A Survey of Cognitive Beamforming Techniques

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Digital beamforming is a spatial-filtering technique in multi-antenna communication systems. A signal processor controls the excitation of antenna array elements to synthesize a desired radiation pattern with the general objective to increase gain in the direction of intended receivers or wanted signal sources and reduce gain in the direction of known or potential sources of interference. In the context of a cognitive radio network, where interference mitigation is a paramount concern, beamforming and precoding techniques offer significant advantages in terms of spectral efficiency, power control, link capacity, transmission security, and improved signal to interference plus noise ratio (SINR). Cognitive beamforming approaches the selection of array coefficients as a convex optimization problem in a machine-learning algorithm. A cognitive engine stores previously derived solutions in a knowledge base and autonomously applies beamforming decisions toward the ultimate goal of predicting channel conditions and proactively adjusting antenna array patterns to maintain network connectivity and performance. This informed decision-making ability distinguishes cognitive beamformers as an evolution of traditional adaptive arrays and smart antenna systems.

This paper presents a survey of various cognitive beamforming techniques in interweave, overlay, and underlay networks. Algorithms are categorized based on their applicability to multiple-input, single output (MISO) or multiple-input, multiple output (MIMO) systems and any constraints or idealization of channel state information and quality of service metrics. The techniques evaluated include distributed, joint, and cooperative beamforming strategies with optimization schemes based in game theory, communication informatics, neural networking, and genetic algorithms. Current limitations of the technology are provided and guidance for future research in the field is suggested.