

In this paper, mathematical frameworks for system-level analysis and design of uplink heterogeneous cellular networks with multiple antennas at the base station (BS) are introduced. Maximum ratio combining (MRC) and optimum combining (OC) at the BSs are studied and compared. A generalized cell association criterion and fractional power control scheme are considered. The locations of all tiers of BSs are modeled as points of homogeneous and independent Poisson point processes. With the aid of stochastic geometry, coverage probability and average rate are formulated in integral but mathematically and computationally tractable expressions. Based on them, performance trends for small- and large-scale multiple-antenna BSs are discussed. Coverage and rate are shown to highly depend on several parameters, including the path-loss exponent, the fractional power control compensation factor, and the maximum transmit power of the mobile terminals. The gain of OC compared with MRC is proved to increase, if a more aggressive power control is used and if the number of BS antennas increases but is finite. For the same number of BS antennas, OC is shown to reach the noise-limited asymptote faster than MRC. All findings are validated via Monte Carlo simulations.