Short Abstract

This thesis focuses on system modeling, optimization and comprehensive performance analysis of wireless information and energy transfer to the Internet-of-Things (IoT) devices. These devices are likely to form a core component of beyond fifth generation (5G) wireless systems in order to support numerous applications foreseen in such systems. We first investigate whether a base station (BS) with massive number of antennas can support joint machine-centric communication among the IoT devices and human-centric communication among the mobile terminals. To this end, we derive downlink spectral efficiency (SE) of the IoT devices with maximum ratio precoding when channel estimates are acquired via the proposed distance-dependent grouping based hybrid pilot assignment strategy. As benchmarks, we also evaluate SE under non-orthogonal pilot assignment and distance-independent grouping. We show that under channel inversion based power control at the BS, the proposed pilot assignment and channel estimation strategy yields the highest sum SE and can serve the largest number of IoT devices when compared to the benchmarks. The corresponding performance under max-min power allocation is also presented.

We then elucidate feasibility of wireless energy transfer (WET) with the help of an intelligent reflecting surface (IRS). We consider a source equipped with multiple antennas and a single radio-frequency (RF) chain. And propose a low complexity rule that does joint antenna selection (AS) at source and passive beamforming at IRS. We derive new expressions for probability of outage in WET under perfect and estimated channel knowledge and for both single and multiple users. For a system with M antennas at source and N passive elements at IRS, we prove that the diversity order equals $M + N$. Generalizations to subset AS, discrete phase shift design, and performance under limited scattering are also presented. Our results show that the proposed AS rule yields near-optimal performance while requiring only $M + N$ pilot transmissions compared to $M + MN$ pilot transmissions required by the optimal AS rule in literature. We illustrate that active RF chains at source can be traded with passive elements at IRS to obtain improved performance both in terms of outage probability (OP) and power transfer efficiency (PTE). And 3-bit IRS is sufficient to obtain good performance at lower complexity.

Thereafter, we study viability of WET from a source that is assisted by double IRS. To this end, we derive new closed-form analytical expressions for OP under non-linear energy harvesting (EH) at the user for different channel fading scenarios. We also generalize our outage analysis to a scenario where all links via the direct path and via the cascaded paths along the two IRSs undergo Rician fading. This analysis involves developing a novel statistical model based on Gamma distribution for the sum of product of Rician fading envelopes corresponding to cascaded paths. We then study the impact of four communication links between source and user on OP. Furthermore, we determine the optimal number of IRS elements that maximizes PTE under double IRS-assisted configuration. As benchmarks, we also derive the corresponding results for single IRS-assisted WET and massive multiple input multiple output enabled WET. The operational regimes in which double IRS aided WET provides improved performance are characterized.

We then investigate simultaneous wireless information and energy transfer to multiple IoT users using IRS under spatial correlation and optimal phase configuration. We derive a new and fairly tight upper bound on OP using Boole-Frechet inequality when the IoT users are served based on round-robin scheduling strategy, share common source to IRS links and adopt non-linear EH at their end. We then derive the diversity order for this system. A new upper bound on SE is also derived. We present results to validate the accuracy of our statistical modeling and novel analytical bounds. The gain in performance relative to random and equal phase shift configurations is also quantified.