Network Capacity Enhancement of OFDMA System Using Self-organized Femtocell Off-load

S. Akbarzadeh([1],[2]), R.Combes ([1],[3]), Z.Altman ([1])

[1]Orange Labs
[2]CNAM
[3]University of Paris VI

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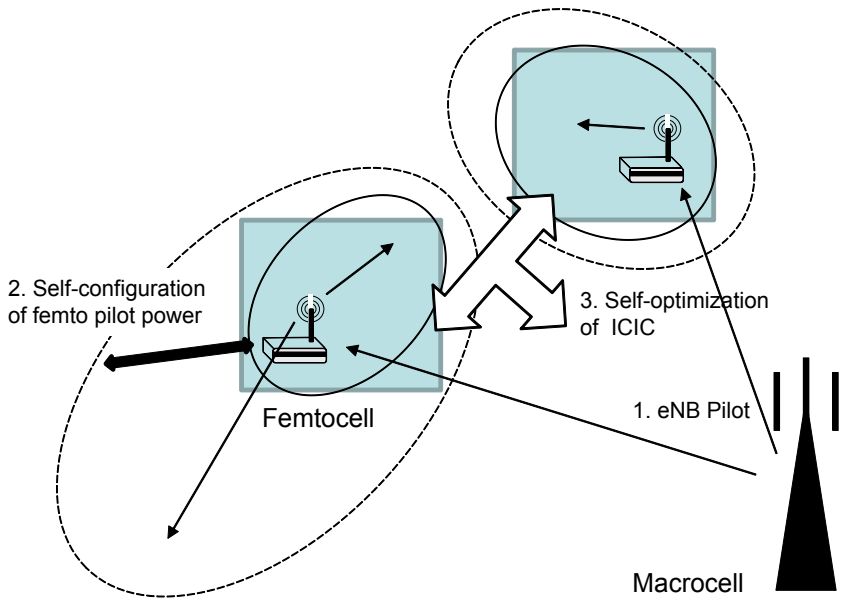
Scope

- Downlink of a wireless network
- Macro-cells + indoor femto-cells
- Elastic traffic, users arrive and depart dynamically
- What is the capacity gain compared with macro-only ?
- How to configure the pilot powers of femtos ?
- In dense networks, how to manage interference ?



The model

- Distance loss at distance d : $A + B\log(d)$
- Indoor-to-outdoor / outdoor-to-indoor: $A + B\log(d) + C$ (penetration margin)
- All stations (macro+femto) interfere with each other
- Users are attached to the station with the strongest received pilot signal

The model (cont'd)

- $R_s(r)$ data rate of a user located at r served by s when all stations transmit at full power (worst case interference)
- Round-robin scheduling, user throughput $\frac{R_s(r)}{n_s}$
- Users arrive in the network according to a Poisson process of intensity λ
- Mean flow size $E[\sigma]$, users leave after completing their transfer

Performance evaluation: one station

- Each station is modeled as M/G/1/PS (processor sharing) queue (BonaldMobicom2003)
- Traffic intensity $I = \lambda E[\sigma]$
- Capacity of station s: $C_s = (\int_{A_s} \frac{1}{R_s(r)})^{-1}$
- Load of station s: $\rho_s = \frac{I}{C_s}$
- Blocking rate of station s : $B_s = \frac{\rho^{N_{max}}}{1+\cdots+\rho^{N_{max}}}$
- Average file transfer time: $T_s = \frac{1}{\lambda \int_{A_s} dr} \frac{\rho_s}{1-\rho_s}$

Performance evaluation: network

- Probability for a user to arrive in s: $P_s = \frac{\int_{A_s} dr}{\int_A dr}$
- Network capacity of station s: $\min_s C_s$
- Network blocking rate: $\sum_s P_s B_s$
- File transfer time: $\sum_s P_s T_s$

Dynamic vs static evaluation

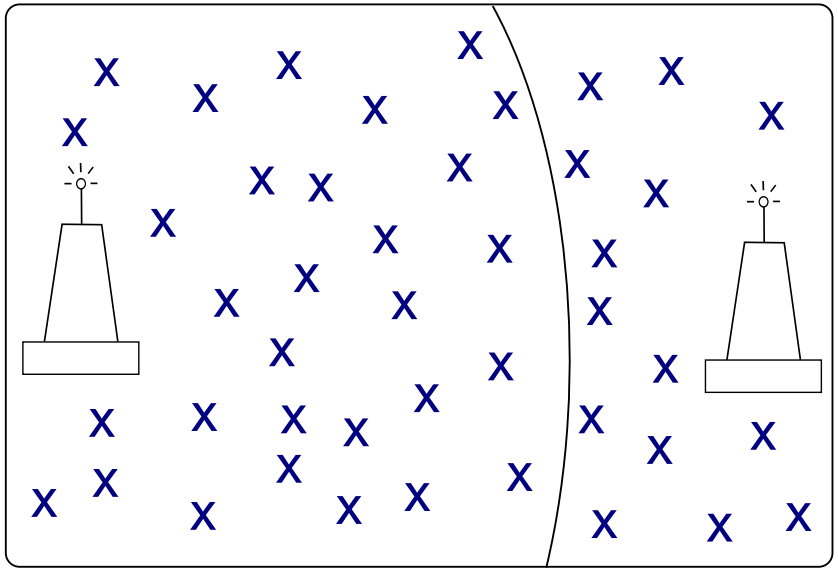


Figure: Static

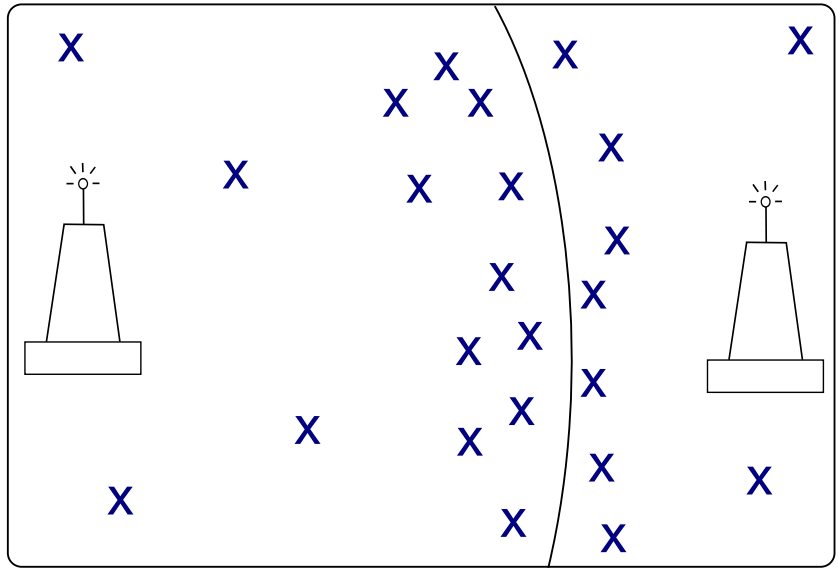


Figure: Dynamic

Pilot auto-configuration for femto-cells

- Femtos provide densification gains
- Trade-off: stations absorb less traffic, but receive more interference
- Based on the received macro pilot, femtos are divided into “interior” and “exterior” femtos (cell center / cell edge)
- Inner femtos use a smaller power (P_{int})than outer femtos (P_{ext})
- Off-line approach: store good values of (P_{int}, P_{ext}) in a data base

Pilot auto-configuration for femto-cells: results

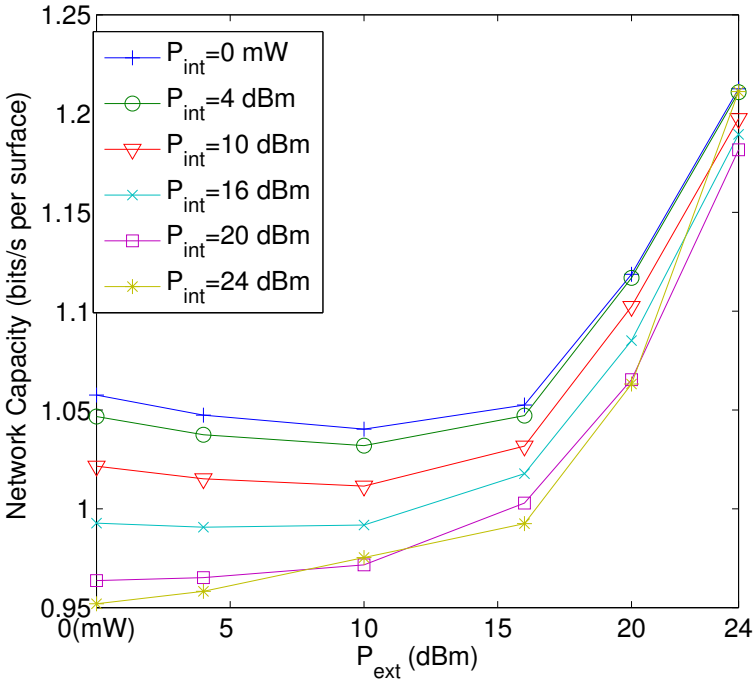


Figure: Sparse femtos

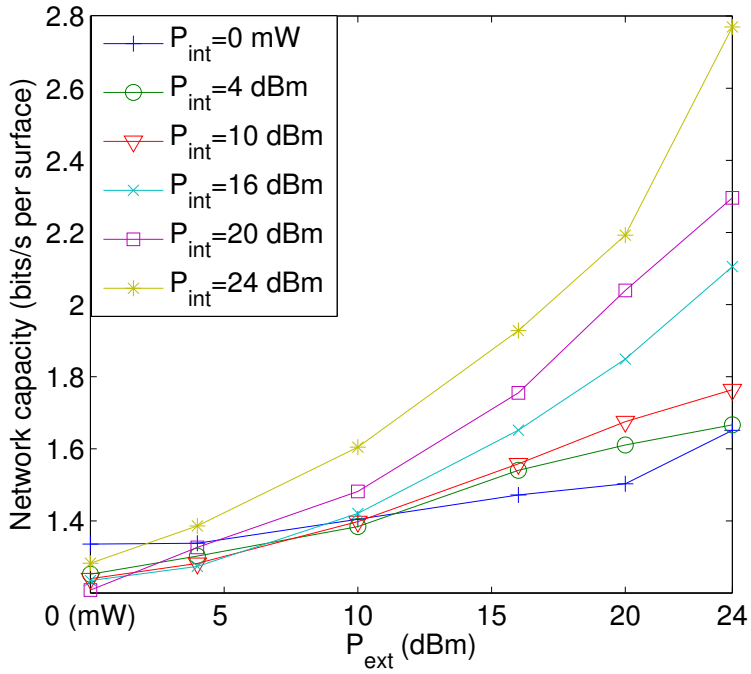


Figure: Dense femtos

Self-organizing ICIC

- Femtos increase the capacity but can create outage for streaming and voice traffic (minimal bit-rate)
- Problematic for dense deployments
- Solution: split the spectrum in sub-bands and adapt the transmitted power on each sub-band
- Transmit power is adapted dynamically to maximize a function of the users throughput (Mo2000ToN): $\sum_i \frac{T_i^{1-\alpha}}{1-\alpha}$
- Search method: *distributed* projected gradient (StolyarInfocom2010, CombesICC2011)

Self-organizing ICIC: results

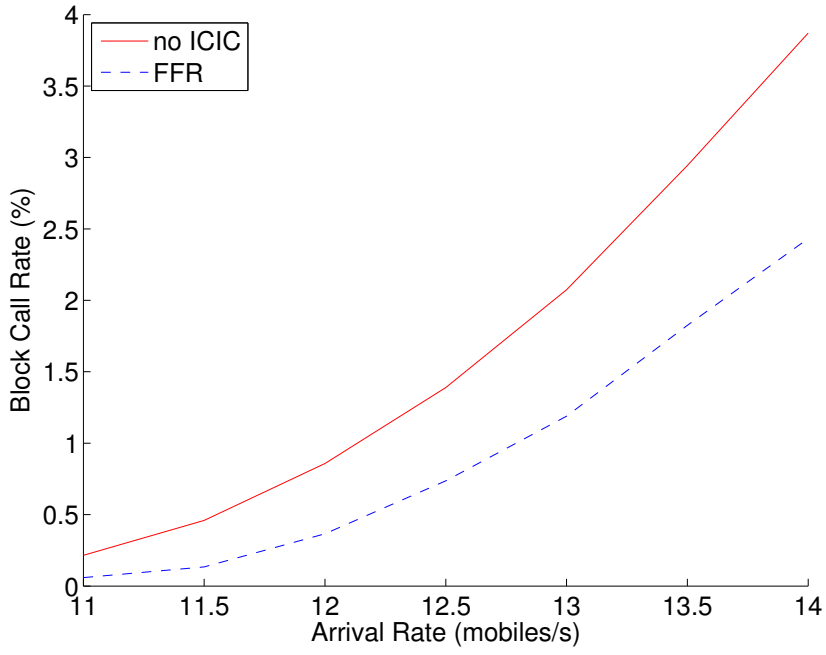


Figure: Block call rate

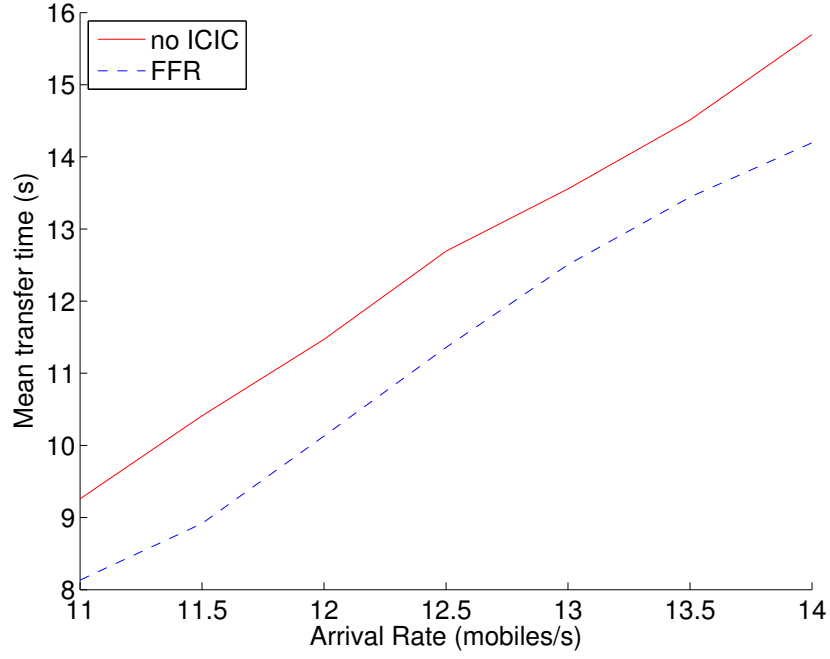


Figure: File transfer time

Thank you for your attention, any questions ?