Resource Allocation in Multi-Antenna Communication Systems with Limited Feedback

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Abstract

The use of multiple transmit antennas is considered a key ingredient to significantly improve the spectral efficiency of wireless communication systems beyond that of currently employed systems. Transmit beamforming schemes have been proposed to exploit the spatial characteristics of multi-antenna radio channels; that is, multiple-input single-output (MISO) channels. In multiuser communication systems, the downlink throughput can be significantly increased by simultaneously transmitting to several users in the same timefrequency slot, by means of spatial-division multi-access (SDMA). Several SDMA beamforming algorithms are available for joint optimal beamforming and power control for the downlink. Such optimal beamforming minimizes the total transmission power, while ensuring an individual target quality of service (QoS) for each user; alternatively the weakest QoS is maximized, subject to a transmit power constraint.

In this thesis, both of these formulations are considered and some of the available algorithms are generalized to enable quadratic shaping constraints on the beamformers. By imposing additional constraints, the QoS measure can be extended to take factors other than the customary signal to interference-plus-noise ratio (SINR) into account. Alternatively, other limitations such as interference requirements or physical constraints may be incorporated in the optimization. The proposed beamforming algorithms are also based on a more general SINR expression than previously analyzed in this context. The generalized SINR expression allows for more accurate modeling; for example, non-zero self interference can be modeled in code-division multi-access (CDMA) systems.

A major limiting factor for downlink resource allocation is the amount of channel-state information (CSI) available at the base station. In most cases, CSI can be estimated only at the receivers, and then fed back to the base station. This procedure typically constrains the amount of CSI that can be conveyed. In this thesis, a minimum mean squared-error (MMSE) SINR estimation framework is proposed, which combines partial CSI with channel-distribution information (CDI); the CDI varies slowly and is assumed to be known at the transmitter. User selection (scheduling) and beamforming techniques, suitable for the MMSE SINR estimates, are also proposed.

Special attention is given to the feedback of a scalar channel-gain information (CGI) parameter. The CSI provided by CGI feedback is studied in depth for correlated Rayleigh and Ricean fading channels. It is shown, using asymptotic analysis, that large realizations of the CGI parameter convey additional spatial CSI at the transmitter; the proposed scheme is thus ideal for multiuser diversity transmission schemes, where resources are allocated only to users experiencing favorable channel conditions. It is shown by numerical simulations that, in wide-area scenarios, feeding back a single scalar CGI
parameter per user, provides sufficient information for the proposed downlink resource-allocation algorithms to perform efficient SDMA beamforming and user selection.