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Dynamic Networks and Distributed Problem-Solving

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Dynamic Network Simulation

- Aims:
  - understand the effect of dynamic changes in network structure on group-level cognitive processing
- Background:
  - rate of information dissemination often seems to be important to collective problem-solving and decision-making
  - precipitant forms of information sharing can compromise collective performance
- Approach
  - computer simulation study
  - 100 agents attempt to find optimal design solutions by progressively adjusting the values of a 20-bit solution string
  - each design solution is associated with a fitness score based on the structure of a fitness landscape
  - agents adopt superior solutions from network neighbours
  - network structure emerges across time – links added randomly between agents

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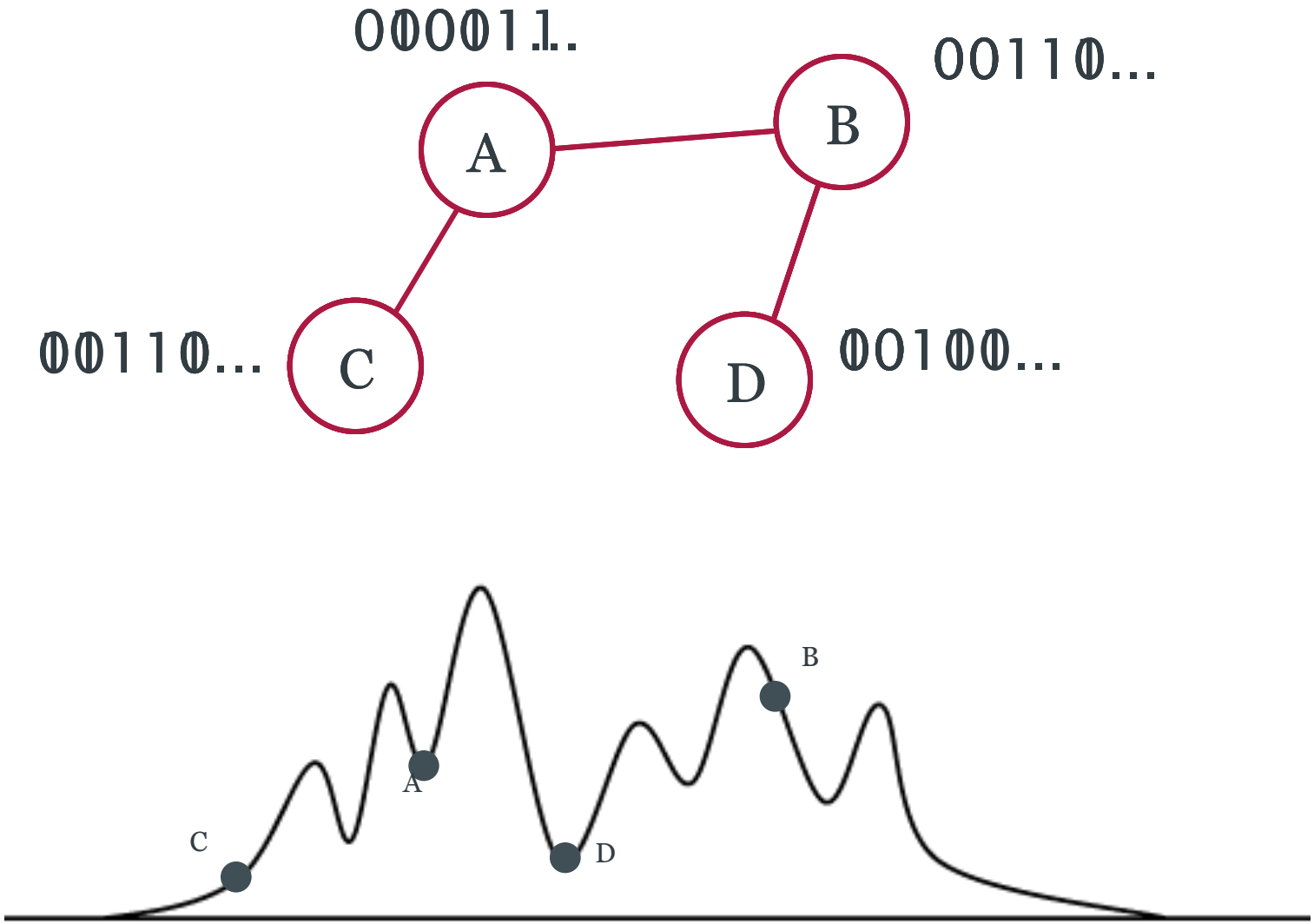

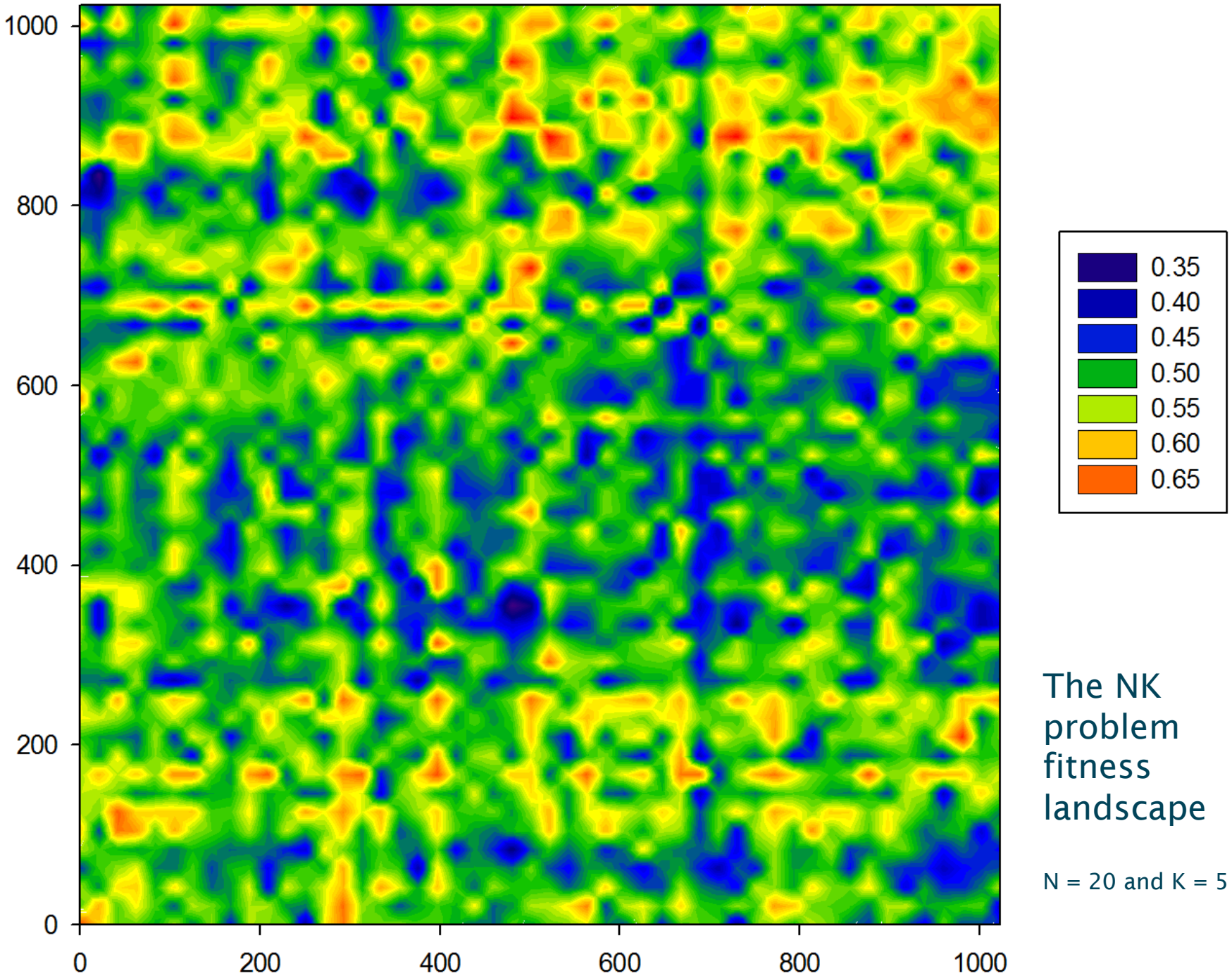

The NK problem fitness landscape

N = 20 and K = 5

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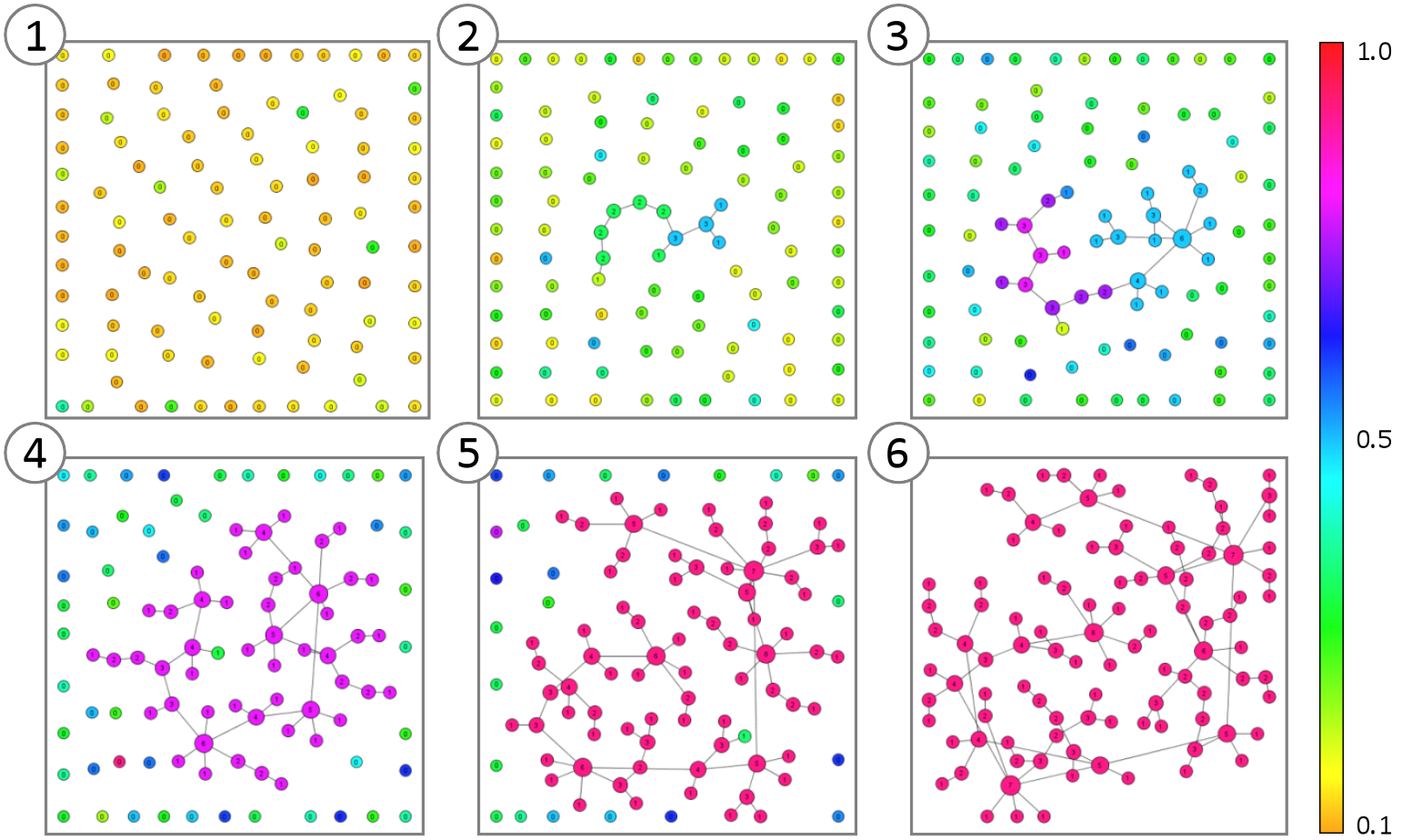
Network Growth



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Experimental Design

- Two independent variables:
  - Network Growth Rate (NGR)
    - 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0 (7 levels)
  - Network Growth Delay Period
    - 0, 10, 20, 30, 40, 50 (6 levels)
- Two-way (7*6) factorial design
  - 42 experimental conditions
  - 1000 simulations per condition
- Research questions
  - what does the temporal profile of performance look like across the various experimental conditions
  - how good is the final solution found by agents in each of the various treatment conditions

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Performance Profile of Dynamic Networks

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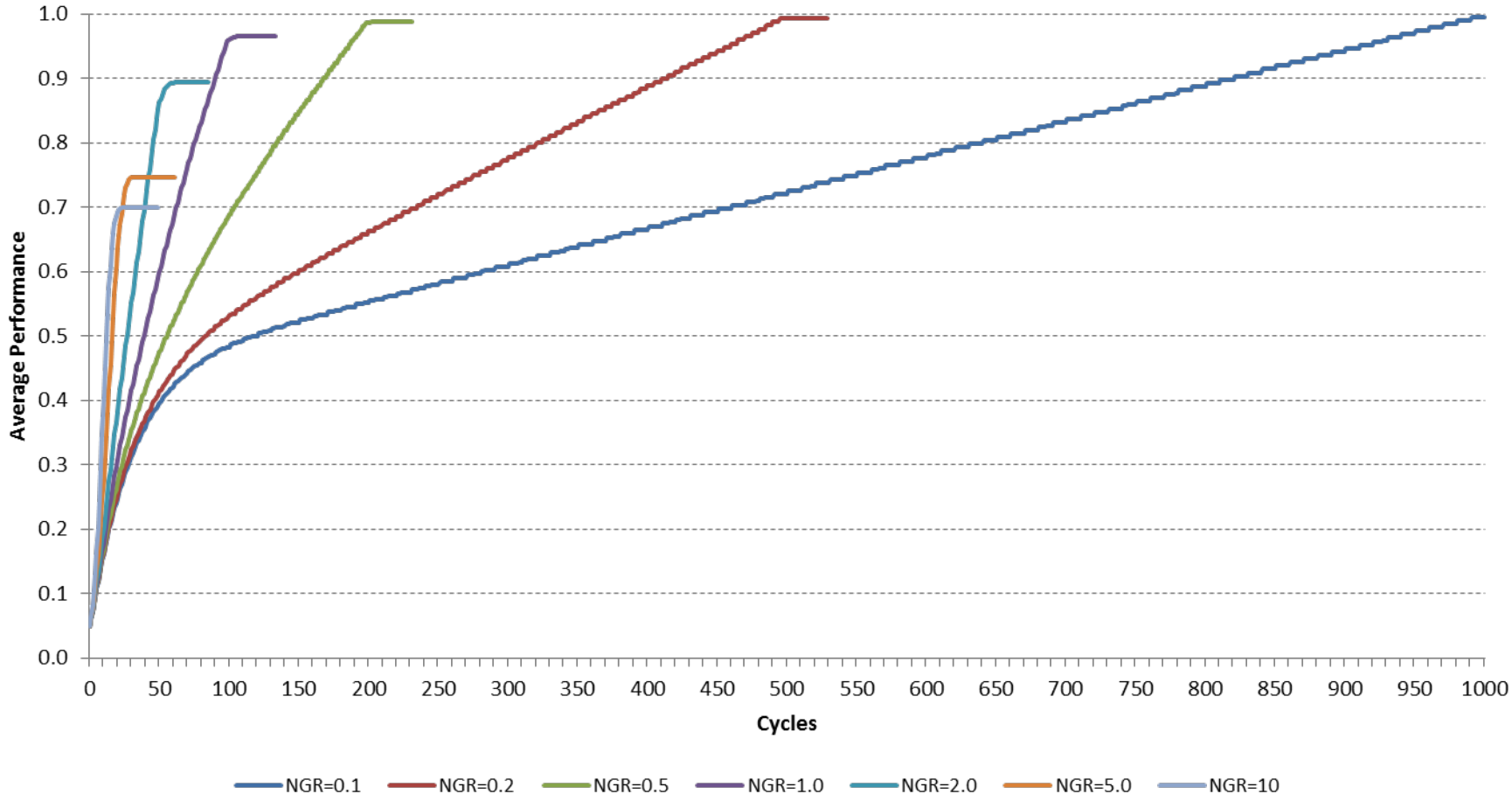
Performance Profile (1)



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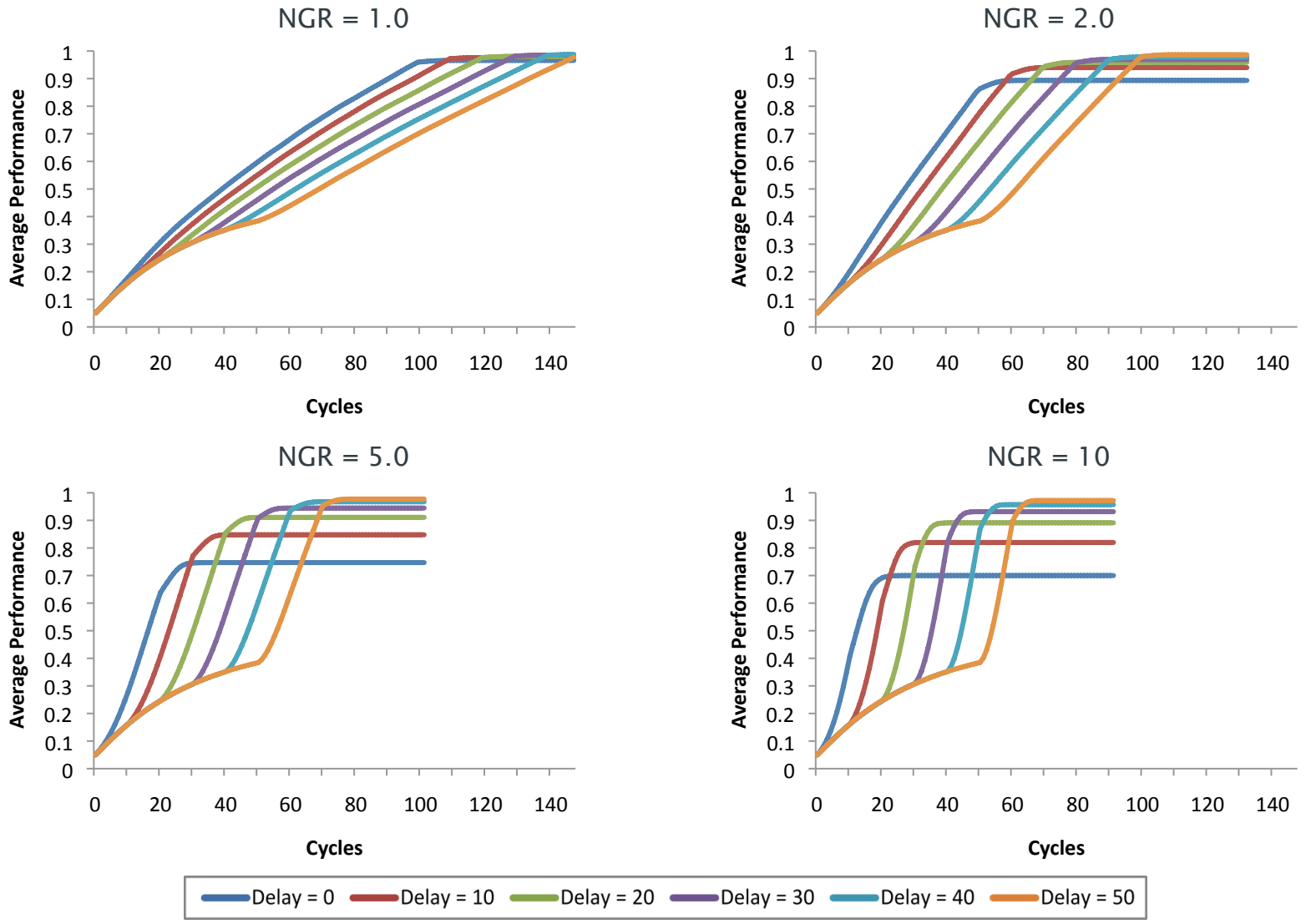
Performance Profile (2)



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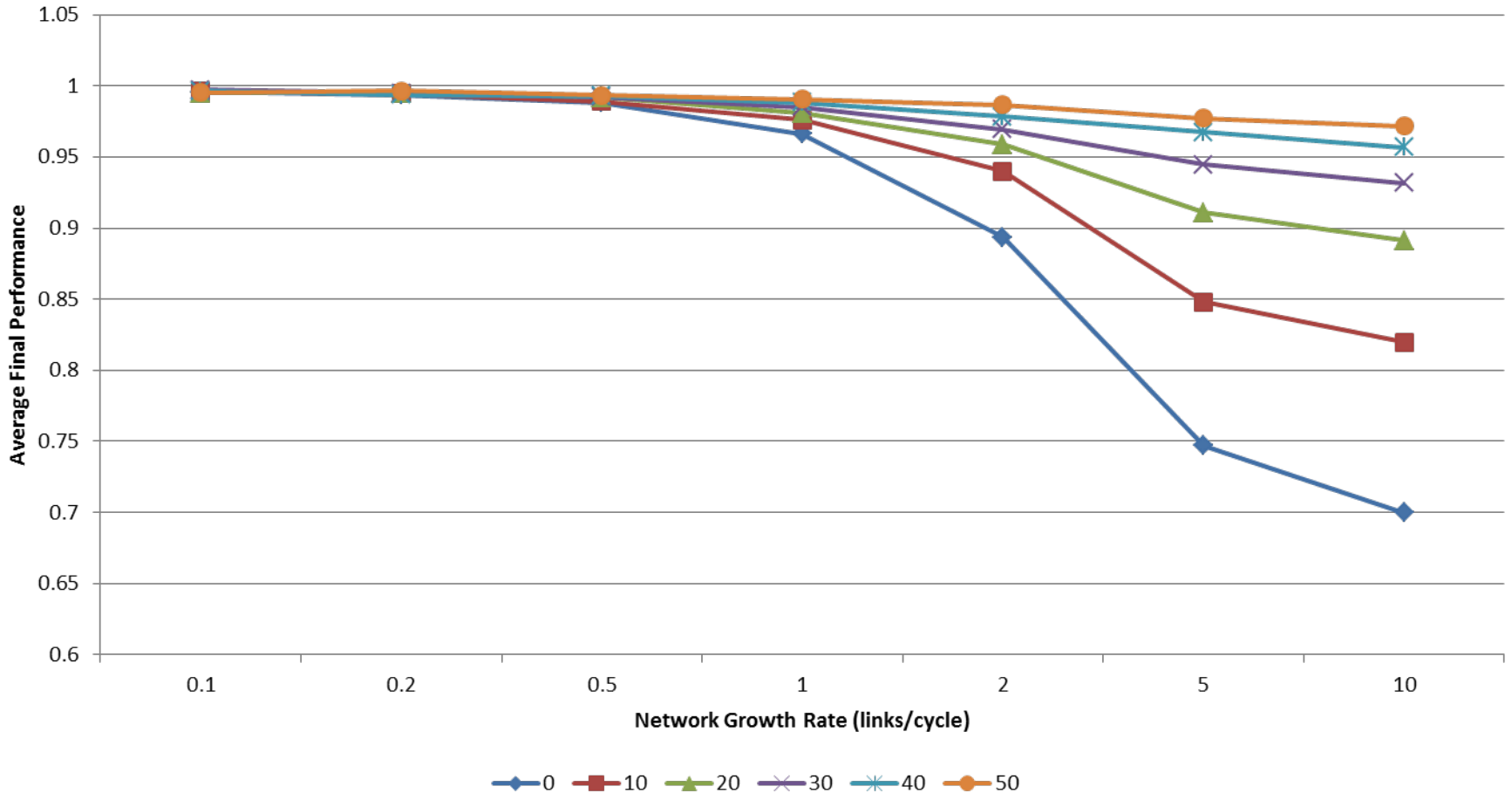
Quality of Final Solutions



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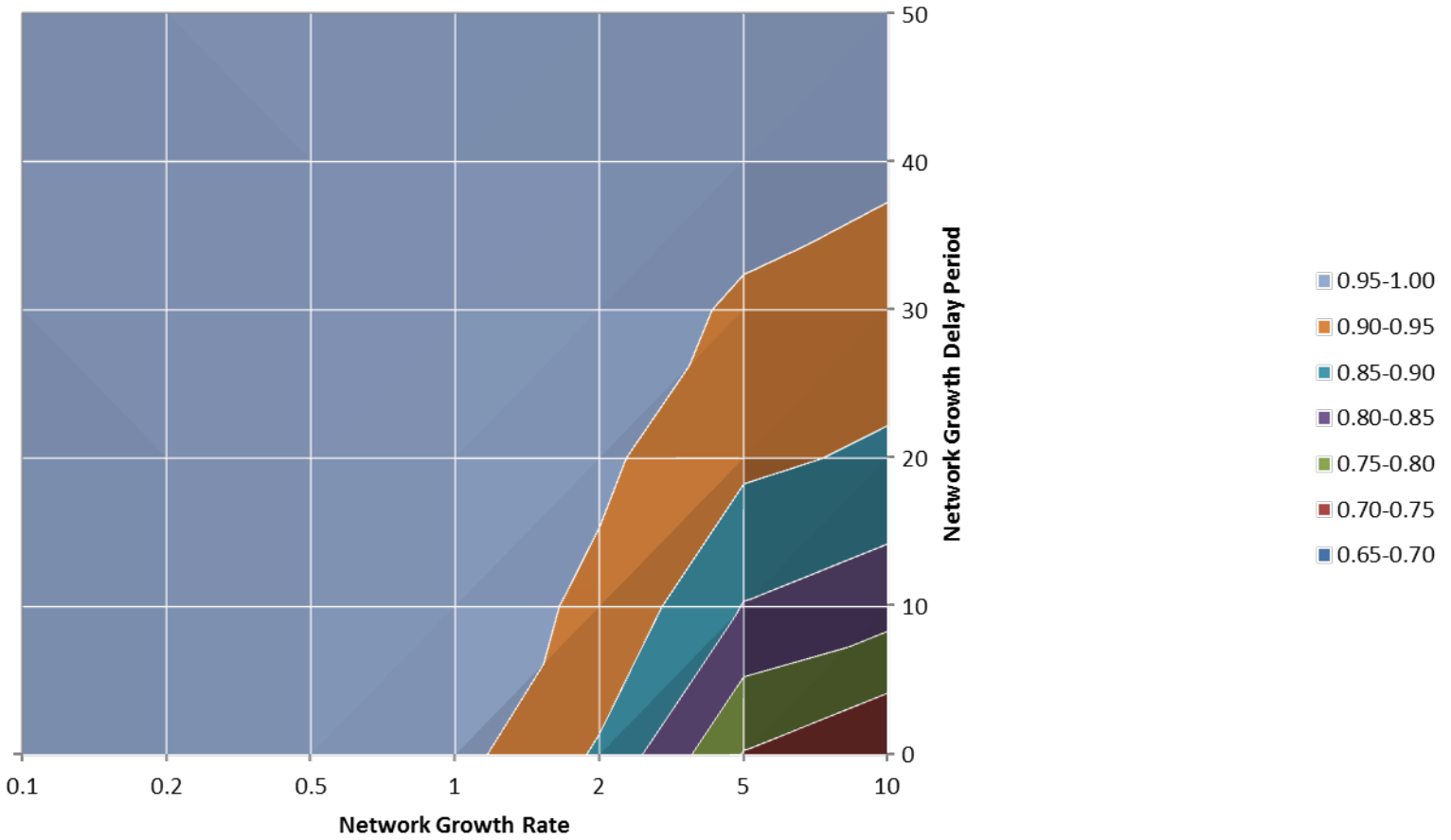
Quality of Final Solutions



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Dynamic versus Static Networks

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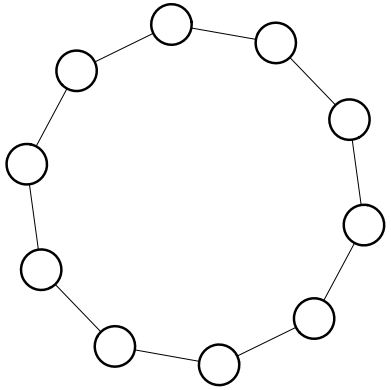
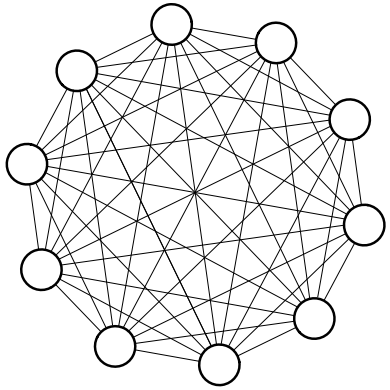
Static Network Structures

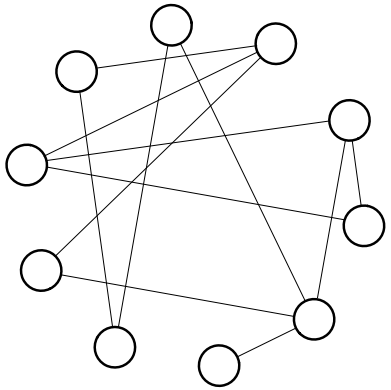
- Static network topologies were used to generate network links in a population of 100 agents.
- Performance of agents within these static networks was then assessed by running 1000 simulations.



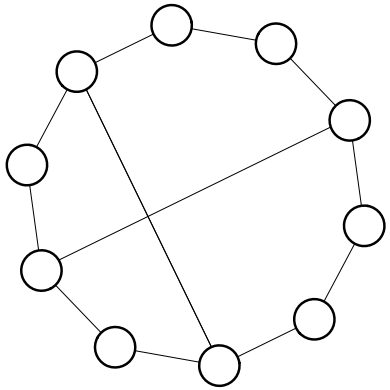
Linear



Fully connected



Random



Small-world

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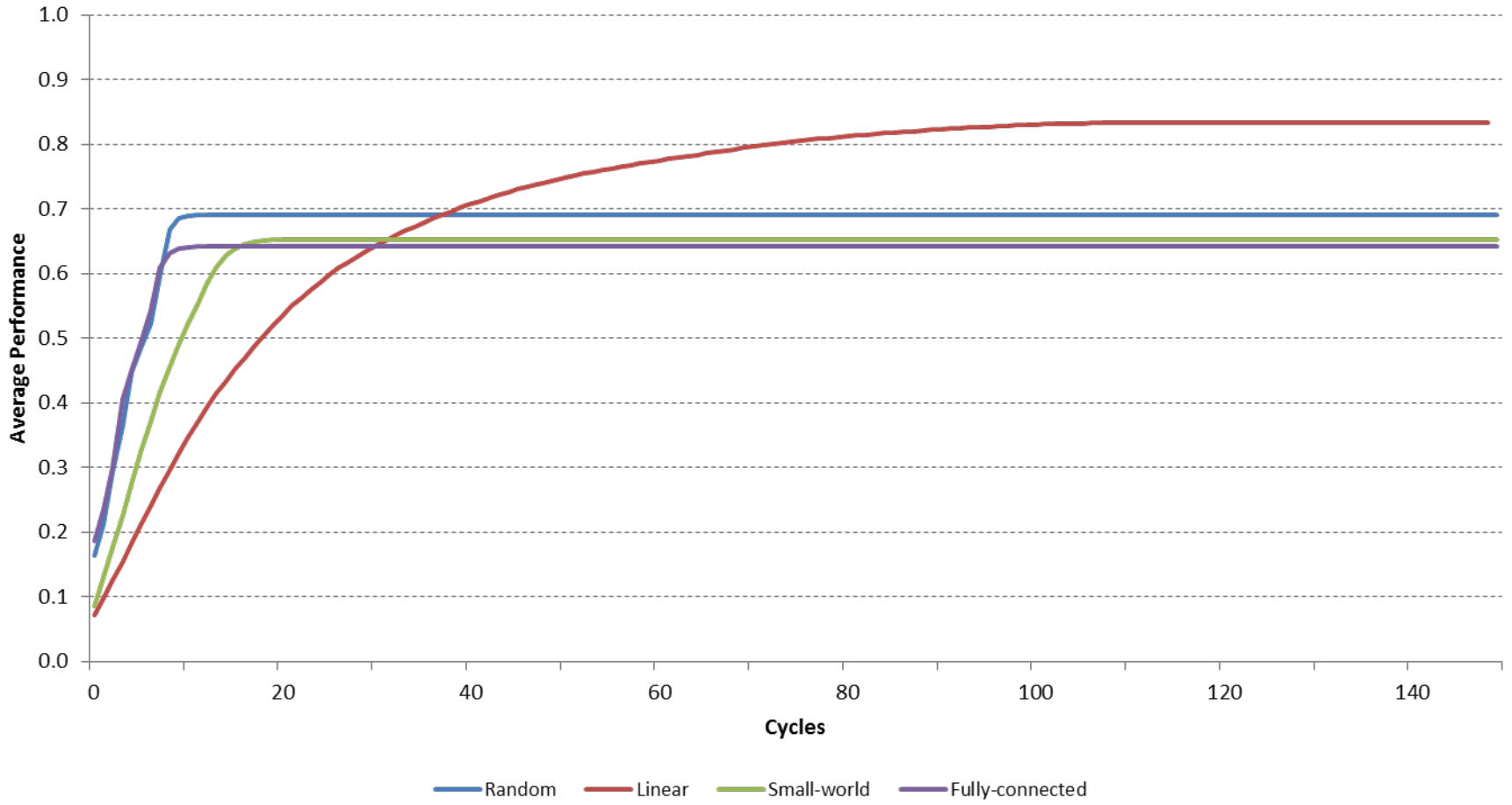
Static Networks – Performance Profile



Dynamic vs Static Networks – Quality of Final Solutions

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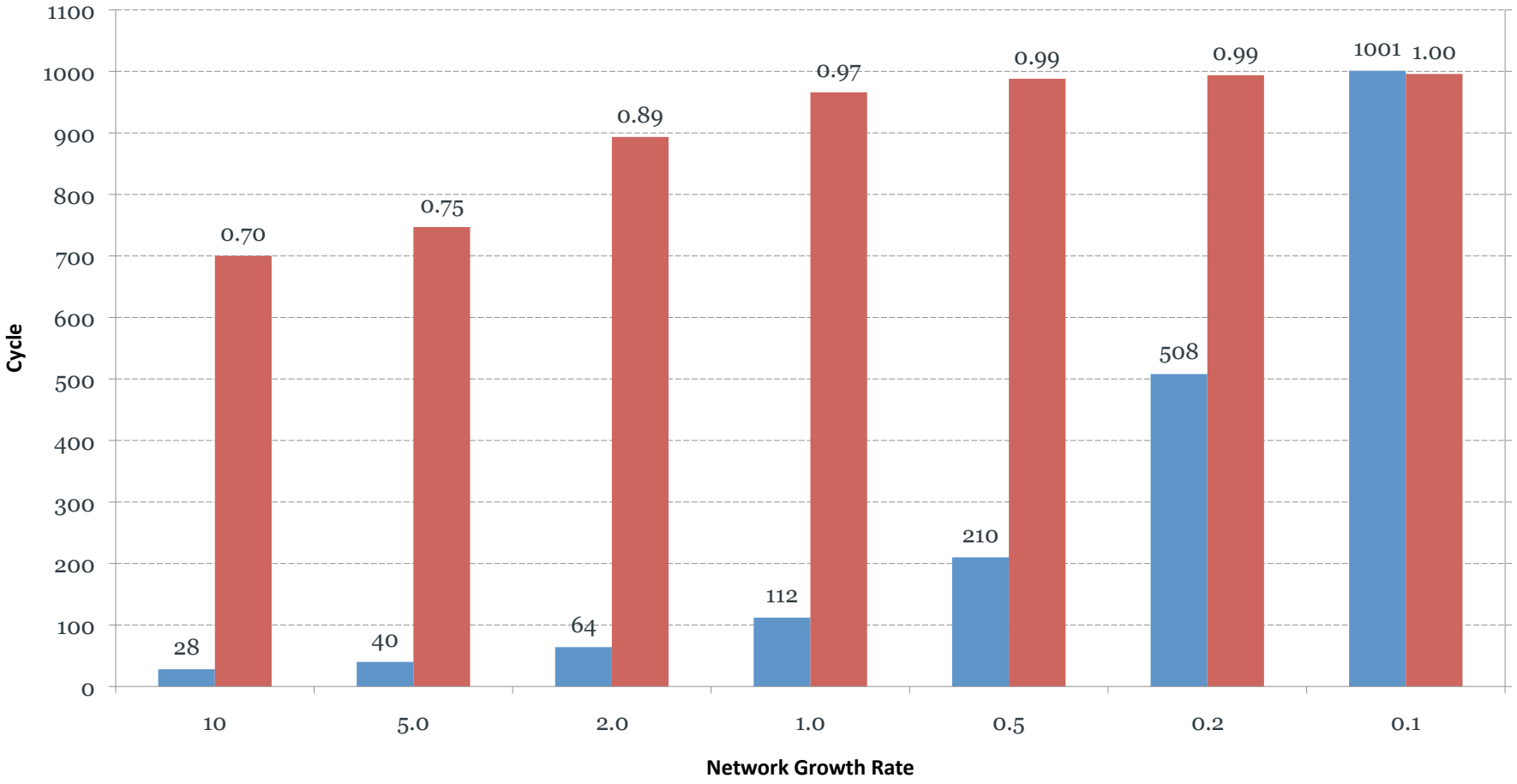

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Conclusions & Future Work

Dynamic Networks and Collective Cognition

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- Dynamic networks contribute to better problem-solving performance (on at least some tasks) compared to static networks
- There is a delicate balance between autonomy and influence, with initial autonomy important for the discovery of better solutions

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Future Focus Areas

- Beyond Collective Search
  - investigation of different types of problem solving contexts.
  - understand how features of tasks relate to network variables and problem-solving performance.
- Inter-agent Trust
  - the adaptive role of distrust.
  - trust-based dynamic rewiring of the network structure.
- Constructive Algorithms
  - network links created according to preferential attachment laws.
- MANETs
  - the impact of patterns of information flow in MANETs on the collective creativity, understanding and decision making potential of groups.
- Network Structure and Shared Interpretation
  - effects of inter-agent communication on the ability to arrive at an accurate shared interpretation of ambiguous environmental information.
  - how do dynamic networks affect belief propagation?
- Hybrid Networks
  - networks consisting of agents, services, sources, sensors, and human actors

Briksdal glacier, Norway.
(Image credits: ECS Glasweb Team)