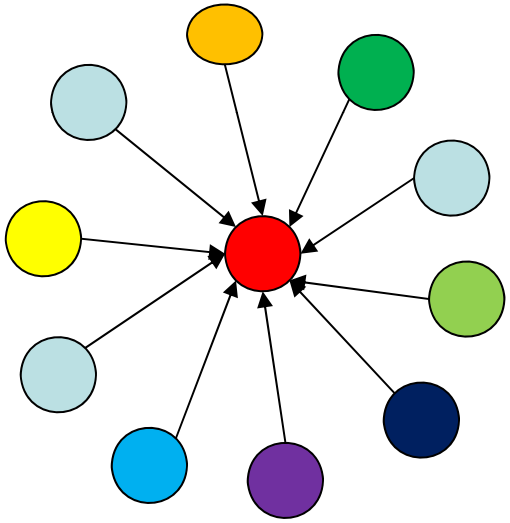
Networks
Contagion and Resilience



Sanjeev Goyal

Faculty of Economics

University of Cambridge

September 2011

Outline

1. Introduction
2. Themes of study
   - Inducing contagion
   - Resilient networks
   - Adaptation and evolution

Introduction

Connections between firms, banks, cities, consumers and countries facilitate flows of ideas, resources and goods and services:

- -- How can actors – govt, firms, hackers -- exploit connections?
- -- How do networks adapt to shocks?
- -- What is the architecture of resilient networks?
- -- What is the role of public policy ?

Introduction

Motivating examples

1. Social networks and marketing: consumers share information and preferences. Firms and governments use social networks to economize costs and maximize sales. Competition for influence in networks.

2. Computer network security: A manager creates links between computers, while a hacker aims to infect them. Creation of links and allocation of security budget… and optimal targeting of attacks.

3. Financial Contagion: Banks borrow/lend to each other to earn interest on their deposits, but collapse of a bank may spread through links. Do banks create the right networks and how can central banks intervene effectively?

Influencing the influencers

Monopoly problem: Galeotti and Goyal, 2009, Rand Journal

Exploit network: choose marketing budget and targets.

Main findings:

- Use of social networks raises sales and greater profits.
- Social networks increase/decrease budget: **content** of interaction
- Optimal target has low/high connections: **content** of interaction.
- Market research on networks yields returns in dispersed networks.

Influencing the influencers

Competitive Contagion: Goyal and Kearns, 2011

Two firms seed a network to maximize market share.

Main issues

Price of anarchy: *Do firms waste resources?*

Sufficient conditions for bounds on inefficiency.

Increasing returns in networks create unbounded inefficiencies.

Price of budget: *Do networks amplify resource inequality?*

Sufficient conditions for upper bound.

Threshold dynamics in networks create advantages for rich player.

Targeting in networks: *How to target to maximize market share?*

Resilient Networks

Conceptual framework

	Random attacks	Intelligent adversary
Designer	Natural disasters *vs* transport networks	Gangs *vs* police LAN *vs* hackers
Decentralized choices	Vaccination *vs* viruses Liquidity shocks *vs* bank networks	Airports *vs* terrorists

Robust networks

Two player game: Goyal and Vigier, 2011

The Designer:

- Chooses a network and allocates defense budget.
- Returns are additive across components, increasing and convex in component size.

The Adversary

- Observes the network and attacks nodes.
- Successful attack on node spreads via links in network.

A network is *robust* if it maximizes returns to designer.

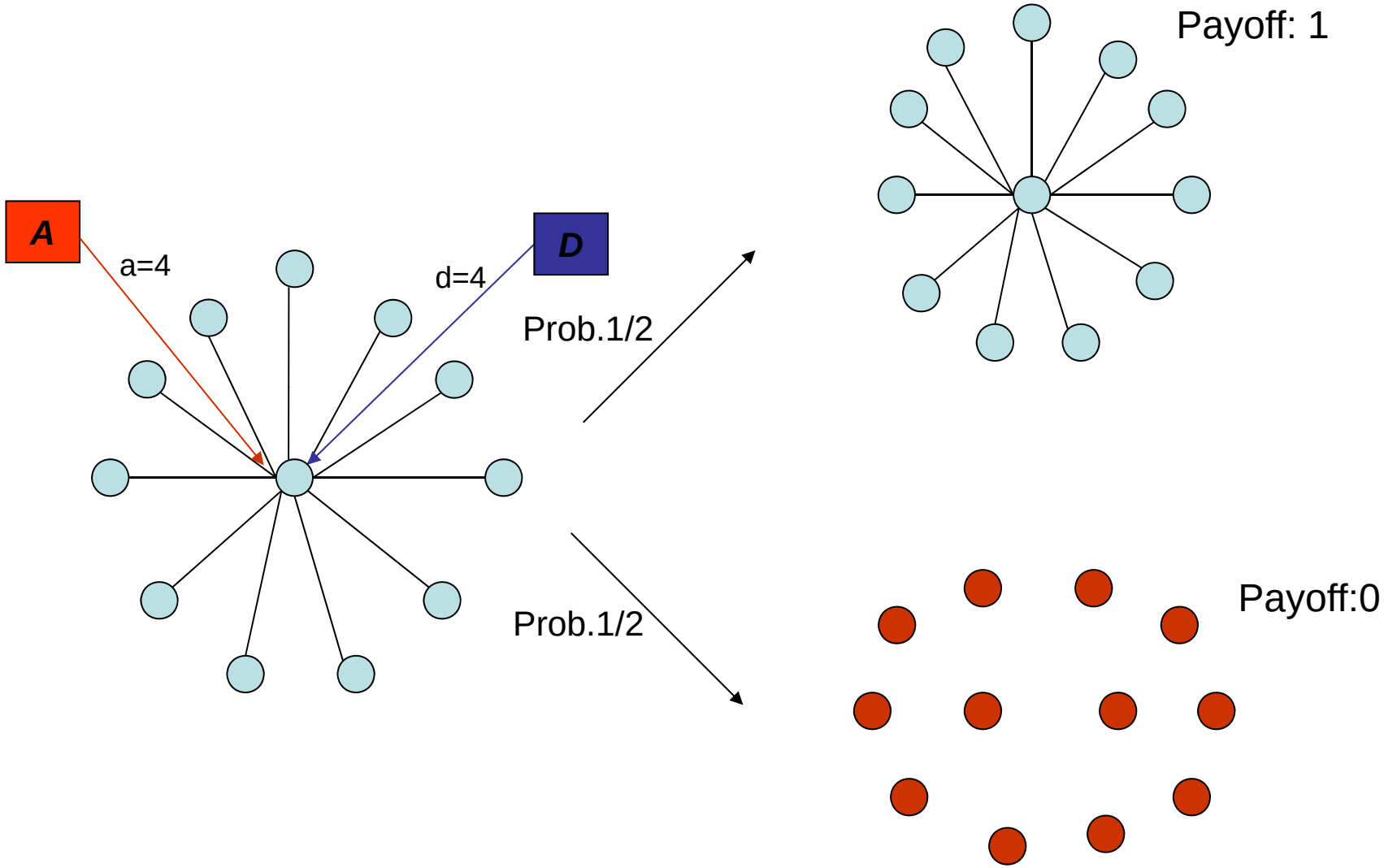
Robust networks

Defence, design and attack game

Theorem:

When defense and attack resources are small, relative to number of nodes, the star is robust. Designer and adversary allocate all resources to single hub node.

- Thus, designer prefers a network in which one successful attack disrupts entire network!


A
a=4
D
d=4
Prob.1/2
Prob.1/2
Payoff: 1
Payoff:0

Security and self-organizing networks

How do agents choose security and connections?

-- Study the effects of strategic adversary on security: competition to avoid strategic adversary leads to excessive investment in security.

-- On-going work explores formation of networks and choice of security.

Adaptation and evolution

Empirical studies

How do shocks diffuse in networks and how does structure adapt?

- Goyal, Moraga and van der Leij (2006, *JPE*), focus on effects of information technology on co-author network.

  -- *identified changing and stable features of large network*.

- In on-going research, we study how movie actor network adapts to the onset of AIDS.

Research Collaborators

- Cambridge Econ: Marcin Dziubinski, Edoardo Gallo, Oliver Baetz
  James Rutt, Bryony Reich
- Essex University: Andrea Galeotti, Christian Ghiglino
- Microsoft Research: Yoram Bachrach, Peter Key
- Imperial College： Moez Draeif
- Univ. of Pennsylvania: Michael Kearns
- University of Bilbao: Jaromir Kovarik
- University of Toulouse: Roberta Dessi