Network Science and Statistical Physics

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Abstract

We consider several challenging problems in complex networks (communication, control, social, economic, biological, hybrid) as problems in cooperative multi-agent systems. We describe a general model for cooperative multi-agent systems that involves several interacting dynamic multigraphs and identify three fundamental research challenges underlying these systems from a network science perspective. We show that the framework of constrained coalitional network games captures in a fundamental way the basic tradeoff of benefits vs. cost of collaboration, in multi-agent systems, and demonstrate that it can explain the emergence or not of collaboration. Multi-metric problems in such networks are analyzed via a novel approach involving multiple partially ordered semirings. We investigate the interrelationship between the collaboration and communication multigraphs in cooperative swarms and the role of the communication topology, among the collaborating agents, in improving the performance of distributed task execution. We show that expander graphs emerge as desirable communication graphs. We describe surprisingly simple distributed schemes that achieve social optimality and explain the role of indirect communications and signaling. We describe the need for new probabilistic models in multi-agent systems. Finally we describe most recent results that employ embedding of such networks in hyperbolic space to solve various optimization, routing and network tomography problems. We relate the approaches described to statistical physics principles and methods.

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