Reconfigurable Antennas, Preemptive Switching and Virtual Channel Management under Partial Observations

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This work considers the performance of wireless communication systems that utilize reconfigurable or pattern-dynamic antennas. The focus is on finite-state channels with memory and performance is assessed in terms of discounted throughput. In a wireless setting, when a slow fading channel enters a deep fade, the corresponding communication system faces the threat of successive decoding failures at the destination. Under such circumstances, rapidly getting out of deep fades becomes a priority. Recent advances in fast reconfigurable antennas provide new means to alter the statistical profile of fading channels and thereby reduce the probability of prolonged fades. This potential for enhanced performance motivates this study of the behavior of point-to-point communication systems with reconfigurable antennas. This work centers around scenarios where only partial state information is available at the transmitter, naturally leading to partially observable decision processes. Situations where using reconfigurable antennas yield substantial performance gains in terms of throughput and average delay are identified. Although pattern-dynamic antennas have been and continue to be the subject of concerted research efforts in the antennas and propagation community, a detailed analysis of their repercussions on the foundations of signal processing and digital communications is still lacking. Key to the widespread adoption of such technologies is provable gains in terms of capacity, delay-throughput profile and network connectivity. Our work seeks to address the need for better understanding the impact of adaptive antenna systems in the context of delay-sensitive communications under limited observation models.

To carry our analysis of reconfigurable systems, we model wireless links as finite-state channels with memory. The delay-sensitive aspect of the problem is captured through a discrete-time formulation akin to a quasi-birth-death model. The conceptual bridge between the physical layer and the packetized system is provided by error correcting codes and the availability of feedback. From an abstract point of view, fast reconfigurable antennas can be employed to establish ancillary virtual connections between multiple devices. Our results suggest that time-dependencies in the evolution of the physical channel can adversely affect the behavior of a queueing system. Also, they point to the fact that having the ability to reconfigure an antenna structure can help mitigate the undesirable effects of channel memory. In making this statement, we assume that, at every decision instant, the transmitter has the ability to select an appropriate code rate or issue an antenna reconfiguration request. The exact state of the channel is hidden from the transmitter; however, it can be estimated from previous acknowledgements and transmission failures. The formulation of a partially-observable Markov decision process is immediate. A distinguishing feature of our framework is that it seamlessly incorporates state estimation, code rate selection, antenna reconfiguration and throughput maximization. This preliminary study offers supporting evidence to the claim that reconfigurable antenna structures can improve the performance of communication systems significantly.