Network Science and Statistical Physics

John S. Baras
Institute for Systems Research and
Electrical and Computer Engineering Department
Fischell Department of Bioengineering
Applied Mathematics, Statistics and Scientific Computation Program
University of Maryland College Park

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.

John S. Baras, Lockheed Martin Chair in Systems Engineering

B.S. in Electrical Eng. from the Nat. Techn. Univ. of Athens, Greece, 1970; M.S. and Ph.D. in Applied Math. from Harvard Univ. 1971, 1973. Since 1973 with the Electrical and Computer Engineering Department, and the Applied Mathematics Faculty, at the University of Maryland College Park. Since 2000 faculty member in the Fischell Department of Bioengineering. Founding Director of the Institute for Systems Research (ISR) from 1985 to 1991. Since 1991, has been the Director of the Maryland Center for Hybrid Networks (HYNET). Fellow of the
IEEE and a Foreign Member of the Royal Swedish Academy of Engineering Sciences. Received the 1980 George Axelby Prize from the IEEE Control Systems Society and the 2006 Leonard Abraham Prize from the IEEE Communications Society. Professor Baras' research interests include control, communication and computing systems.

Email: baras@umd.edu  Web page: http://www.isr.umd.edu/~baras/