

Distributed Resource Brokering in Complex Network Environments

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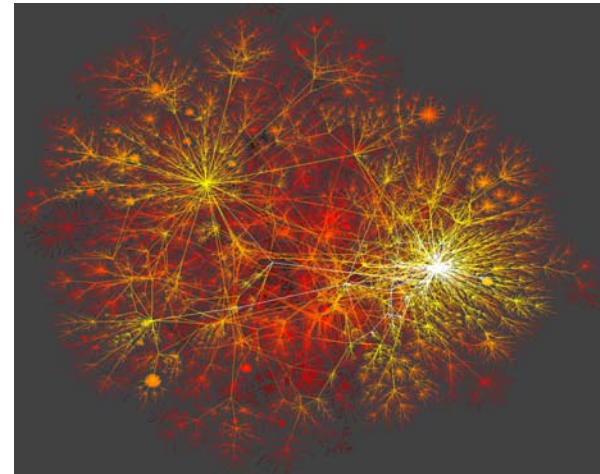
Problem

- The quality of a peer-to-peer (P2P) system depends on complex structural and behavioral properties of its network.
 - Protocols for discovery & connecting, query routing, etc.
 - Peer dynamics (transience, supply & demand loading)
- Dominant features to study in simplified (static) models include:
 - Network topologies and distributed query routing protocols
 - Interaction effects and tradeoffs:
 - Time efficiency (short path lengths), vs.
 - Space efficiency (few redundant messages), vs.
 - Robustness against attack / failure (redundant paths, connection regularities)
- Research question: Can we find topologies that effectively balance the tradeoffs, and that can also be grown and maintained by the parallel local decision-making of individual peers?

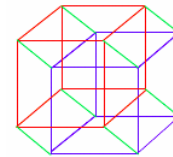
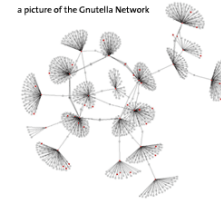
Background

- **Number of connected undirected graph topologies of n nodes:**

- 3: 2,
- 4: 6,
- 5: 21,
- 6: 112,
- 7: 853,
- 8: 11117,
- 9: 261080,
- 10: 11716571,
- 11: 1006700565,
- 12: 164059830476,
- 13: 50335907869219,
- 14: 29003487462848061,
- 15: 31397381142761241960,
- 16: 63969560113225176176277,
- 17: 245871831682084026519528568,
- 18: 1787331725248899088890200576580,
- 19: 24636021429399867655322650759681644



a picture of the Grutella Network



- **Only a tiny fraction of these have been studied using graph theory, probability and statistics, or heuristic search techniques.**

Objective

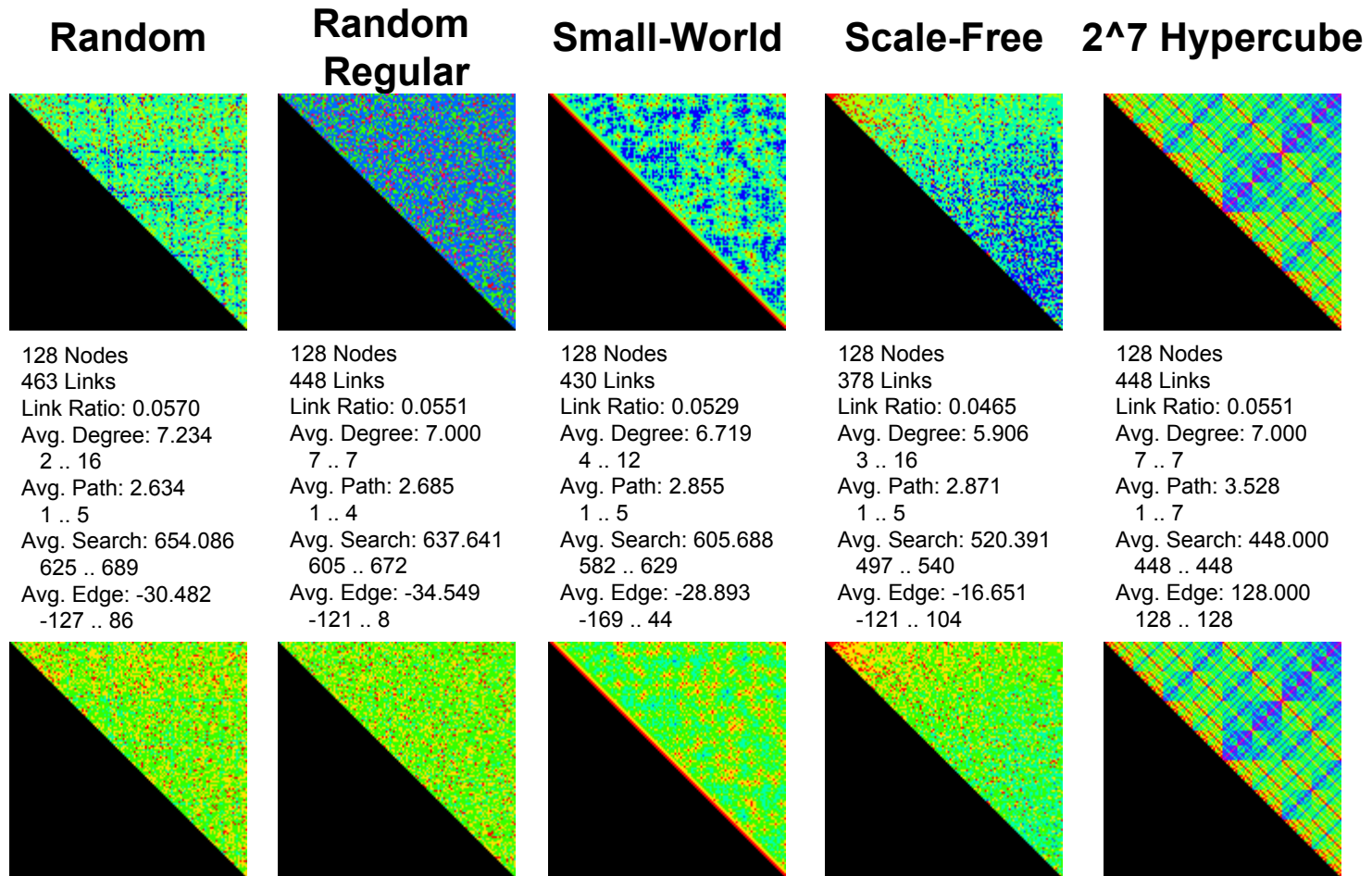
- To understand topological effects of P2P networks through modeling and simulation
- To develop metrics and visualizations that characterize structural and behavioral aspects of our models
 - Degree (# of edges per node)
 - All pairs minimum path length (max value is graph *diameter*)
 - Message cost (for Gnutella-like routing)
 - Edge utilization cost
- To characterize tradeoffs of efficiency vs. robustness
- To devise local behavior that can lead to improvements of global network performance
 - e.g., thinning and folding operations

Activities

- **Mathematical modeling, simulation, and analysis of hypercube topologies:**
 - K-D cubes (base K, dimension D)
 - Sparse vs. dense hypercubes (Lee distance)
 - Diameter folding (adding cross-cube shortcuts)
- **Modeling, simulation, and analysis of other topological families:**
 - Random nets (Erdős and Rényi)
 - Structured small-world nets (Watts & Strogatz)
 - Scale-free nets (Barabási & Albert)
- **Heuristic search to improve topologies:**
 - Removing wasteful edges (thinning)
 - Adding helpful shortcuts (folding)
- **P2P protocol study, analysis, and testing:**
 - Project JXTA (Juxtapose)

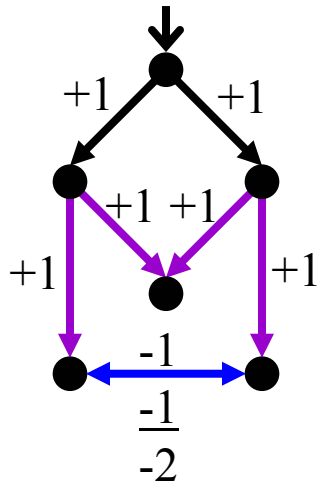
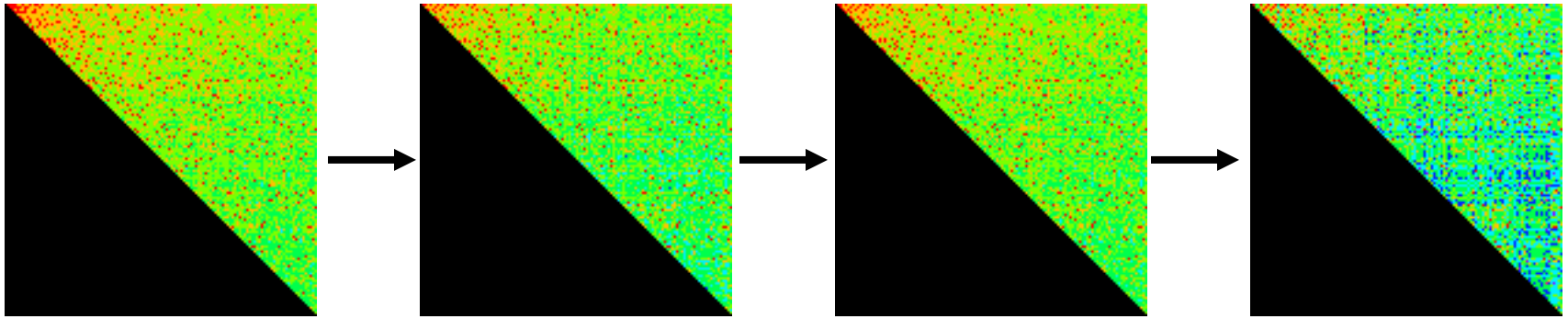
Highlight

Topologies Compared - Mimicking the Hypercube (min paths visualized, scales normalized at bottom)

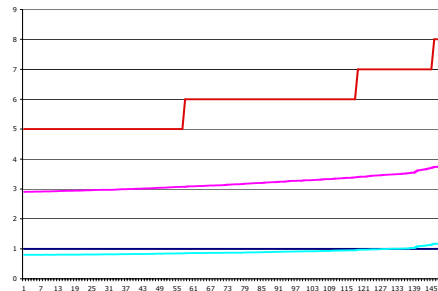
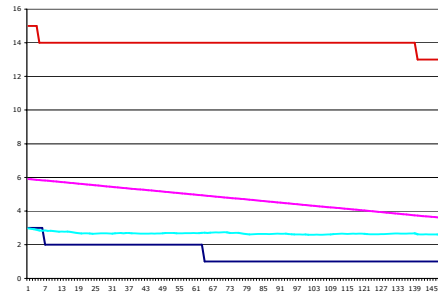


Highlight

Edge-Thinning a Scale-Free Network



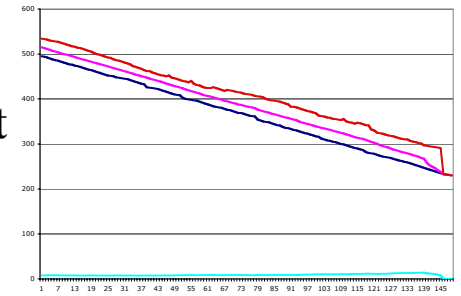
- 1st Gen
- 2nd Gen
- 3rd Gen



Degree
Stats

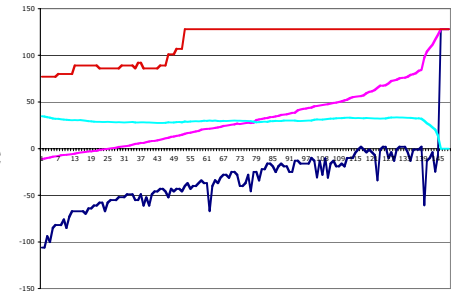
Search Cost
Stats

- Max
- Mean
- Min
- Std Dev



Min Path
Stats

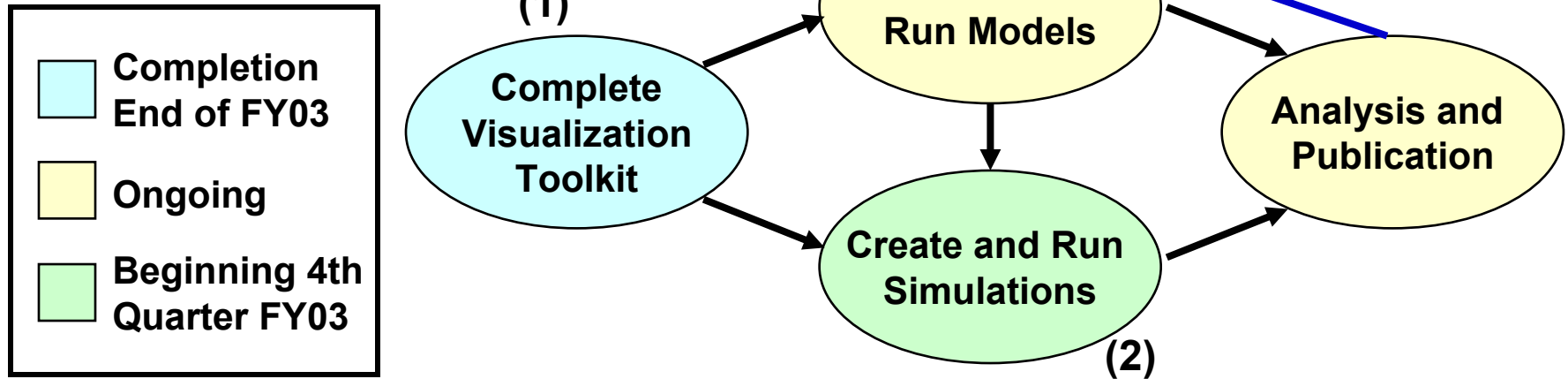
Edge Score
Stats



Impacts

- **Peer-to-peer networks of resource brokers can help us achieve scalable, timely, and robust global information and resource management.**
 - **Witness interest in network centric warfare, GRID computing, and Joint Battlespace Infosphere (JBI) technologies**
- **Understanding how to build these networks in ways that are self-healing, adaptive, and efficient is a challenge. This research will help.**

Future Plans



1) The current toolkit creates the edge maps (Highlight slides). Future work includes integration of both statistical and graph visualization tools.

2) Simulations will include use of the JXTA P2P protocol as well as the DiMeS broker technology. Network simulations might use OPNET technology.

3) With the completion of each testing and analytical cycle, further complexity will be added to the models such as peer transience, non-uniform network loads, and the distribution of responsibilities.