Heterogeneous Cellular Networks with Flexible Cell Association: A Comprehensive Downlink SINR Analysis

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In this paper we develop a tractable framework for SINR analysis in downlink heterogeneous cellular networks (HCNs) with flexible cell association policies. The HCN is modeled as a multi-tier cellular network where each tier's base stations (BSs) are randomly located and have a particular transmit power, path loss exponent, spatial density, and bias towards admitting mobile users. For example, as compared to macrocells, picocells would usually have lower transmit power, higher path loss exponent (lower antennas), higher spatial density (many picocells per macrocell), and a positive bias so that macrocell users are actively encouraged to use the more lightly loaded picocells. In the present paper we implicitly assume all base stations have full queues; future work should relax this. For this model, we derive the outage probability of a typical user in the whole network or a certain tier, which is equivalently the downlink SINR cumulative distribution function. The results are accurate for all SINRs, and their expressions admit quite simple closed-forms in some plausible special cases. We also derive the \emph{average ergodic rate} of the typical user, and the \emph{minimum average user throughput} -- the smallest value among the average user throughputs supported by one cell in each tier. We observe that neither the number of BSs or tiers changes the outage probability or average ergodic rate in an interference-limited full-loaded HCN with unbiased cell association (no biasing), and observe how biasing alters the various metrics.

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