Network Theoretic Approaches for Wireless Systems

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MITRE Sponsored Research

Problem

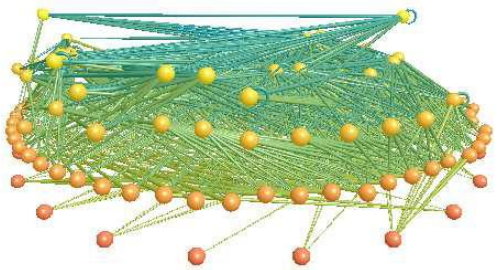
- **Mobile ad hoc networking continues to suffer from lack of theory and dependence on current Internet design model**

- **Network scientific models are needed for**

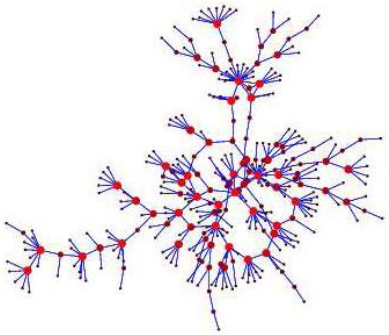
  1) **Capturing complexities arising from dynamic interactions between nodes**

  2) **Quantifying impact of complexities on overall network behavior**

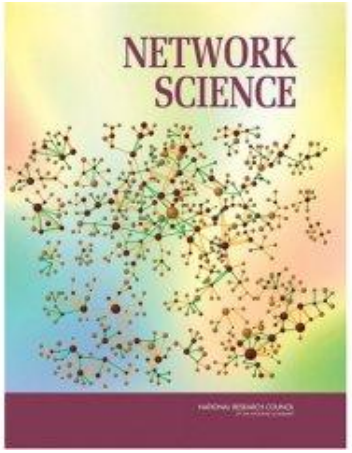
Background



Network scientific models will play a critical role in improving ability to design and predict performance of complex wireless networks



- **A growing recognition of need:**
  - **From 2006 JASON Report JSR-05-135**: "Far too little is understood about [Mobile Ad hoc Networks] MANETs to predict how the system will operate under a wide range of circumstances. Essentially every aspect of MANETs is still an active research area; there is no settled lore."
  - **From 2005 National Academy of Sciences report on Network Science**: "Current military concepts of 'net-centricity' are based on applications of computer and information technology that are far removed from likely results of basic research in network science."



Objective

- **The objective of this research project is to explore new approaches for modeling and studying wireless systems that provide for the discovery of fundamental principles governing system behavior, and lead to an improved understanding of the complex problem of mobile wireless network design and management.**

- **Current year objective is to apply agent based modeling techniques to discern emergent behavior in autonomous wireless networks**

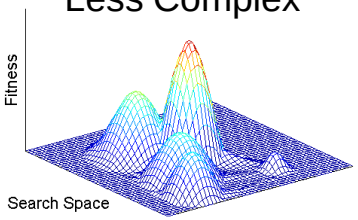
Activities

- Delay analysis for wireless fading channels
- Evolutionary model for studying global behavior and achievable performance in multi-hop wireless networks
- Agent-based modeling approach for studying emergent behavior in autonomous wireless networks
- Data-centric dissemination-based approach to autonomous networking

Highlight: An Evolutionary Approach

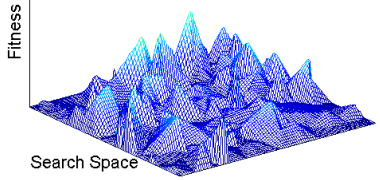
Fixed Wireless Networks

Less Complex



Fitness Landscapes describe design space for adaptive resource (power, bandwidth, time) allocation. Fitness, in our case, is mean delay in network.

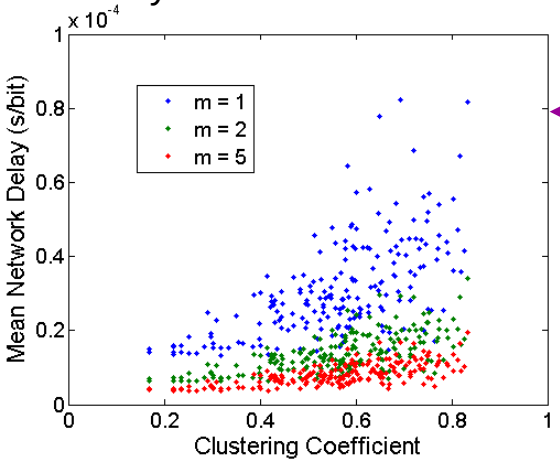
More Complex



Characterizations of network complexity vary in effectiveness

Clustering Coefficient

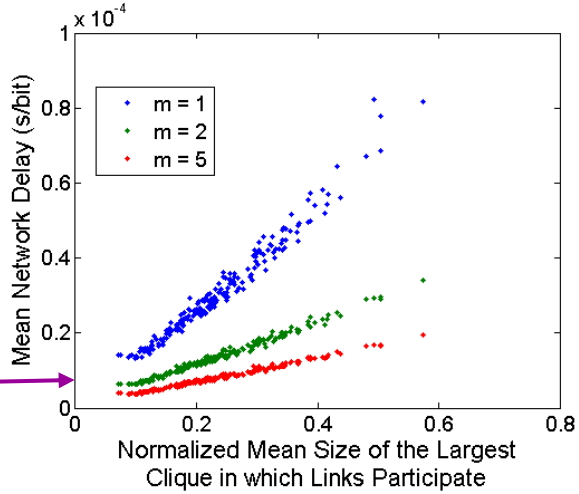
(commonly used in social networking)



Not a great predictor of achievable wireless network performance

For wireless networks, clique structure of *conflict graph* yields more information about network behavior

Maximal Clique statistics



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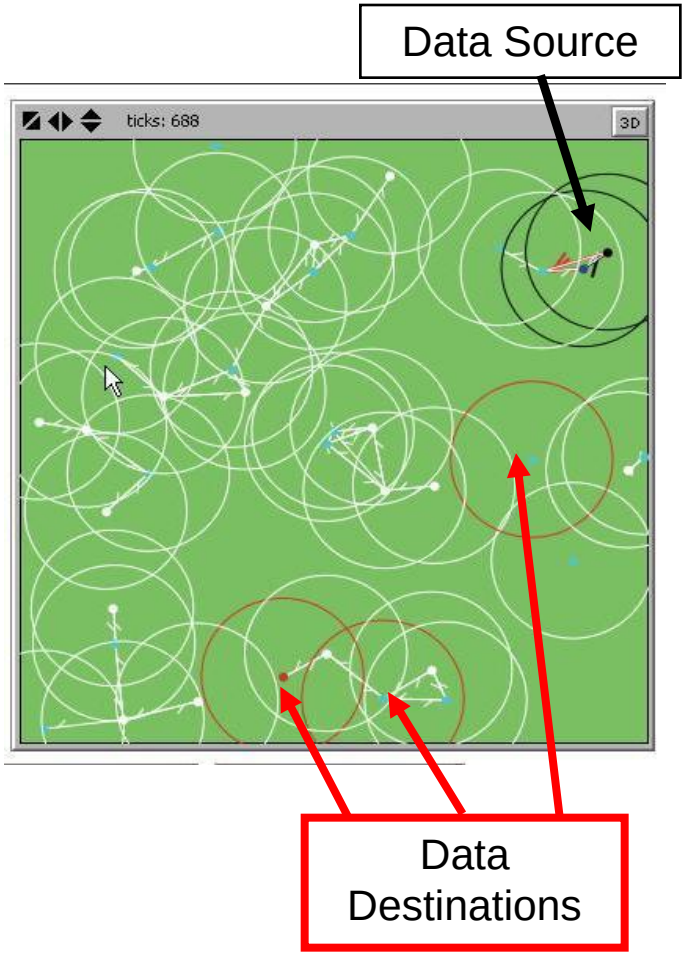
Demonstration: Agent-Based Modeling (ABM) of Wireless Networks

- Using *NetLogo* (open-source) http://ccl.northwestern.edu/netlogo/
- Autonomous nodes
- Data dissemination based on *gossip* approach
- Flexible model includes:
  - Multiple mobility profiles, fixed and mobile nodes, power adaptation, high-level modeling of MAC, multiple path-loss areas

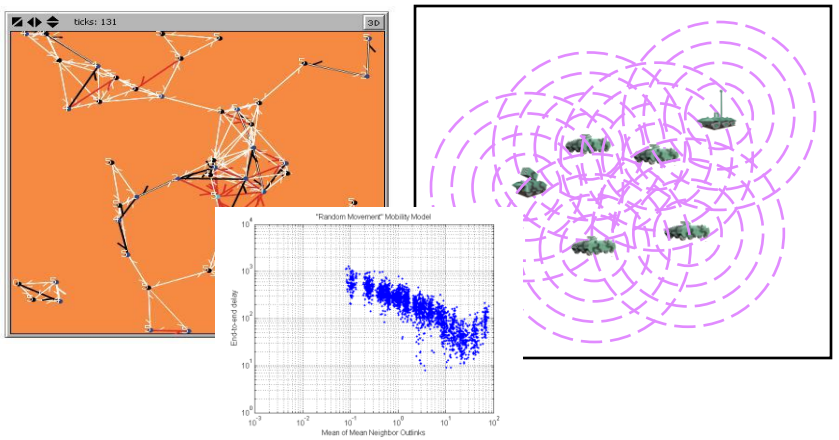


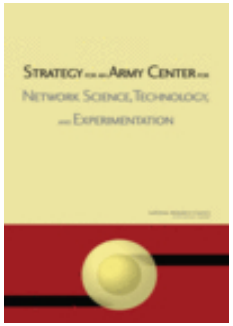
Impacts

- Powerful network science methodology capable of quantifying achievable network performance and studying important tradeoffs
- New strategies for network planning and design
- Guidance for DoD acquisition programs
- Potential transition opportunities with Army Center for Network Science Technology and Experimentation (NSTE)
- Contributions to research developments in the academic community and creation of collaborative opportunities

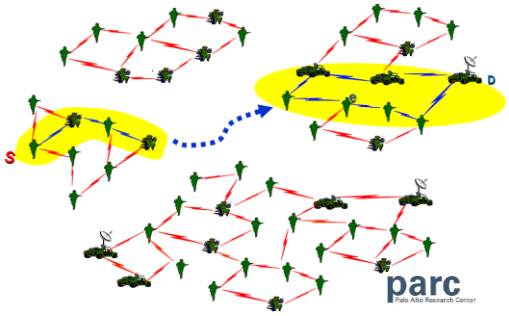
Future Plans

Innovative approach combining agent-based modeling (ABM) and data-centric dissemination networking to more closely couple wireless network *science* and *design*





Transitions to potential MITRE sponsors: e.g. Army Center for Network Science, Technology & Experimentation (NSTE)



Collaborative relationships with Industry/Academia: e.g. *Content-centric* approaches for autonomous networking (PARC)