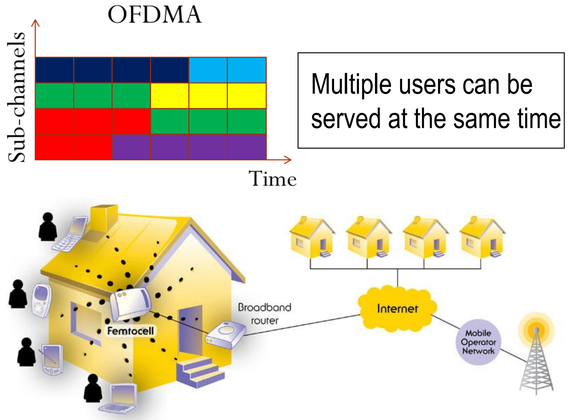
# Cross-tier Interference Mitigation for Two-tier OFDMA Femtocell Networks

**Min-Sung Kim (Adviser: Fouad A. Tobagi)**
Computer System Labs. Stanford University

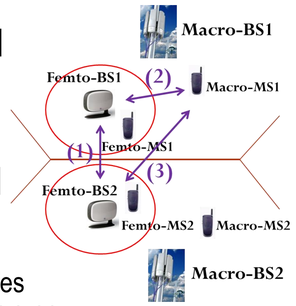
## OFDMA Femtocell Networks




[Femto Base Station (BS)]
- Customer-owned, low cost, low power, in-building
- Same licensed band with cellular systems
- Use customers' broadband access as backhaul

[Benefits of Femtocells]
- Proximity between BS and mobile station (MS)
  - Much higher spectral efficiency per area
  - Reduction of power consumption of a MS
- Wired backhaul at customer's premise
  - Offload wireless traffics to wired networks
  - Site acquisition is not required
- In-door base station
  - Indoor rich services with cell phones

## Challenges of Interference Management




[Additional Interference]
- Inter-femto (1)
- Cross-tier (2), (3)

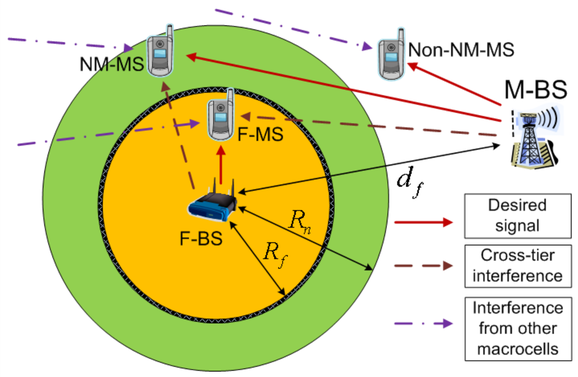
[Customer-installed BS]
- No pre-planning
- Self-configuration
- Different access policies
  : Open, Closed, and Hybrid
- IP backhaul may be operated by 3rd ISP

[Distributed Nature]
- Limited Information of other macro/femtocells
- Low levels of coordination among network entities
- Minimum changes to existing networks

## Proposed Neighbor-Friendly (NF) Scheme

- Maximize the sum-rate of femto/macro MSs
- While mitigating downlink cross-tier interference
- By appropriate power allocation by femto BSs
- Assuming that operation of macro BSs is the same as when there are no femtocells
- Based on assessment by the femto BS of channel gains of macro MSs

## Formulation



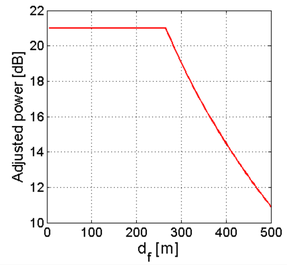

$$\arg\max_{\{p_F^{(1)},\ldots,p_F^{(N)}\}} \sum_{n=1}^{N}\left(\omega_m' C_F\left(p_F^{(n)}\right)+\omega_m \widehat{C_{NM}}\left(p_F^{(n)}\right)\right)$$

$$\text{s.t.} \sum_{n=1}^{N} p_F^{(n)} \le \widetilde{P_F} \le P_{F,max}$$

1. Find the adjusted total transmit power of a F-BS, $\widetilde{P_F}$
   a. Compare the average received signal strength from the M-BS and that from the F-BS with $P_{F,max}$, at the outer wall of the building
   b. If the former is stronger, use $P_{F,max}$; else, reduce $P_{F,max}$ to $\widetilde{P_F}$ to make the two signal strengths the same

$$\frac{\widetilde{P_F}}{L_w} \times R_f^{-\alpha_f} = P_M d_f^{-\alpha_m}$$

$$\widetilde{P_F} = L_w R_f^{\alpha_f} P_M d_f^{-\alpha_m}$$




2. Solve the above optimization after approximating

$$\widehat{C_{NM}}\left(p_F^{(n)}\right) = \log_2\left(1+\widehat{SINR_{NM_j}^{(n)}}\left(p_F^{(n)}\right)\right)$$

[SINR of NM-MS $j$ for Sub-channel $n$]

$$SINR_{NM_j}^{(n)}\left(p_F^{(n)}\right) = \frac{|h_{M,M_j}^{(n)}|^2 p_M^{(*)}}{U_F^{(n)}|h_{F,M_j}^{(n)}|^2 \frac{p_F^{(n)}}{L_w} + I_{M_j}^{(n)} + \sigma^2}$$

- Unknown information: channel gains
  - From M-BS ($|h_{M,M_j}^{(n)}|^2$)
  - From F-BS ($|h_{F,M_j}^{(n)}|^2$)
  - From other macro-BSs ($I_{M_j}^{(n)}$)
- Impossible to calculate the SINR

[A Lower Bound of Average of SINR]
- Instead, maximize a lower bound of ensemble average

$$E\left[SINR_{NM_j}^{(n)}\left(p_F^{(n)}\right)\right] = E\left[\frac{|h_{M,M_j}^{(n)}|^2 p_M^{(*)}}{U_F^{(n)}|h_{F,M_j}^{(n)}|^2 \frac{p_F^{(n)}}{L_w} + I_{M_j}^{(n)} + \sigma^2}\right]$$

$$\ge \frac{E\left[|h_{M,M_j}^{(n)}|^2\right] p_M^{(*)}}{U_F^{(n)} E\left[|h_{F,M_j}^{(n)}|^2\right] \frac{p_F^{(n)}}{L_w} + E\left[I_{M_j}^{(n)}\right] + \sigma^2}$$

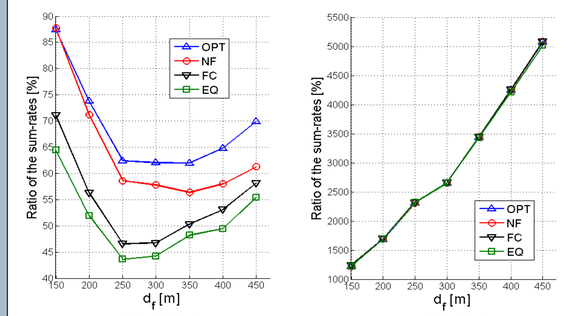
[Approximations of The Averages]
- Observations
  - $d_f \gg R_n$
  - Channel gain is common for every sub-channel
- Approximations
  - $E\left[|h_{M,M_j}^{(n)}|^2\right] = E\left[|h_{M,F}^{(*)}|^2\right]$ (inside NM-MS)
  - $E\left[|h_{F,M_j}^{(n)}|^2\right] = E\left[|h_{M_j,F}^{(*)}|^2\right]$
  - $E\left[I_{M_j}^{(n)}\right] = E\left[I_F^{(*)}\right] \times L_w$ (outside)

## Other Schemes To Be Compared

- Optimal (OPT): $C_{NM}\left(p_F^{(n)}\right)$, instead of $\widehat{C_{NM}}\left(p_F^{(n)}\right)$
- Femto-centric (FC): $\omega_m = 0$
- Equal power (EQ): $p_F^{(1)} = \cdots = p_F^{(N)} = \widetilde{P_F}$ / N

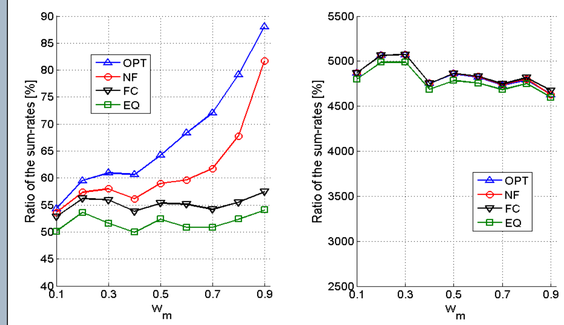
## Results

[Degradation / Gain of MSs ($\omega_m$=0.5)]



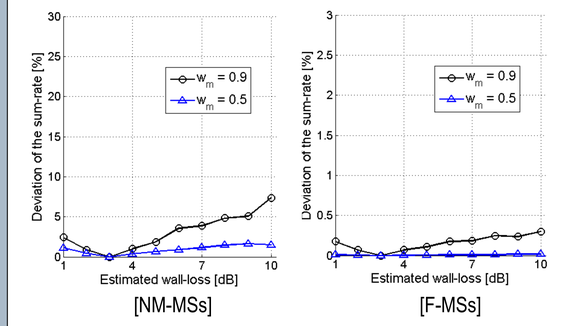

[NM-MSs] [F-MSs]

[Role of $\omega_m$ in NF ($d_f = 450m$)]




[NM-MSs] [F-MSs]

[Effect of The Estimation Error of $L_w$]




[NM-MSs] [F-MSs]

## Conclusions

- The proposed NF scheme
  - Enables femtocells with limited macrocell information to maintain desirable sum-rates while minimizing cross-tier interference
  - Can further reduce the performance degradation of NM-MSs by controlling $\omega_m$
  - Is robust against the estimation error of $L_w$

minsung@stanford.edu