Royal Dutch Defense Academy

Military Operational Art & Science

The Influence of Secrecy on the Communication Structure of Covert Networks

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Presentation Overview

- Introduction
- Motivation
- Graph Theoretic preliminaries
- Secrecy and Communication
- Game Theoretic Bargaining
- Main Results
- Conclusions

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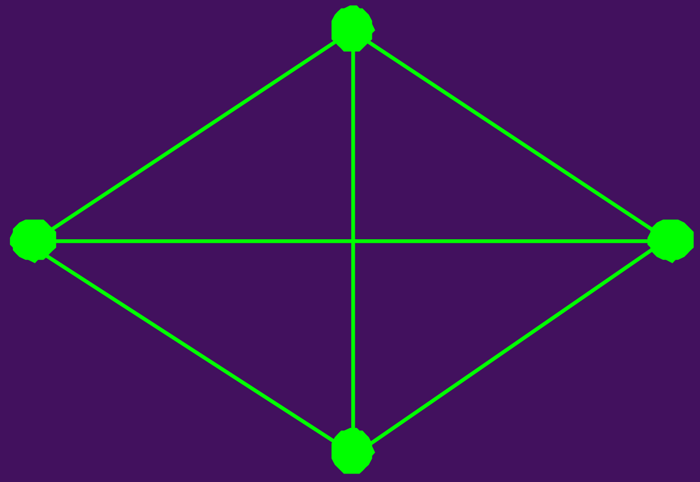
Motivation 1

"*Every secret organization has to solve a fundamental dilemma: how to stay secret and at the same time ensure the necessary coordination and control of its members.*"

[Baker & Faulkner, 1993]



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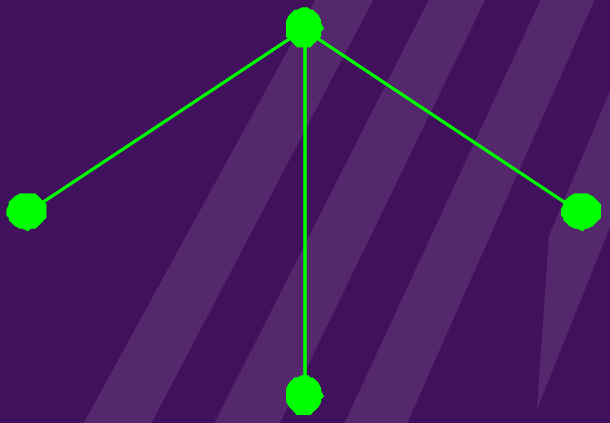

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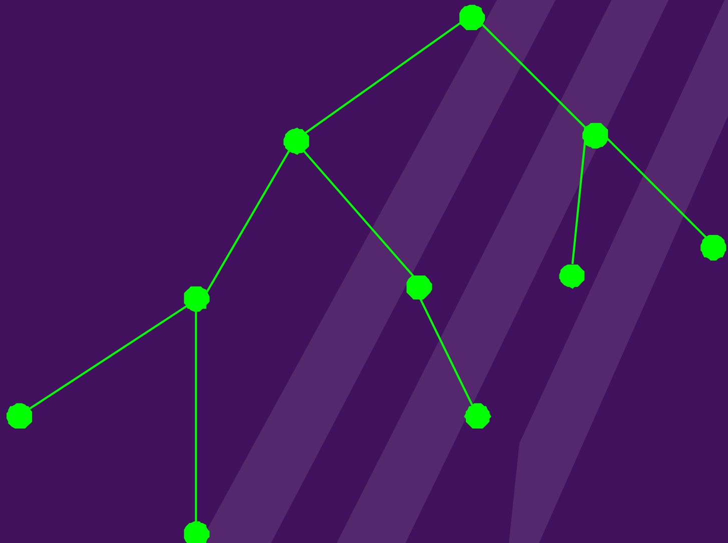
Motivation 2

Abu Mousab al Suri (Al Qaeda affiliate) video lecture (dated august 2000) recovered in Afghanistan

“how to keep jihadist cells secure”

Provides a critique of hierarchical structure:



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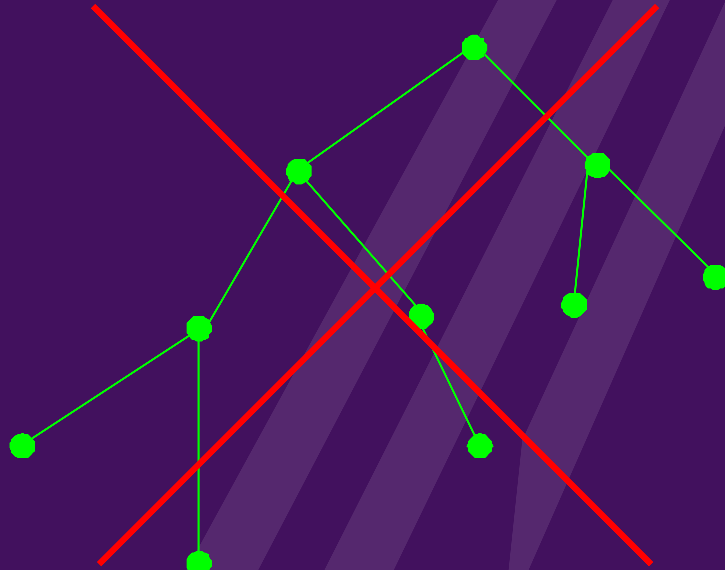
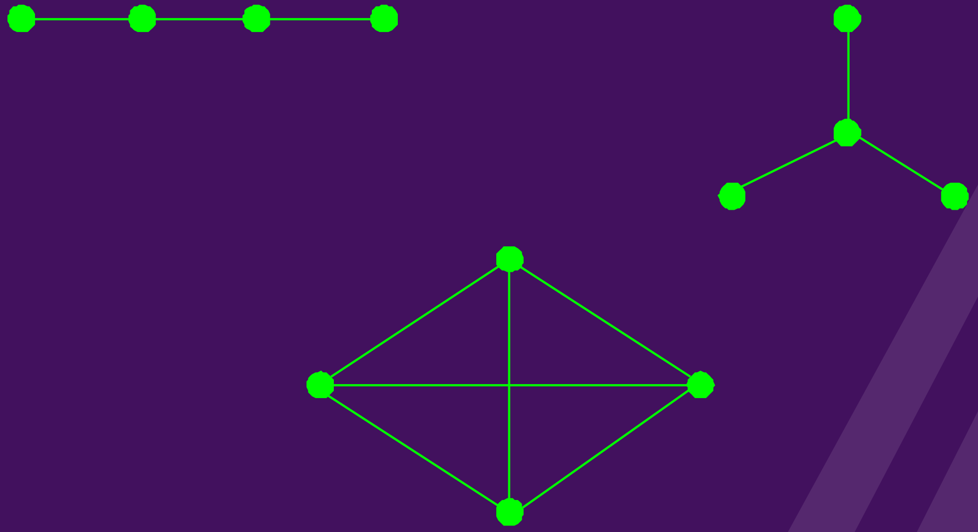


Motivation 3

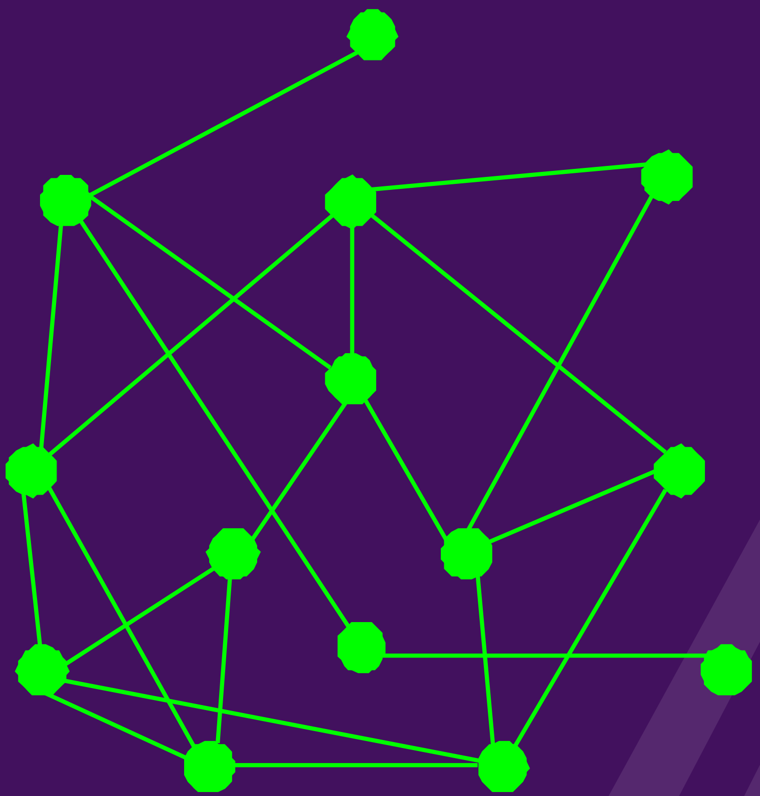
Design military (swarming) networks that depend on stealth and secrecy.
Most common: path / star / complete



Arquilla & Ronfeldt: hybrids….. But which?

Motivation 4

A priori information to recognize patterns in social networks:



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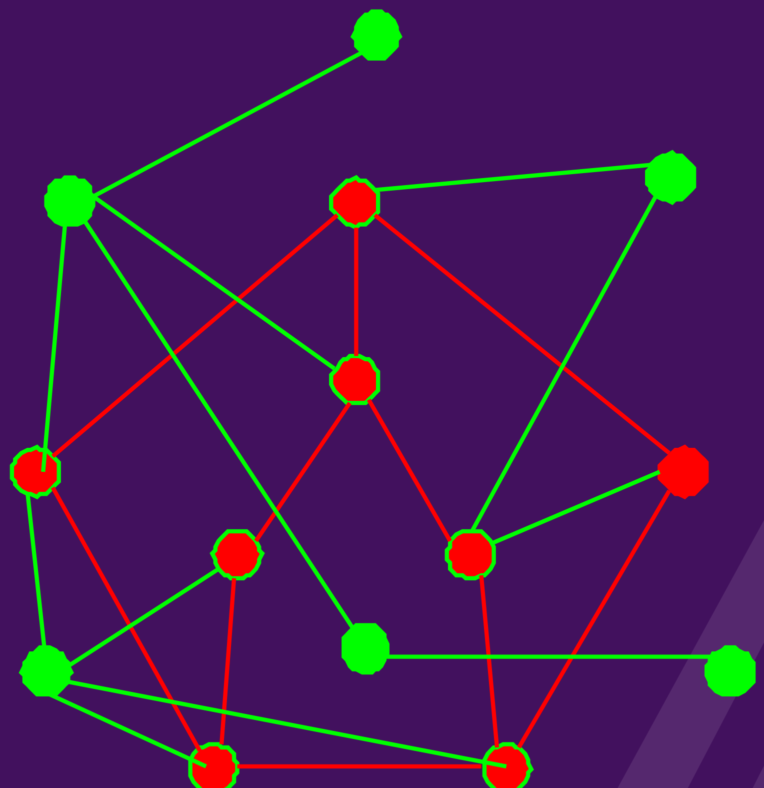
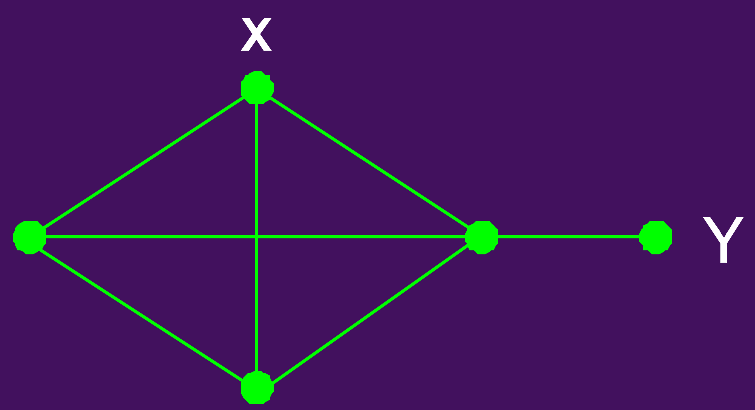


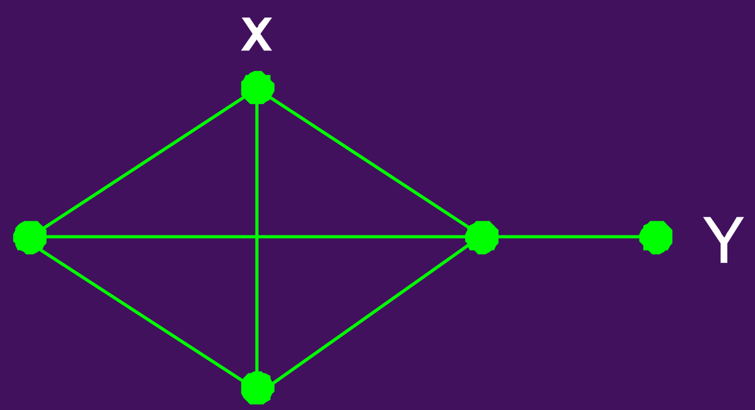
Graph preliminaries

- Graph g is ordered pair of disjoint sets, vertices V and edges E



Graph preliminaries

- Graph g is ordered pair of disjoint sets, vertices V and edges E
- Geodesic Distance: shortest distance between vertices in graph (infinity when no path exists)



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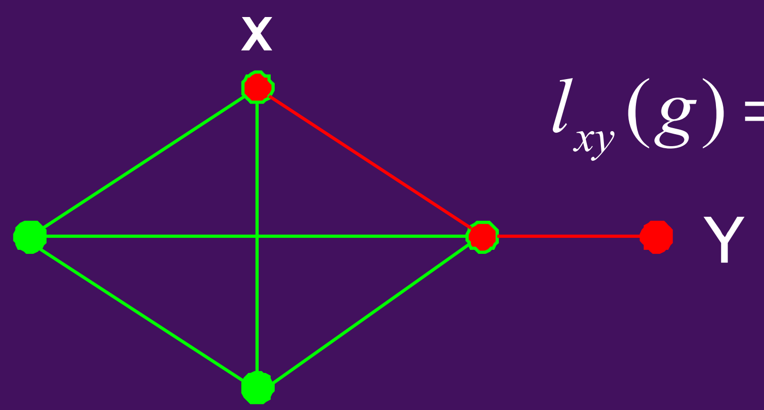
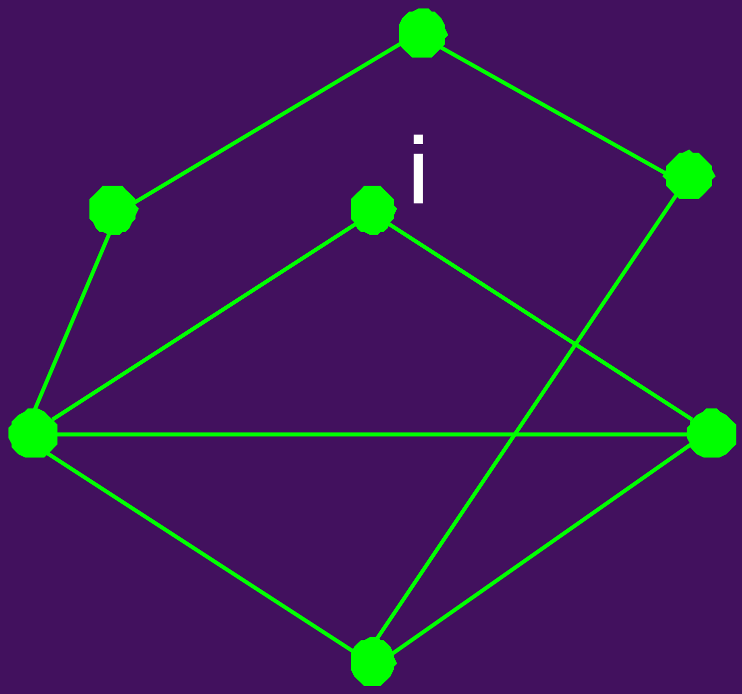


$$l_{xy}(g) = 2$$

Graph preliminaries

- Degree of vertex i is the number of his neighbors:



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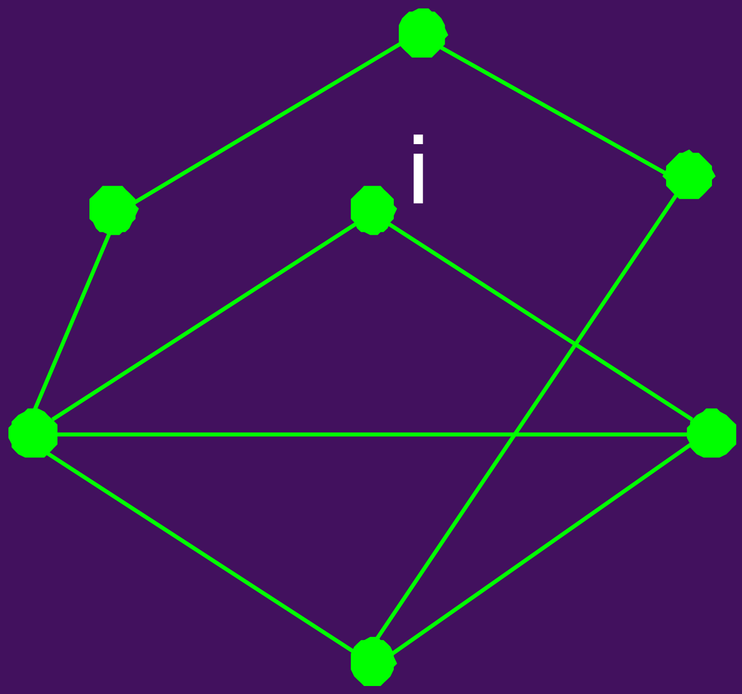


$$d_i = 2$$

Communication measure of graph

- Number of individuals in network: n

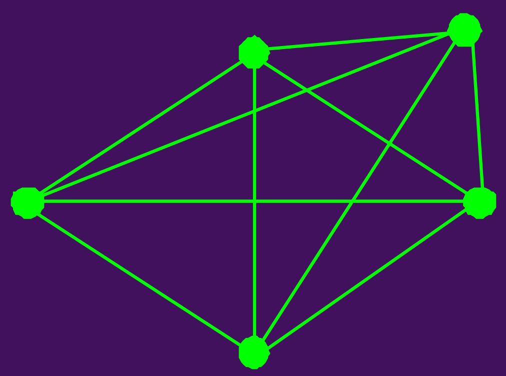
$$I(g) = \frac{n(n-1)}{\sum_{i,j} l_{ij}(g)}$$

$$0 \leq I(g) \leq 1$$

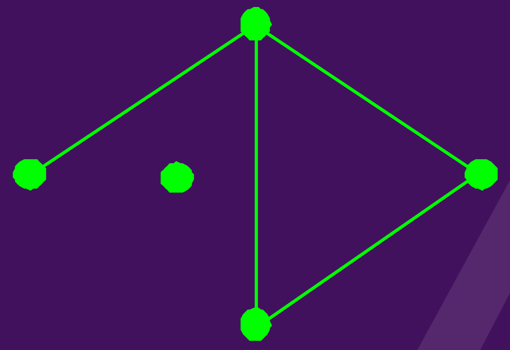
Communication measure of graph

Example:

- Number of individuals in network: $n = 5$



$I(K_5) = 1$



$I(g) = 0$

Secrecy measure of graph

Two factors contribute to individual's security in a network:

- 1. Probability of being identified as member of network
- 2. The part of the network an individual exposes when being monitored

Define network security as convex combination of these:

$$S(g) = \sum_i \alpha_i s_i(g)$$

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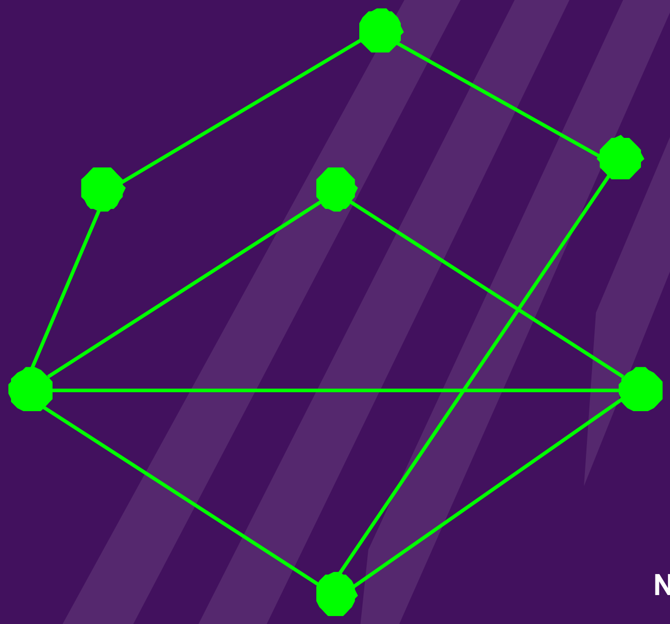
Secrecy measure of graph

Scenario 1:

- Uniform detection
- Uncovering all neighbors

$$\alpha_i = \frac{1}{n}$$

$$s_i = \frac{1}{n}(n - d_i + 1)$$



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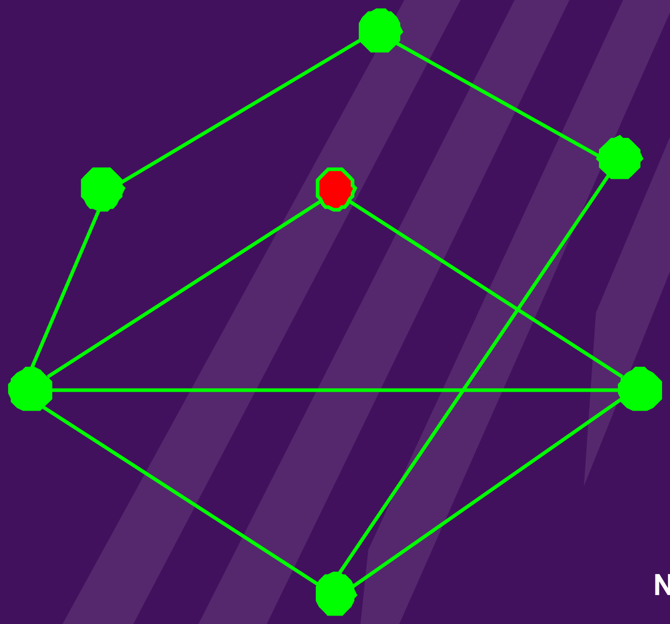

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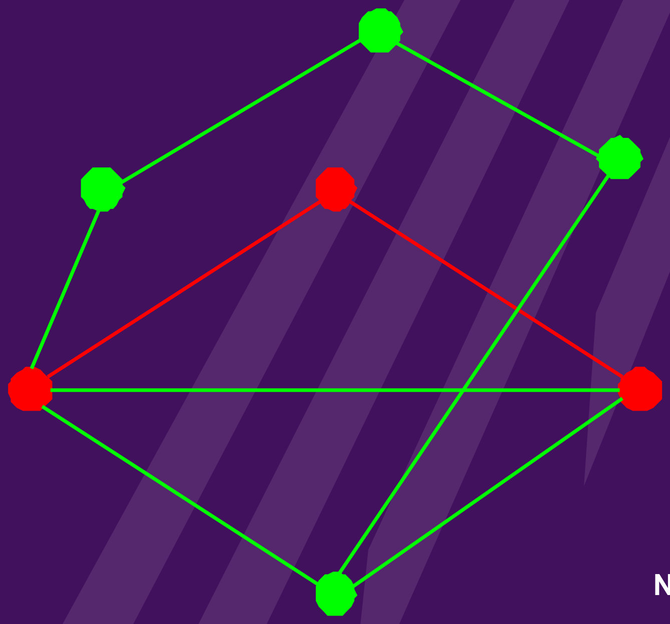

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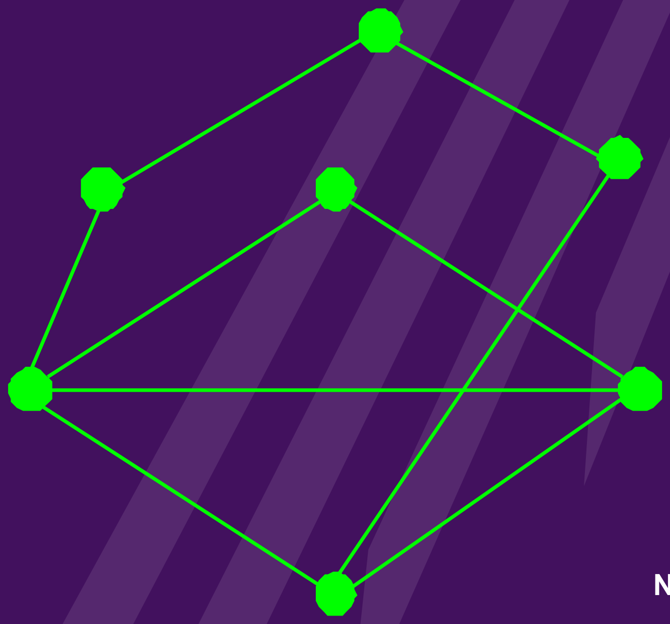
Secrecy measure of graph

Scenario 2:

- Uniform detection
- Uncovering neighbors independent with probability p

$$\alpha_i = \frac{1}{n}$$

$$s_i = \frac{1}{n}(n - pd_i + 1)$$



Secrecy measure of graph

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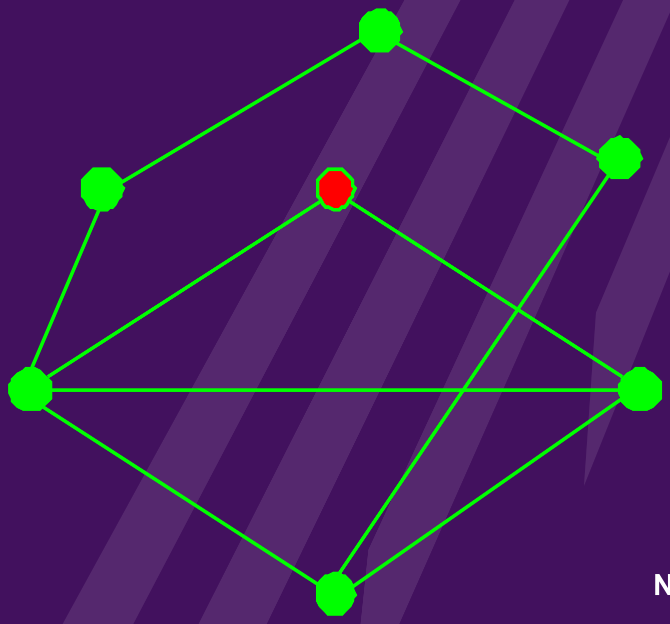


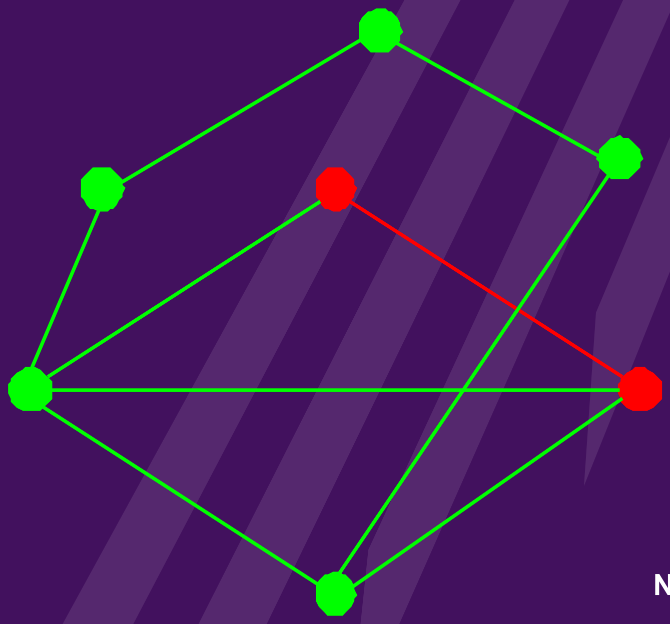
Secrecy measure of graph

<u>Scenario 2</u>:

- Uniform detection
- Uncovering neighbors independent with probability p=1/2

$$\alpha_i = \frac{1}{n}$$

$$s_i = \frac{1}{n}(n - pd_i + 1)$$



Secrecy measure of graph

Scenario 3:

• Detection according to ‘information centrality’ (equilibrium distribution of random walk on graph)

• Uncovering all neighbors

$$\alpha_i = \pi_i$$

$$s_i = \frac{1}{n}(n - d_i + 1)$$

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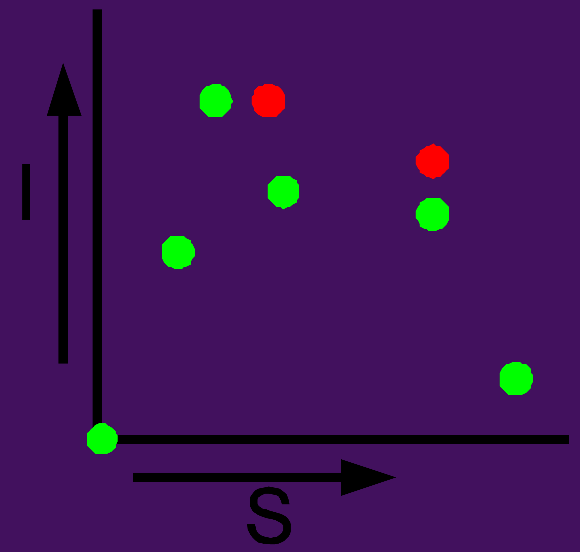
Thus far…

Agents discuss which network structure to adopt by considering the *tradeoff* between secrecy and coordination and control capability

Model this as game theoretic bargaining

Bargaining

Two agents bargain over the set of connected graphs of given order with utilities $S(g)$ and $I(g)$



Nash's Bargaining Solution:

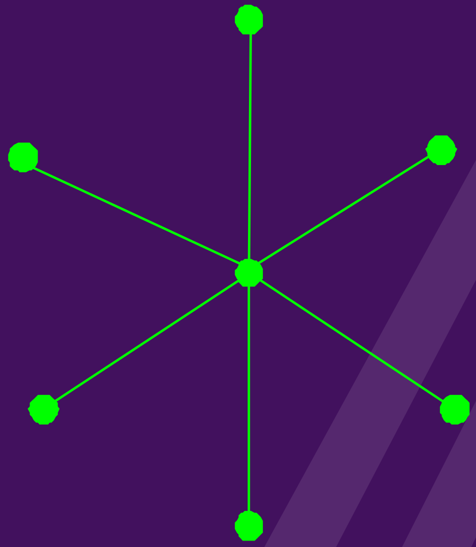
$$\arg\max_{g \in G^n} S(g) \cdot I(g)$$

Main Results Scenario 1

Scenario 1:

- Uniform detection
- Uncovering all neighbors

Theorem: The Nash Bargaining Solution equals the star graph

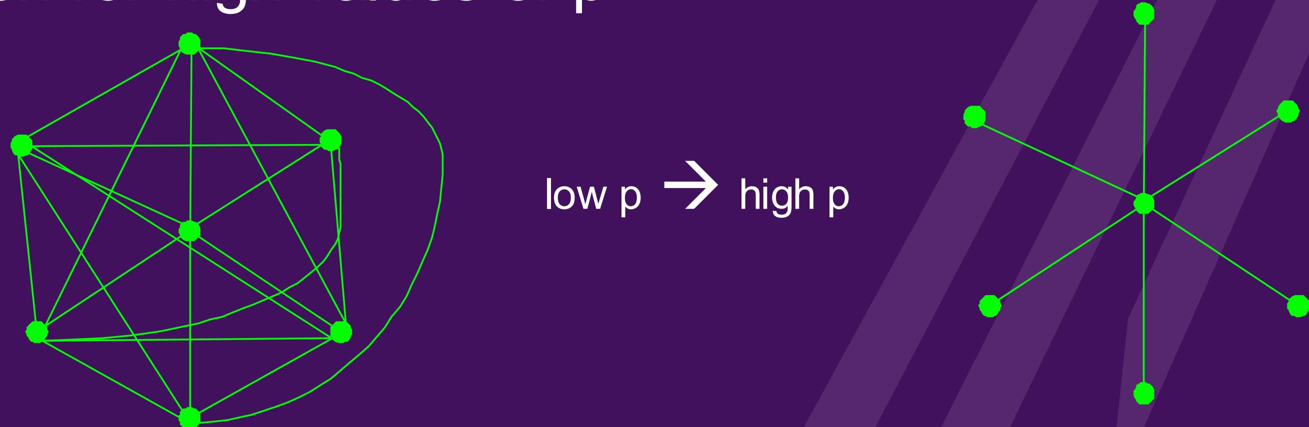


Main Results Scenario 2

Scenario 2:

- Uniform detection
- Uncovering neighbors independent with probability p

Theorem: The Nash Bargaining Solution equals the complete graph for low values of p, and the star graph for high values of p

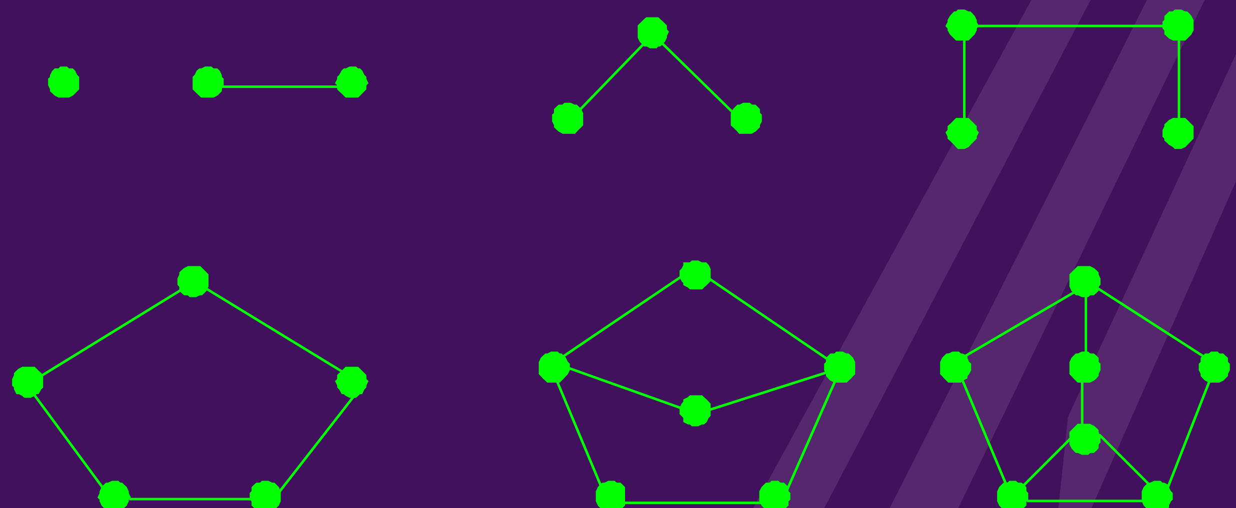


Main Results Scenario 3

Scenario 3:

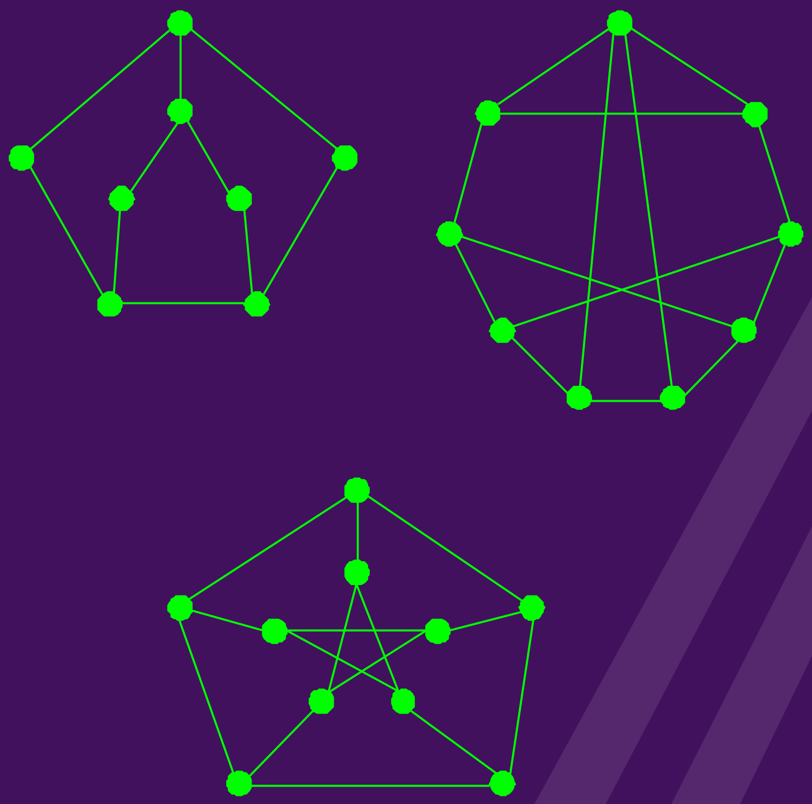
- Detection according to ‘information centrality’ (equilibrium distribution of random walk on graph)
- Uncovering all neighbors

- Exact solutions for $1 \leq n \leq 7$:



Main Results Scenario 3

- Simulated (local optimization algorithm and random graph) ‘solutions’ (n=8, 9, 10):



Conclusions

- Optimal network structure a covert organization should adopt when taking secrecy and communication into account:

2. All-to-all when it is very unlikely that communication / individuals will be detected

4. Star network when it is likely that communication can be intercepted, but hard to distinguish individuals

5. Cellular taking information centrality into account

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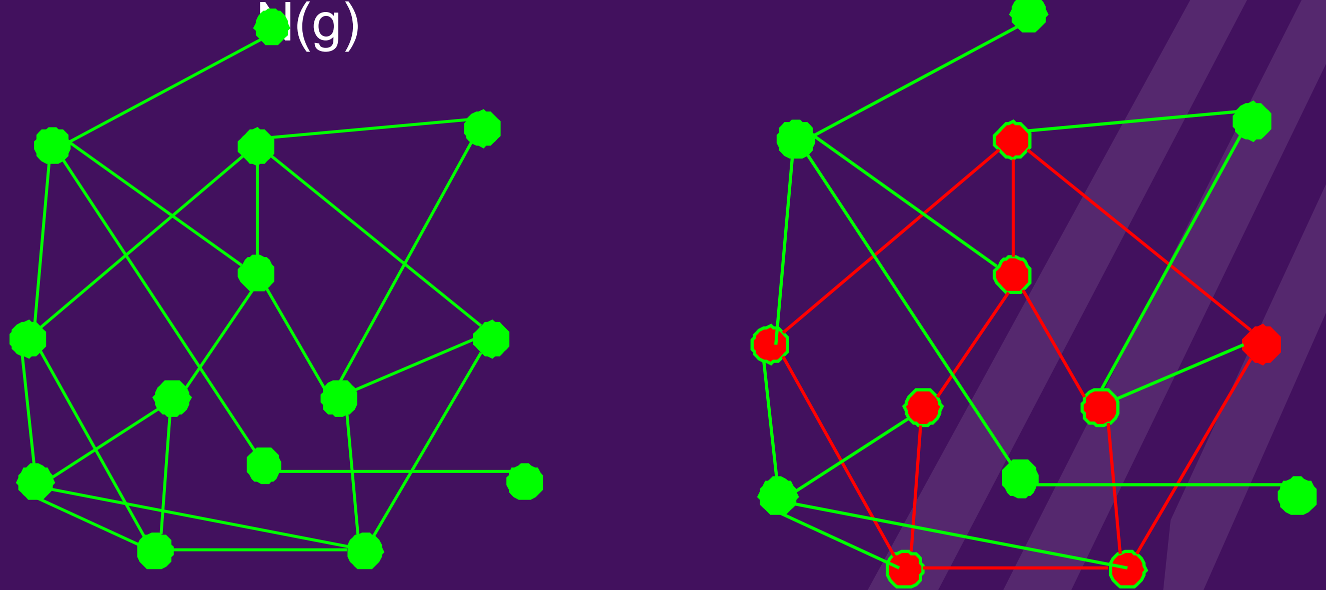
Conclusions

- Provides a metric for intelligence to predict expected network structure:
  - » Historical data: value of N(g) organisation adopts
  - » Current data: look for structures that 'are close to' N(g)

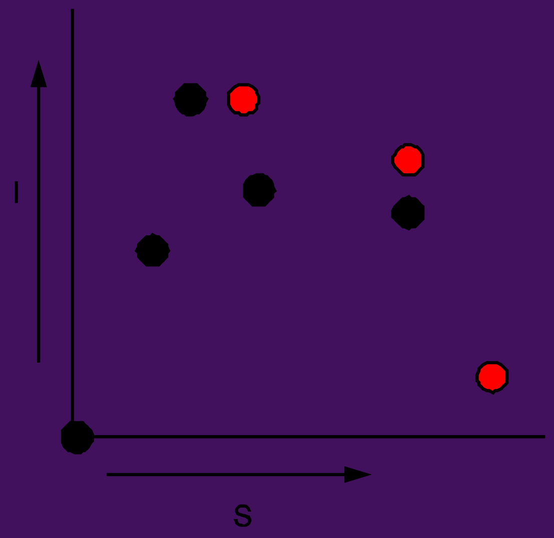


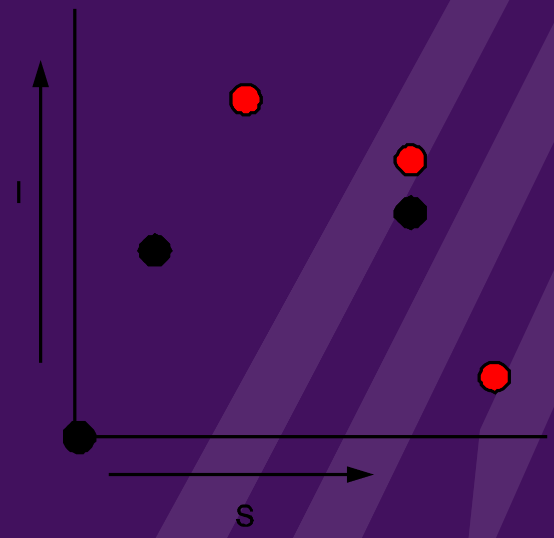
Questions?

Bargaining Properties

- Independence of Irrelevant Alternatives:

  If the initial set of alternatives is reduced, and the solution of the original set is contained in the reduced set then the solution of the reduced set equals that of the initial set:

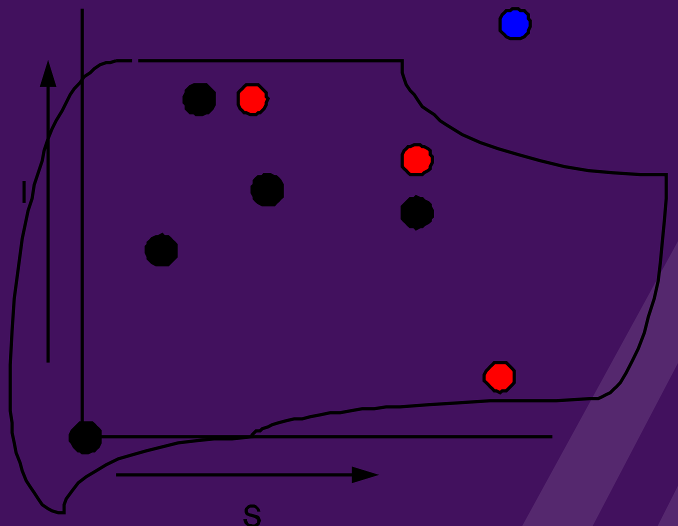




Bargaining Properties

- Weak Pareto Optimality:

  If there exists a graph, g, with both larger $S(g)$ and $I(g)$ than any graph in the solution set, then g can not be a member of the initial set



Bargaining Properties

- Covariance with scale transformations:

  'scaling' $S(g)$ and $I(g)$ does not alter the solution

- Symmetry:

  If for all graphs with (S=a,I=b) there exists a graph with (S=b,I=a) then if (S=x,I=y) is a solution then also (S=y,I=x)

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