Marginal Effects of Femtocells in Cellular Networks

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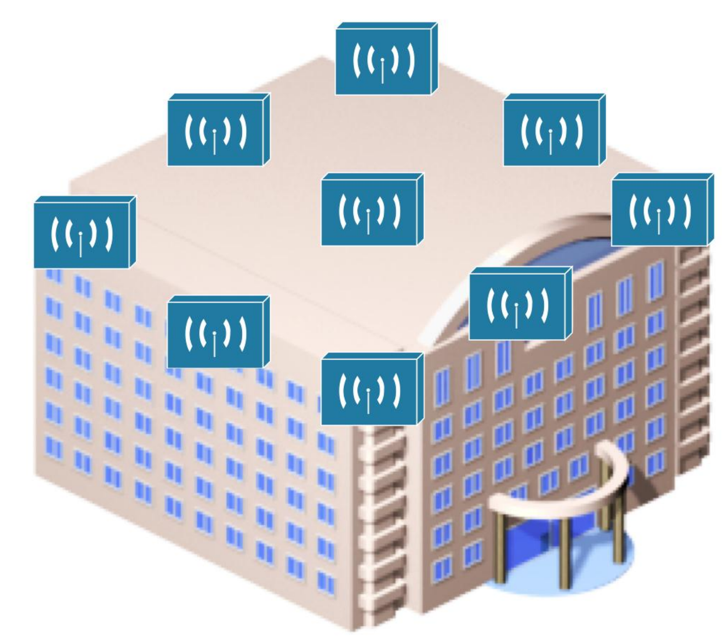
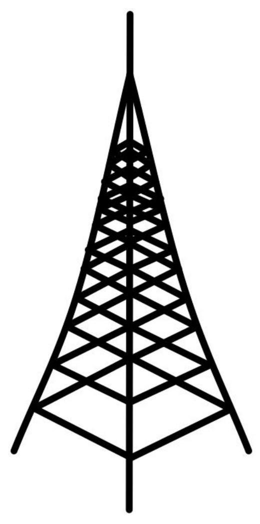
Femtocells challenge traditional base station planning and management by giving end-users the ability to deploy low-power base stations in their homes without coordinating with service providers. Femtocells operate in the same frequency bands as operated-managed macrocells, which creates *cross-tier interference* between femtocells and macrocells. We model a high-density femtocell deployment using stochastic geometry to understand two problems:

- What density and spatial configuration of femtocells, λ_f and Φ_f, in a fixed area will lead to a high probability of outage for non-femtocell users, thereby leading to an overall *reduction* in network capacity?
- What centralized auto-configuration or deployment policies can prevent this from happening?

Deployment Scenario

- High-density femtocell deployment
- Closed or open access policies
- Frequency re-use:
  - CDMA systems are interference-limited
  - Cross-tier interference between the macrocell and femtocells
  - Co-tier interference amongst femtocells
- Mobiles connect to either a femtocell or the macrocell, but not both
- Handovers between macrocell and femtocells are possible





Network Model

- Macrocell at origin, M_0; we assume the entire unit square is covered by the macrocell
- Path loss function, $l(r)$ with indoor/outdoor path loss exponents α, β
- Femtocells distributed via a spatial Poisson process, Φ_f, with intensity λ_f
- Mobiles distributed via a spatial Poisson process, Ψ_m, with intensity λ_m
- Macrocell and femtocell transmit powers, P_M and P_{ϕ_i}, $i = 0, 1, \ldots$
- Additive white Gaussian noise, G

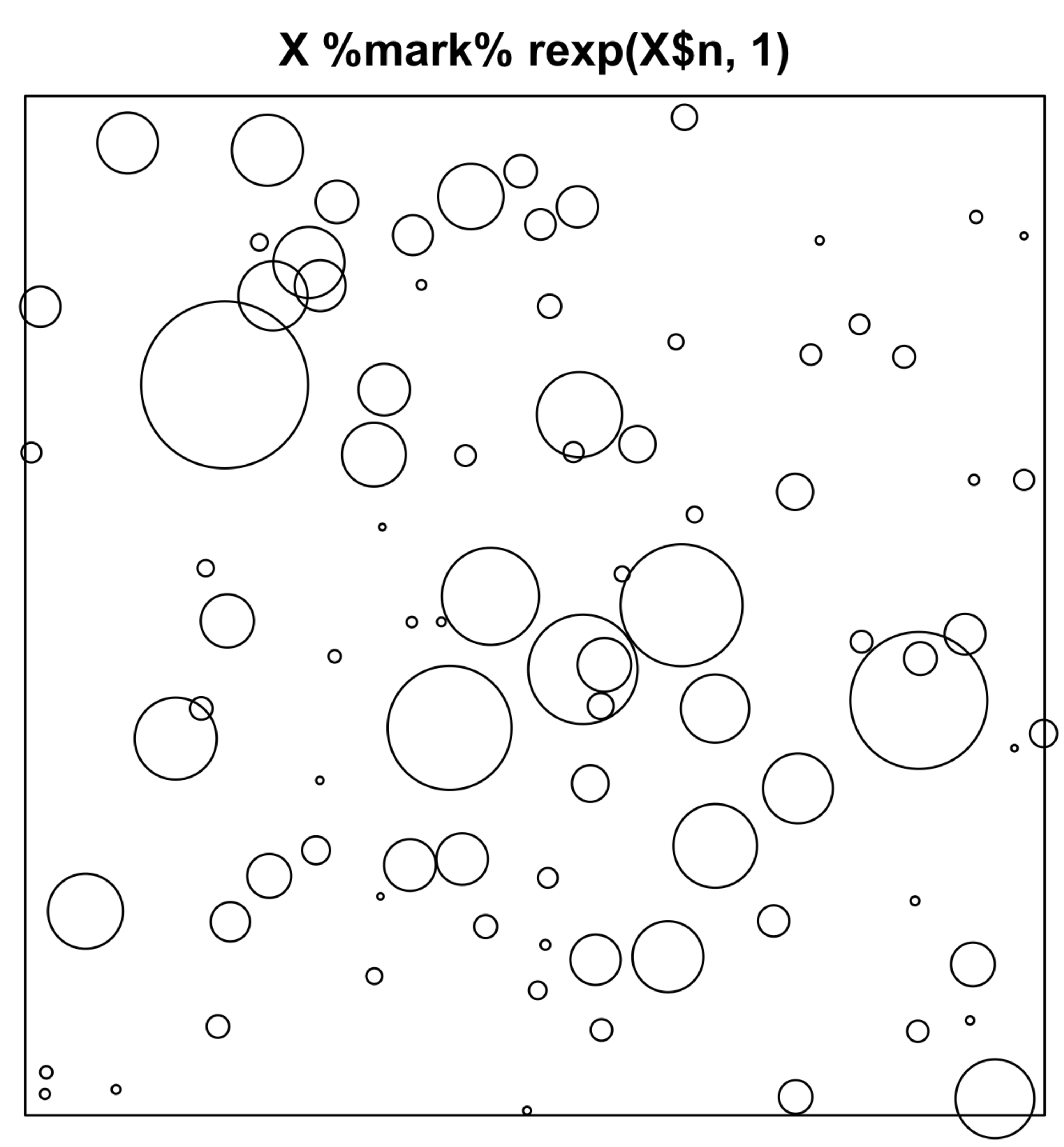
We are interested in determining the signal-to-noise-plus-interference ratio ξ_π for mobiles at point π connected to the macrocell or a femtocell, $\psi_{M,\pi}, \psi_{\phi_i,\pi}$.

$$\xi^{\pi}_{\psi_M} = \frac{P_M / l(|\pi - 0|)}{\sum_{i \in \Phi_f} P_{\phi_i} + G}$$

$$\xi^{\pi}_{\psi_{\phi_i}} = \frac{P_{\phi_i} / l(|\pi - \phi_i|)}{P_M + \sum_{j \in \Phi_f, j \neq i} P_{\phi_j} + G}$$

Then the probability of outage at π is:

$$P(\xi^{\pi} \leq t)$$



Future Work

We are continuing to develop our model and running system-level simulations to characterize the impact of femtocell density on outage and handover probabilities.