Assignment 1

Modeling and Analysis of Random 5G Networks

Due: 10th February

1 Assignment Questions

1. Recent results on heterogeneous cellular networks have shown that downlink and uplink user associations to the available base stations do not have to be symmetric. In such decoupled association strategies, it is often optimal for a user to associate to the nearest base station in the uplink. Let us assume that in a heterogeneous network, there are three tiers of base stations. Let the locations of these base stations be modeled as independent Poisson point processes Φ_i with intensities λ_i respectively. Here $i \in \{1, 2, 3\}$.

   (a) Let us consider a typical user located at the origin. What is the probability that the typical user associates to a base station of tier 1 (the locations of which are governed by Φ_1) in the uplink following the "nearest BS association" strategy? **[3 points]**

   (b) Let us assume that the transmit powers of tiers 1 and 2 are 0 dB and 10 dB respectively, and the BS deployment densities are $\lambda_1 = 50$ km^{-2}, $\lambda_2 = 10$ km^{-2}, and $\lambda_3 = 1$ km^{-2}. Plot in MATLAB the downlink association probabilities with all the three tiers as a function of P_3. Assume "max power association" strategy. **[2 points]**

2. Let us assume a two-tier network with the following parameters: One macro base station (MBS) tier and one small cell base station (SBS) tier.

   - Macro Tier (MBS): Carrier frequency: 2.6 GHz, modeled using PPP ϕ_M, transmit power P_M, deployment density λ_M.
   - Small Cell Tier (SBS): Co-channel with MBS, modeled using PPP ϕ_S, transmit power P_S, deployment density λ_S, Cell Range Expansion parameter: Q_T.

   (a) Derive the expression for SINR coverage probability for a typical user located at the origin, if it associates to the tier which provides the maximum downlink power. **[2 points]**

   (b) In case of such co-channel transmissions, prove that the maximum power association is the same as maximum SINR association, i.e., in both strategies, the user associates to the same tier. **[1 point]**

   (c) Simulate this two tier network in MATLAB by generating the PPP realizations, and show how the SINR coverage compares to the analytical results, where the SINR threshold varies from -40 dB to 30 dB. Assume $\lambda_M = 5$ km^{-2} and $\lambda_S = 50$ km^{-2}. **[2.5 points]**

   (d) Let us fix the SINR coverage threshold to be -10 dB. Plot the SINR coverage probability at -10 dB for varying Q_T. Does there exist an optimal value of Q_T? **[2.5 points]**

   (e) Let us remove the co-channel assumption for both the tiers, and assume that the SBS tier is operating at 3.2 GHz. Numerically redo the part (d) above and comment on the existence of an optimal bias. **[2 points]**

2 Notes

- To perform the integrals in MATLAB, it is useful to be familiar with the symbolic toolbox. See the help pages in MATLAB for "integral", "int", and "integral2".
- All the assignments **must** be submitted before 8/02/2019 23:59 hrs.
- The assignment consists of two questions and has a total of 15 points. As in the evaluation only 10 percentage of weight is given to Assignment 1, the rest 5 points can be earned as bonus to compensate other evaluation parameters.
- The simulations are expected to be done in MATLAB, although if the student prefers, he/she can use other platforms as well such as Python or Mathematica (it is usually very simple to simulate such problems in Mathematica).
- Take help of Wolfram Alpha (https://www.wolframalpha.com/) to try to evaluate the integrals in closed form. In case closed-form solutions do not exist, the integral form is an acceptable solution.
- The path-loss to be assumed in this assignment is the standard power-law path-loss model. Particularly, in case the transmitter and the receiver are located at a distance r from each other, the instantaneous received power is given by $PKhr^{-\alpha}$, where, h represents the fast-fading and P is the transmit power.
- K is the path-loss coefficient. It is calculated as $K = \left(\frac{\text{carrier wavelength}}{4\pi}\right)^2$, where carrier wave-length is calculated as velocity of light divided by the operating frequency.
- Assume the fast-fading to be Rayleigh distributed with variance 1.
- Although the SINR coverage calculation are done by taking fast-fading into account, the association of the users to BSs in the downlink take place by averaging out the fast fading.
- Assume the bandwidth to be $B = 20$ MHz. And the noise to be -174 dBm/Hz + $10\log_{10}(B)$ + 10 dB.