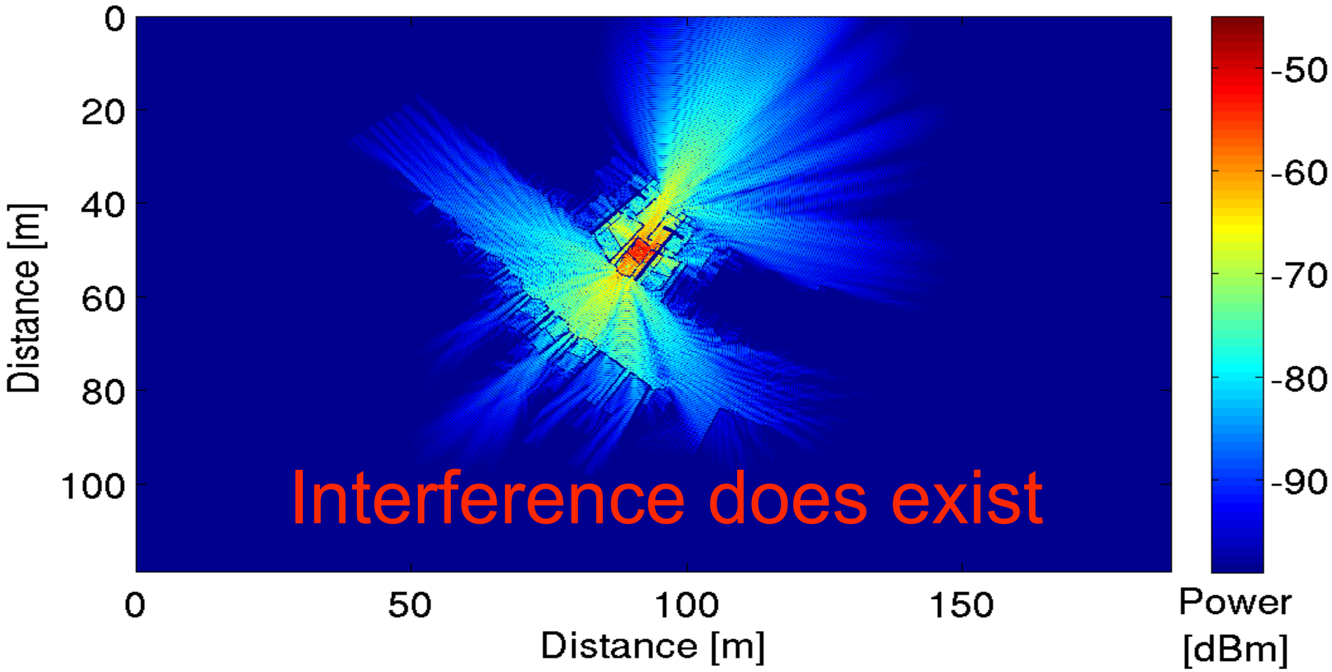
- OFDMA / Time Division Duplex (TDD) frame structure, e.g. LTE, WiMAX





Introduction

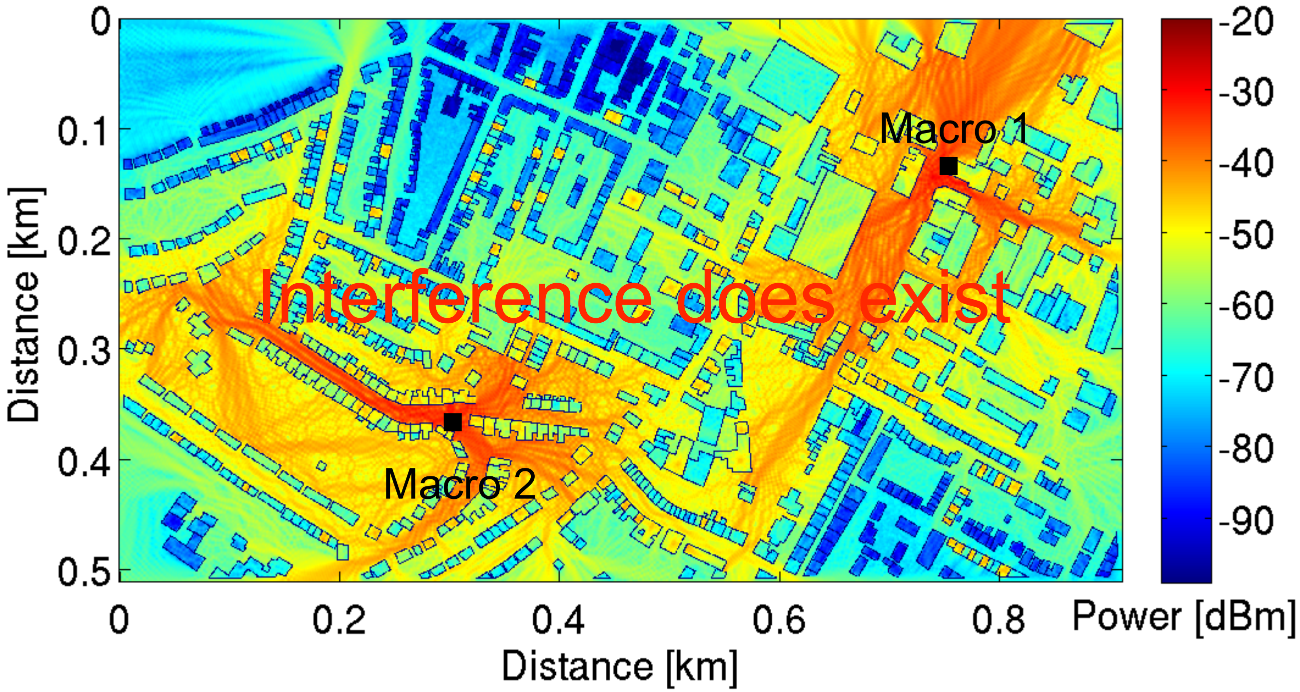
- Received Signal Strength prediction of a femtocell [1]



[1] A. Valcarce, G. De La Roche, A. Jüttner, D. López-Pérez and J. Zhang, "Applying FDTD to the coverage prediction of WiMAX femtocells," in EURASIP Journal of Wireless Communications and Networking. Volume 2009, Article ID 308606, 13 pages.

Introduction

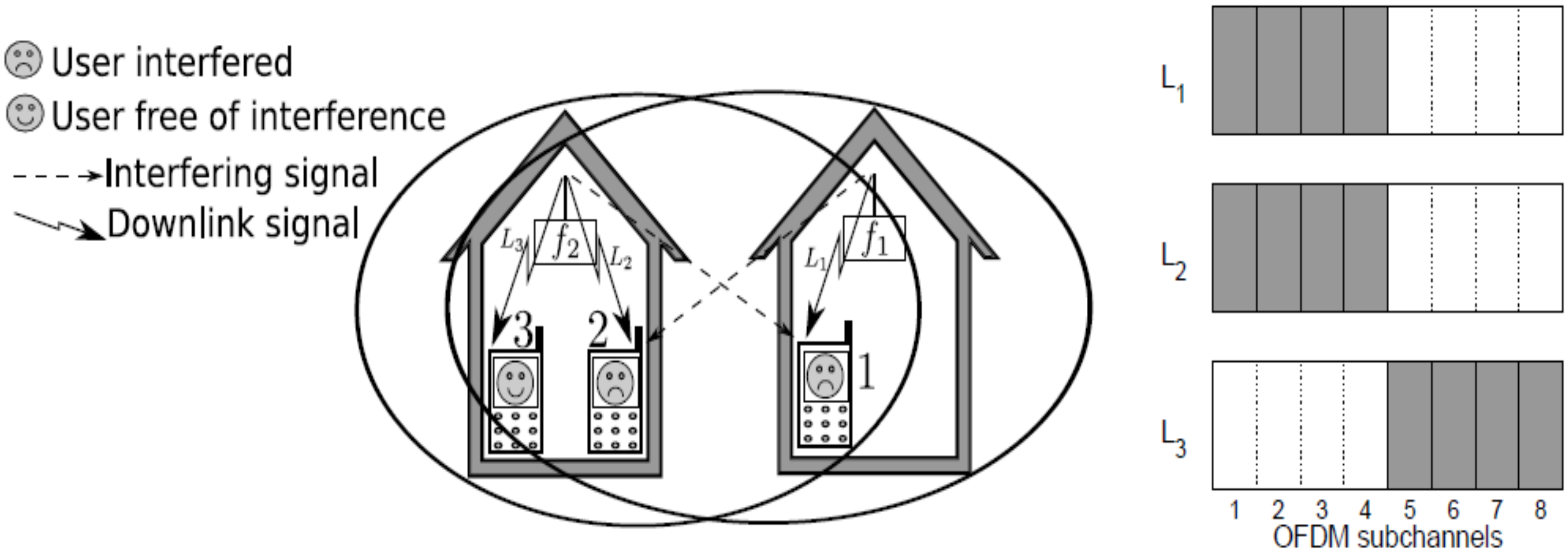
- Received Signal Quality (best server) prediction of a femtocell layer [2]



[2] “Femtocells – Technologies and Deployment”, Wiley, Q3 2009. (Lead authors: Prof. Jie Zhang and Dr Guillaume de la Roche ; Contributing authors: Alvaro Valcarce, David Lopez, Enjie Liu and Hui Song)

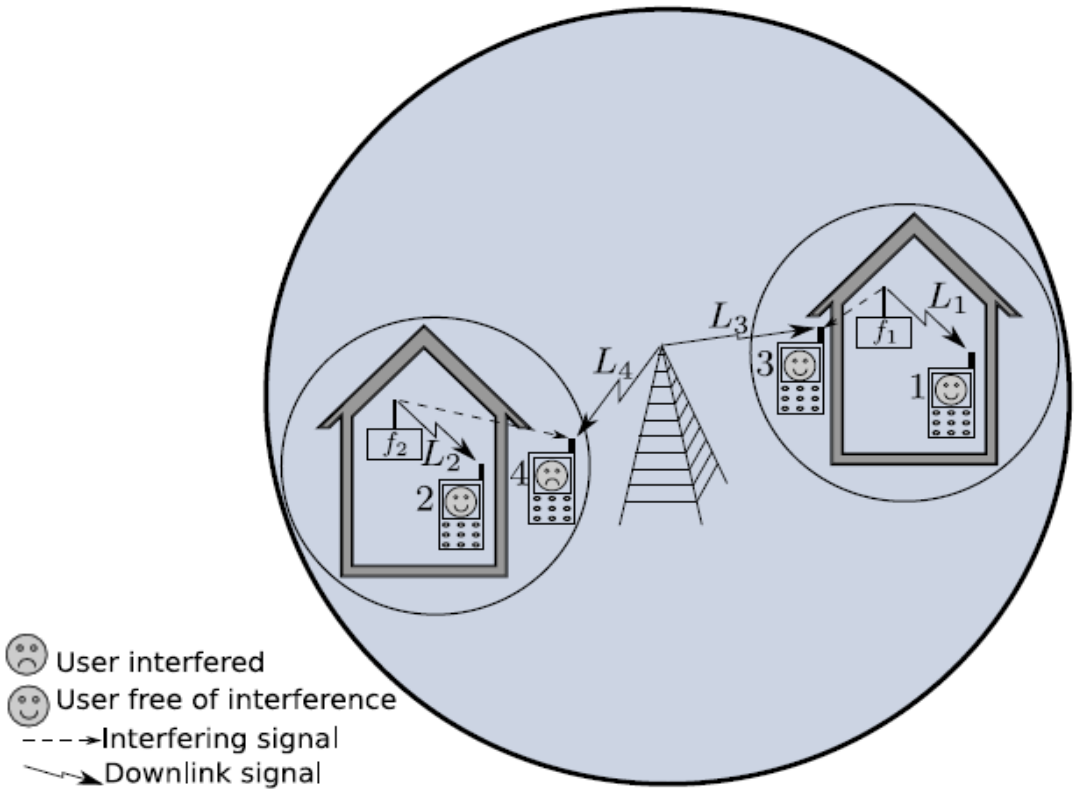
Co-Layer Interference

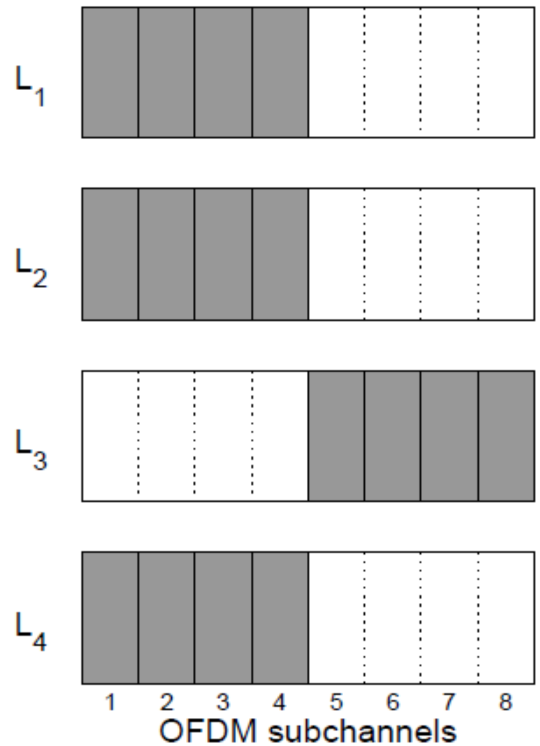
- Co-layer downlink interference in an OFDMA femtocell network [2]



Cross-Layer Interference

- Cross-layer downlink interference in an OFDMA femtocell network [2]





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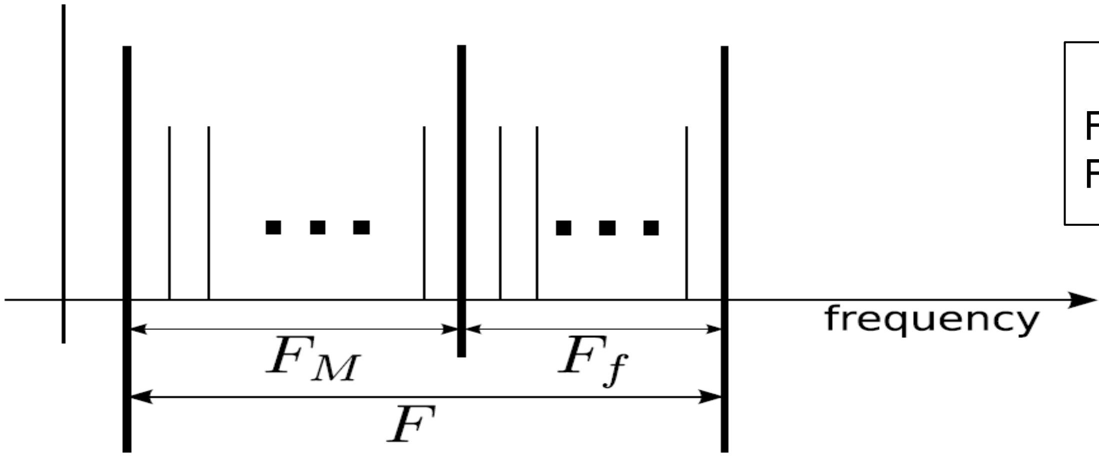
Spectrum Allocation

- Orthogonal and Co-channel deployments
  - Orthogonal deployments suppress cross-layer interference, but results in a low spectrum efficiency (*bit/s/Hz*).
  - Co-channel deployments enhance spectrum efficiency (*bit/s/Hz*), at the expense of managing the interference.



<u>Orthogonal deployment:</u>
F_M macrocell subchannels
F_f femtocell subchannels

Self-organisation of Femtocells

- Co- and cross-layer interference can be avoided in co-channel deployments using self-organisation strategies.
- Self-organisation strategies are divided into 2 phases: the sensing phase and the tuning phase.
- Proposed approaches in the literature:
  - Power management (pilot and data) [3]
  - Mobility Events [4]
  - Antenna pattern [5]
  - Sub-channel assignment (our research)

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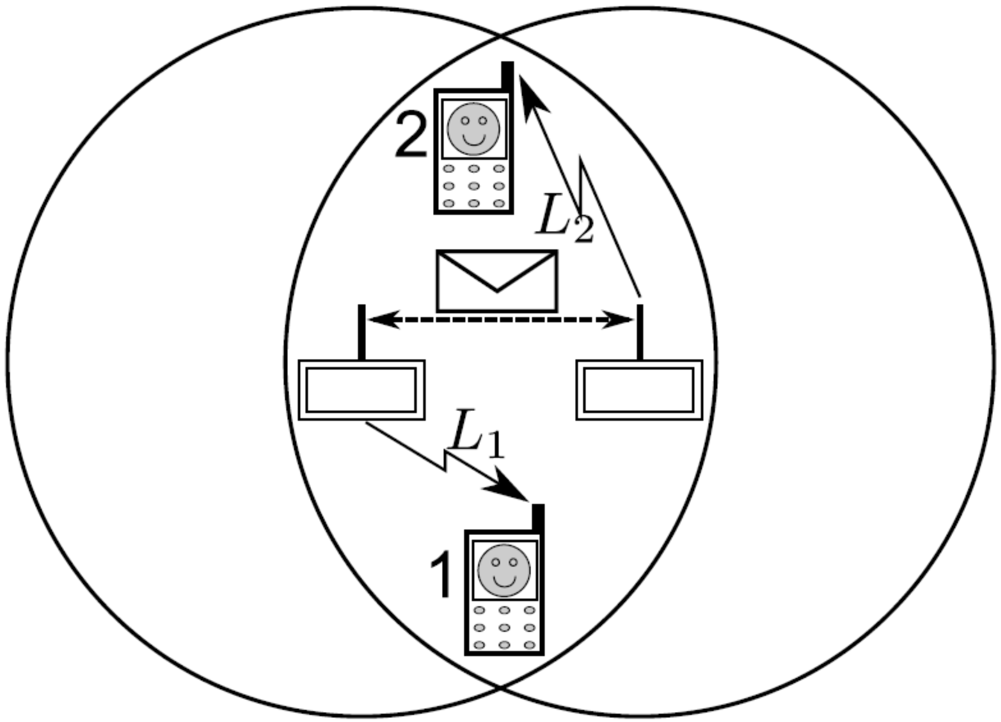
Broadcast message

- SENSING techniques: broadcast message.

a) Possible when coverage areas overlap



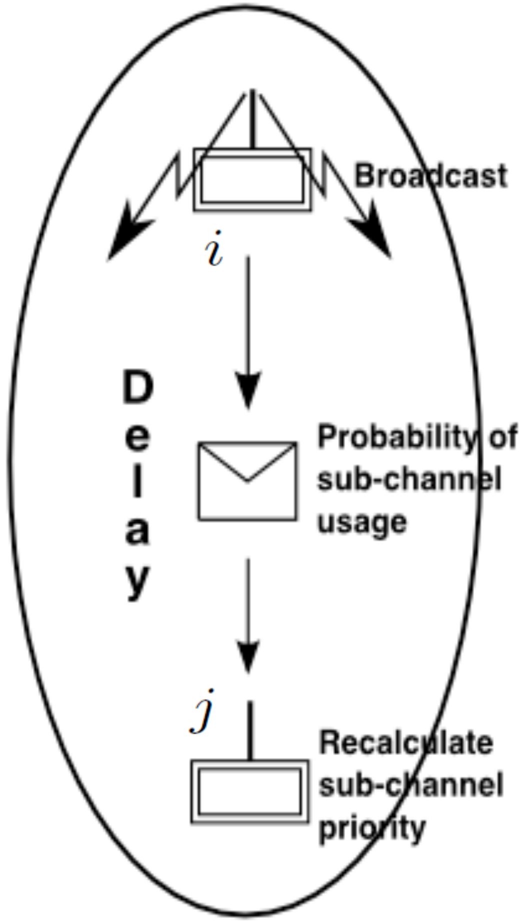
Broadcast message

1) Every femtocell broadcasts a message on regular basis (T_{update}), or when an event happens (change on the channel assignment)

   This broadcasted message indicates the probability of usage of each sub-channel.

2) Then, each femtocell updates its priority of sub-channel usage according to a cost function.

3) Finally, the users are reassigned to new sub-channels according to the new priority



Broadcast message

- The new sub-channel priority is computed by using the following cost function:

$$badness_j(k) = \sum_{i \in \mathcal{N}_j} p_i^{interf}(k)^{\alpha} \cdot p_i^{usage}(k)^{\beta}$$

$\mathcal{N}_j$ ⟶ set of neighbors of *j*

$p_i^{interf}(k) \in [0, 1]$ ⟶ “intensity” of interference

$p_i^{usage}(k) \in [0, 1]$ ⟶ probability of usage

α and $\beta \in [0, 1]$ ⟶ constants

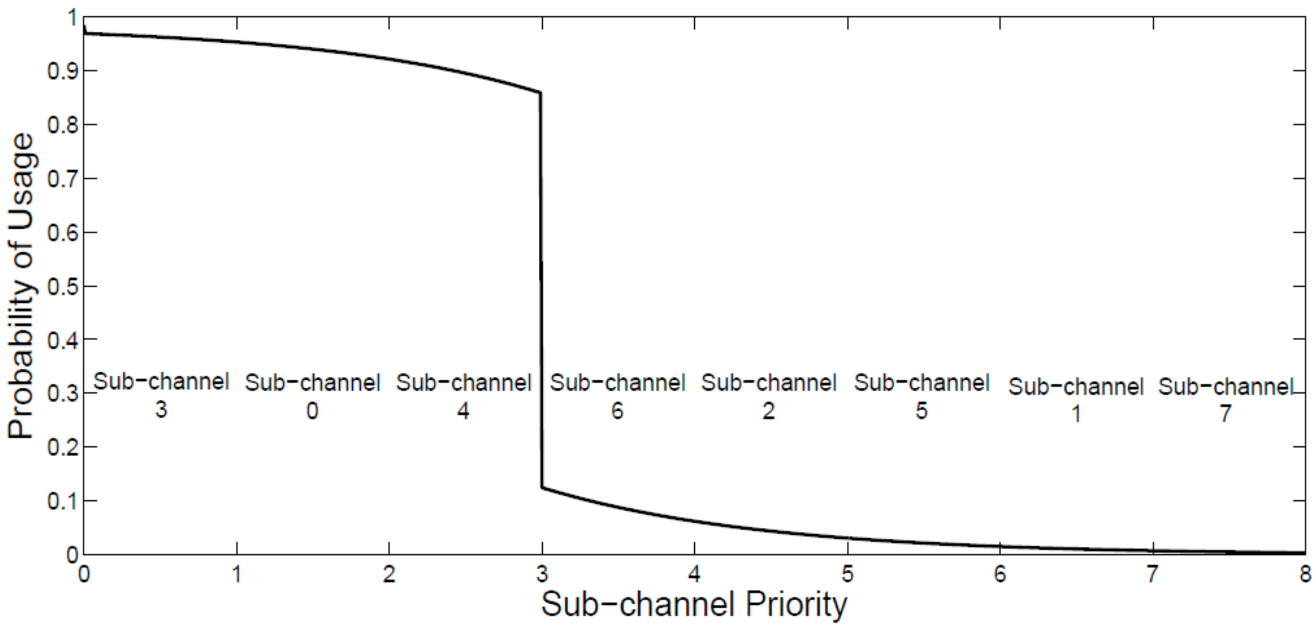
$\{0, \cdots, k, \cdots, K-1\}$ ⟶ sub-channel

Broadcast message

- The probability of usage (based on probabilistic modeling)

E.g. 8 sub-channels and 3 connected users:

- If a new user appears, s/he will use k=6
- If an existing user dies, k=4 will be freed



Broadcast message

- The probability of usage

The probability of a user appearing/disappearing is computed according to a probabilistic model:

Probability of *a* user arriving on a specific femtocell in a network of *n* femtocells

$$P(k, \lambda T) = \frac{(\lambda T)^k \cdot e^{-\lambda T}}{k!}$$

$$P_k^a = \binom{k}{a} \cdot \left(\frac{1}{n}\right)^a \cdot \left(\frac{n-1}{n}\right)^{k-a}$$

$$P_{arrival}(a) = \sum_{i=0}^{\infty} P(a+i, \lambda T) \cdot P_{a+i}^a$$

Probability of *l* users leaving a specific femtocell with *c* users

$$P_{leave1} = 1 - e^{-\lambda T}$$

$$P_{leave}(l) = \binom{c}{l} \cdot (P_{leave1})^l \cdot (1 - P_{leave1})^{c-l}$$

Probability of having an increment *of x* users on a specific femtocell

$$P_x = \sum_{\theta} P_{arrival}(a) \cdot P_{leave}(l)$$

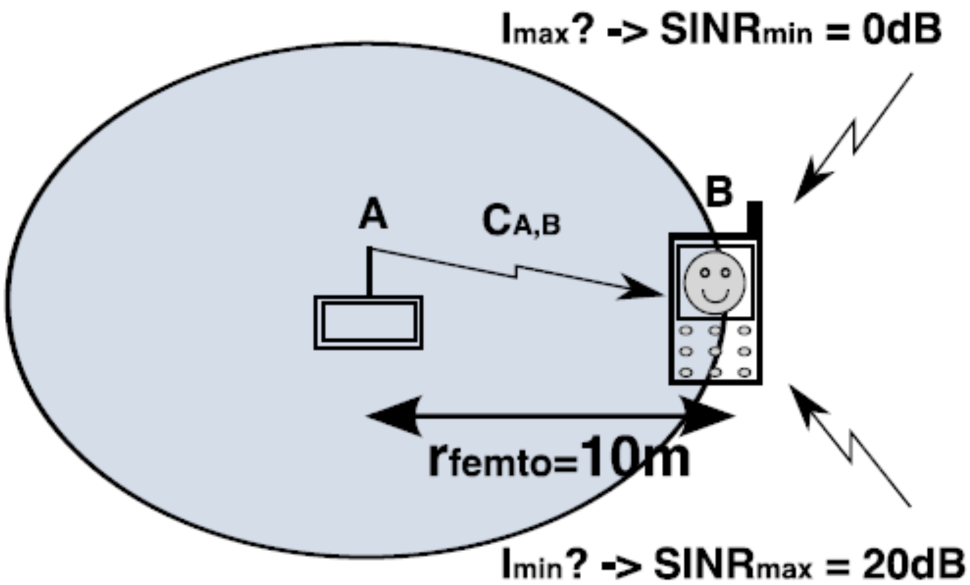
$$\theta = \{a, l \mid a - l = x, 0 \le a \le K - c, 0 \le l \le c\}$$

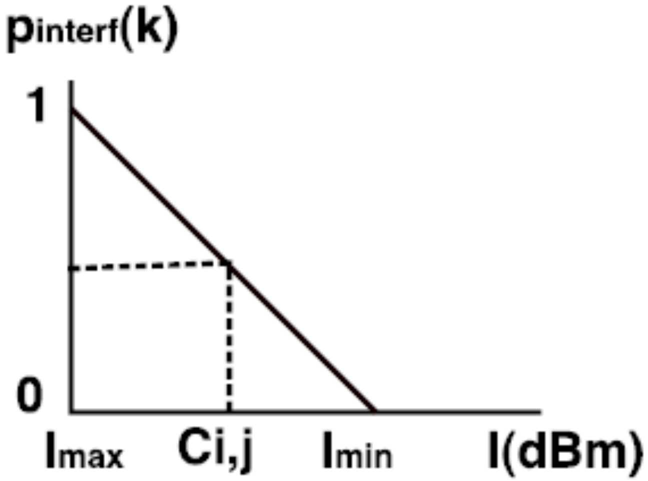
Broadcast message

- The "intensity" of interference is computed according to the received signal strength ($C_{i,j}$) of the message and the following model

$$I_{min} = \frac{C_{A,B}}{SINR_{max}} - \sigma$$

$$I_{max} = \frac{C_{A,B}}{SINR_{min}} - \sigma$$

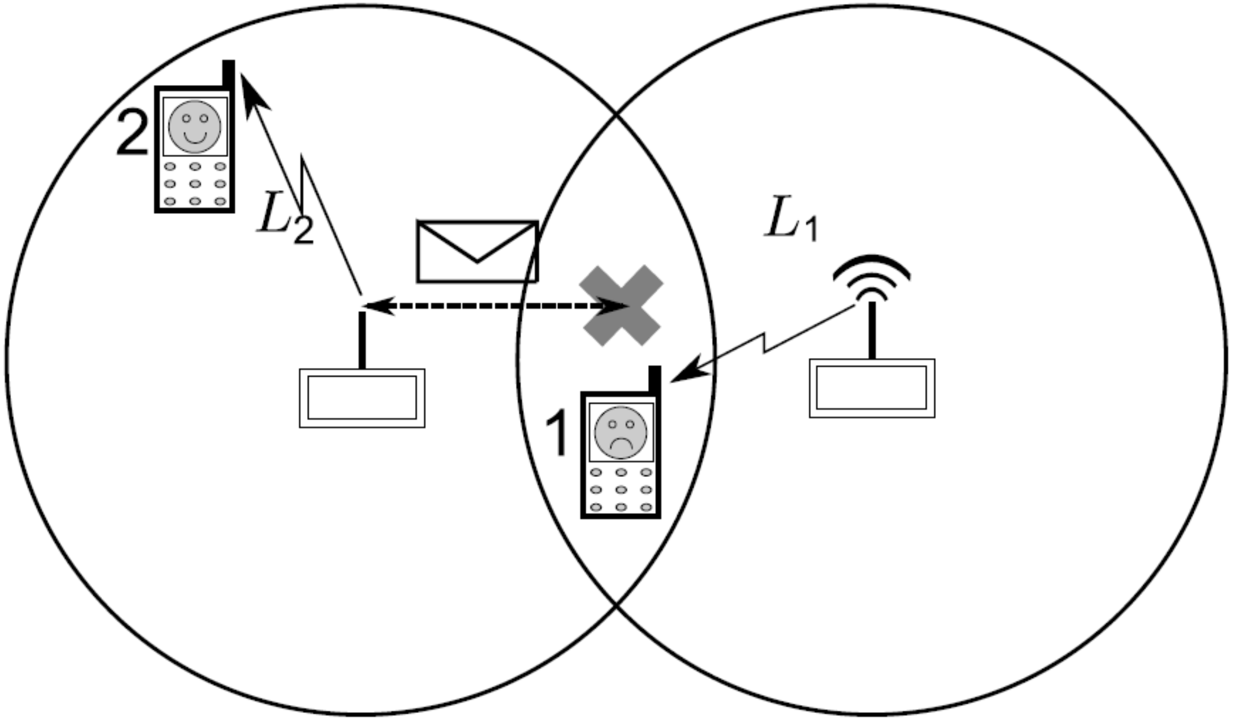




Self-organisation of Femtocells

- The Hidden femtocell problem [2]:

Not possible when coverage areas do not overlap



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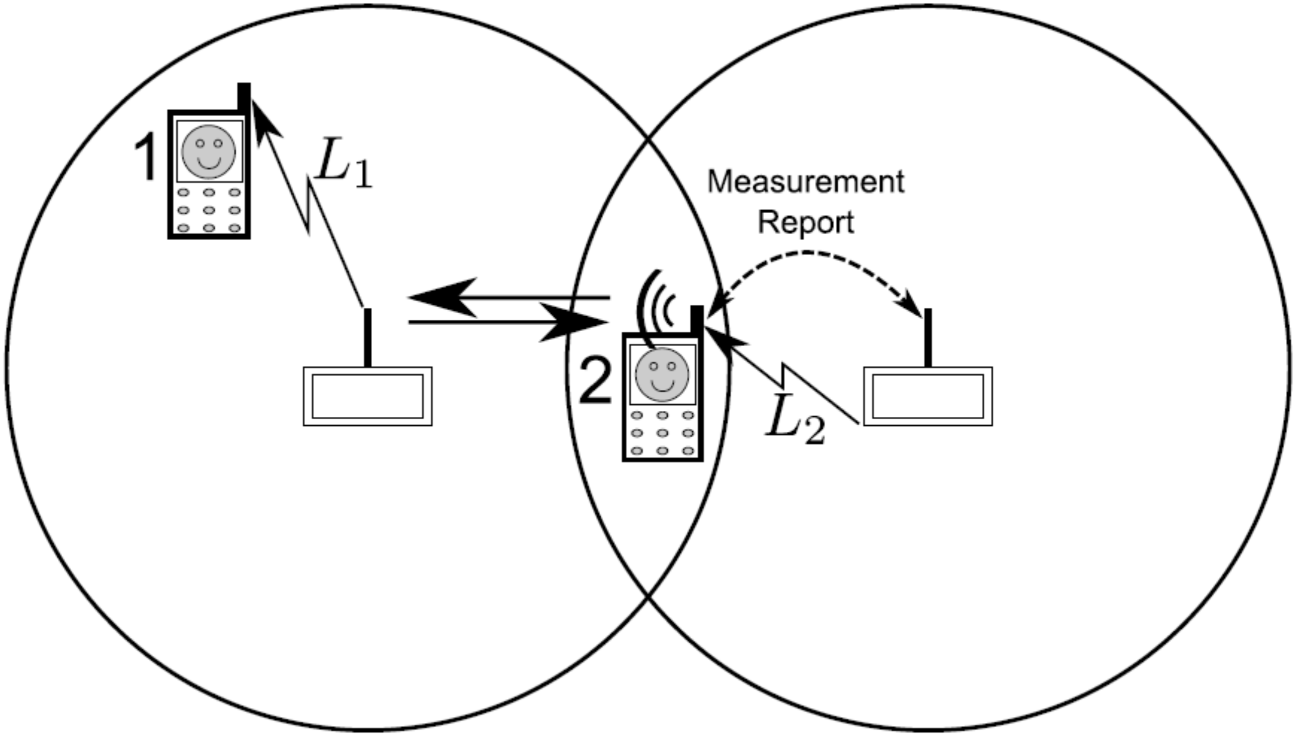
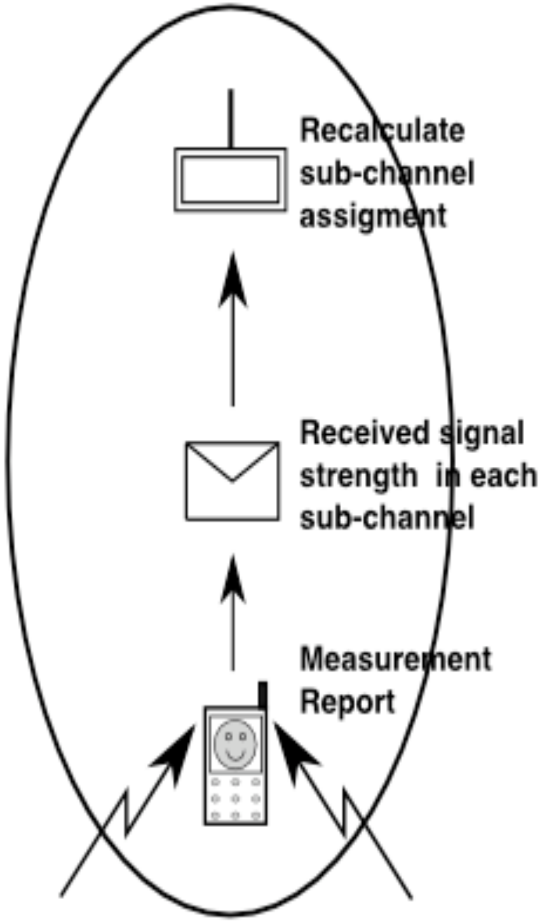
Measurement Reports

- SENSING technique: measurement report.



Measurement Reports

- Every user sends a Measurement Report on regular basis (TMR).
- The MR indicates the received signal strength in each sub-channel.
- Each femtocell updates its sub-channel priority according to the MRs of its users.
- The target of the sub-channel allocation procedure is to minimize the suffered interference of the femtocell users.



Measurement Reports

- Interference matrix (*M* x *K*) $\begin{cases} X & \text{connected users} \\ K & \text{sub-channels} \end{cases}$

Received Signal Strength (dBm)

Sub-channels

Users	0	1	2		k	K-2	K-1
0	I_{00}	I_{01}					$I_{0,K-1}$
1	I_{10}						
2							
m							
M-2							
M-1	$I_{M-1,0}$						$I_{M-1,K-1}$

Measurement Reports

- Optimisation problem $\begin{cases} X & \text{connected users} \\ K & \text{sub-channels} \end{cases}$

$$min \sum_{m=0}^{M_i-1} \sum_{k=0}^{K-1} w_{m,k} \cdot \gamma_{m,k}$$

subject to:

$$\sum_{m=0}^{M_i-1} \gamma_{m,k} \leq 1 \qquad \forall k$$

$$\sum_{k=0}^{K-1} \gamma_{m,k} = 1 \qquad \forall m$$

$$\gamma_{m,k} \in \{0, 1\} \qquad \forall m, k$$

	0	1	2		k	K-2	K-1
0	I_{00}	I_{01}					$I_{0,K-1}$
1	I_{10}						
2							
m							
M-2							
M-1	$I_{M-1,0}$						

- ***Assumption*** **: Each user demands one sub-channel**

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Evaluation: Traffic Model

- Event driven dynamic system level simulation
- Traffic generation (maximum 4 users per femtocell):
  - User generation: Poisson process
  - Holding time: Exponential distribution
  - Users are uniformly distributed within a radius of *10m* around a random selected femtocell
  - Assumption: Each user demands one sub-channel

Evaluation: Interference Model

- Interference Calculation (OFDMA):

•Signal Quality (Signal to Interference plus Noise Ratio)

$$SINR = \frac{C}{I + \sigma}$$

•Carrier Signal Strength (dBm)

$$C_{x,k}^{DL} = P_{i,k} \cdot G_i \cdot L_i \cdot Lp_{i,x} \cdot G_x \cdot L_x$$

•Interference Signal Strength (dBm)

$$I_{i,k,t}^{UL} = \sum_{y=1,y\neq x}^{M-1} \sum_{t=0}^{T-1} (P_{y,k} \cdot G_y \cdot L_y \cdot Lp_{y,i} \cdot G_i \cdot L_i) \cdot \theta_{x,k,t}$$

Evaluation: Throughput calculation

- Throughput Calculation (OFDMA):

RAB	Modulation	Coding	Efficiency (bits/symbol)	SINR Threshold (dB)
RAB1	QPSK	1/2	1	2.88
RAB2	QPSK	3/4	1.5	5.74
RAB3	16QAM	1/2	2	8.79
RAB4	16QAM	3/4	3	12.22
RAB5	64QAM	1/2	4	15.88
RAB6	64QAM	2/3	4.66	16.80
RAB7	64QAM	3/4	6	17.50

•Slot Bit Rate

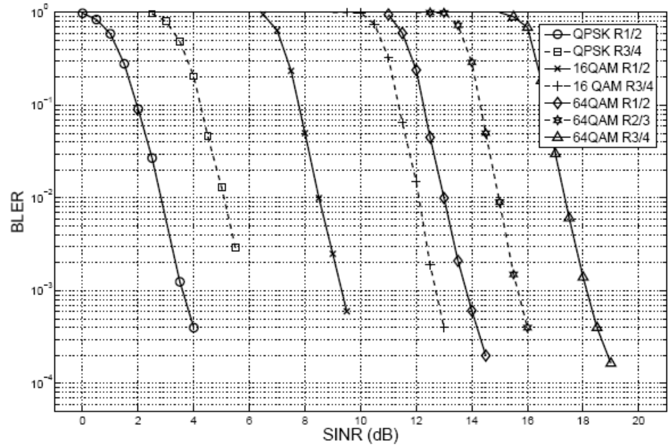
$$BR_{slot}^{i,k,t} = \frac{RAB_{eff}^{i,k,t}}{T_{frame}} \cdot \frac{C}{K}$$

•Slot Throughput

$$TP_{slot}^{i,k,t} = BR_{slot}^{i,k,t} \cdot (1 - BLER_{i,k,t}(SINR, RAB))$$

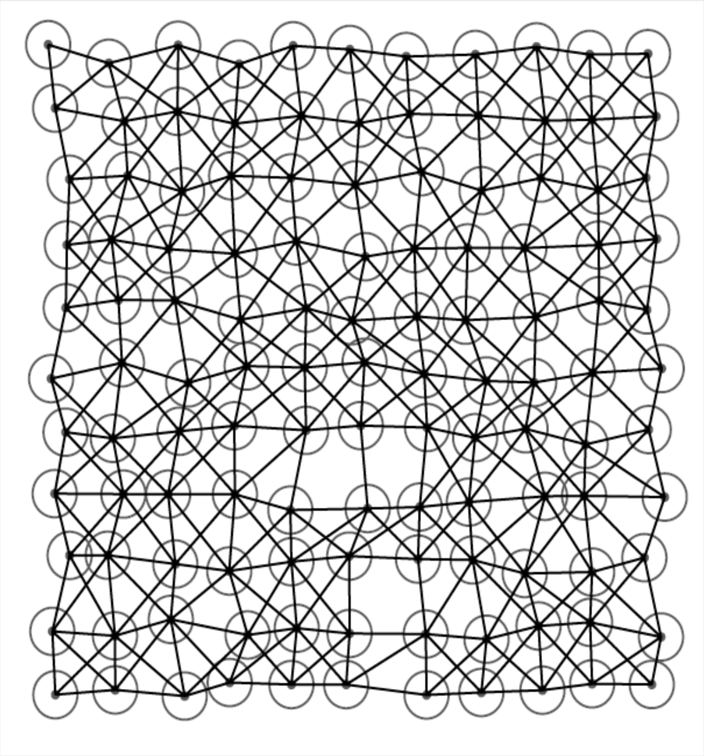
•User Throughput

$$TP_x = \sum_{k=0}^{K-1} \sum_{t=0}^{T-1} TP_{i,k,t} \cdot \phi_{i,k,t}$$



Performance Evaluation

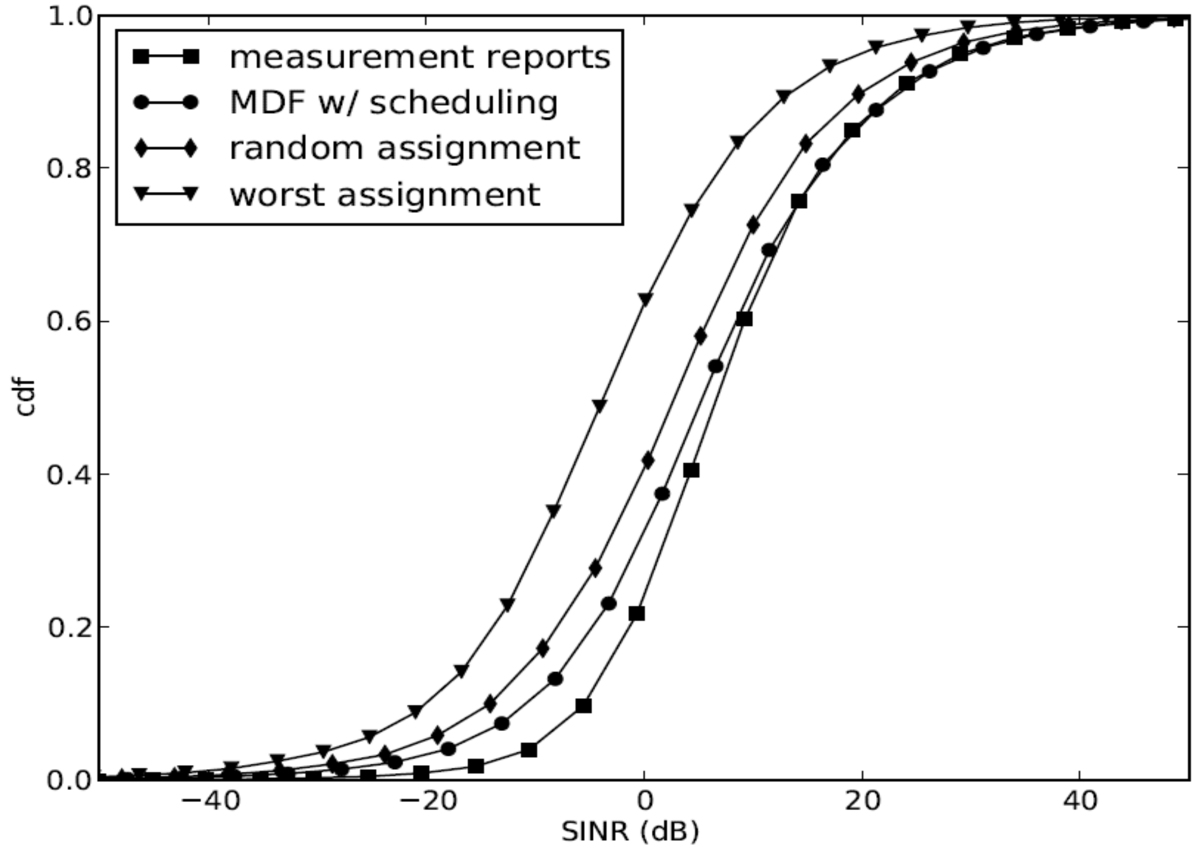
- Simulation parameters



Parameter	Value	Parameter	Value
Scenario size	$300 \times 300m$	F_i radius (r_{femto})	$10\,m$
Femtocells	130	F_i TX Power	$10\,dBm$
Carrier	$2.3\,GHz$	F_i Ant. Gain	$0\,dBi$
Bandwidth	$5\,MHz$	F_i Ant. Pattern	Omni
Duplexing	TDD 1:1	F_i Ant. Sensi. (θ)	-108 dBm
DLsymbols (T_{DL})	19	F_i Noise Figure	$4\,dB$
ULsymbols (T_{UL})	18	UE_x Ant. Pattern	Omni
Preamble symbols	2	UE_x Noise Figure	$7\,dB$
Overhead symbols	11	UE_x Body Loss	$0\,dB$
T_f	$5\,ms$	λ_{arr} $user/hour$	1500
Sub-carriers (R)	512	t_H	$600\,s$
R_{pilot}	48	$T_{bc}^{up,regular}$	$600\,s$
R_{data}	384	$T_{bc}^{up,event}$	$1\,s$
Sub-channels (K)	8	$T_{mr}^{up,regular}$	$10\,s$
Thermal Noise Density	-174 dBm/Hz	Path Loss Model	COST 231 Hata

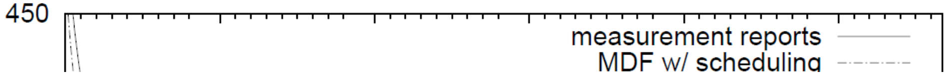
Performance Evaluation

- Results – Cumulative Density Function of User's SINR



Performance Evaluation

- Results – Average User Throughput



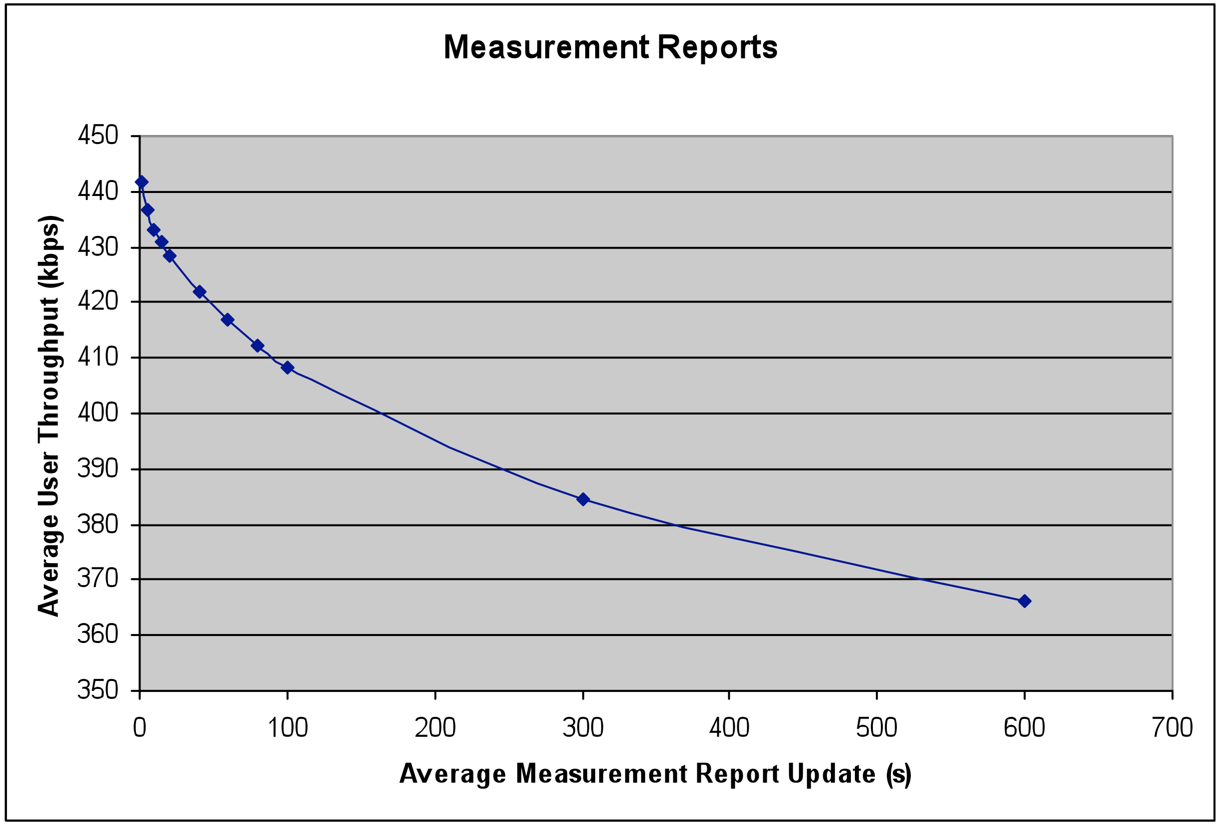
AVERAGE USER THROUGHPUT

Method name	**Average throughput** (kbps)	**Average throughput** (%[a])
Measurement Reports	563.79	135.96%
Message Exchange	493.76	119.08%
Random assignment	414.66	100%
Worst assignment	236.94	57.14%

[a] compared to the random assignment

Performance Evaluation

- Measurement Report Frequency



References

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[3] H. Claussen, L. T. W. Ho, and L. G. Samuel. An overview of the femtocell concept. *Bell Labs Technical Journal - Wiley*, 3(1):221–245,May 2008.

[4] H. Claussen, L. T. W. Ho, and L. G. Samuel. Self-optimization coverage for femtocell deployments. In Wireless Telecommunications Symposium, 24-26, pages 278–285, April 2008.

[5] H. Claussen and F. Pivit. Femtocell coverage optimization using switched multi-element antennas. In *IEEE International Conference on Communications*, Dresden, Germany, June 2009.

Thanks you for the attention!

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