Course Introduction and Overview

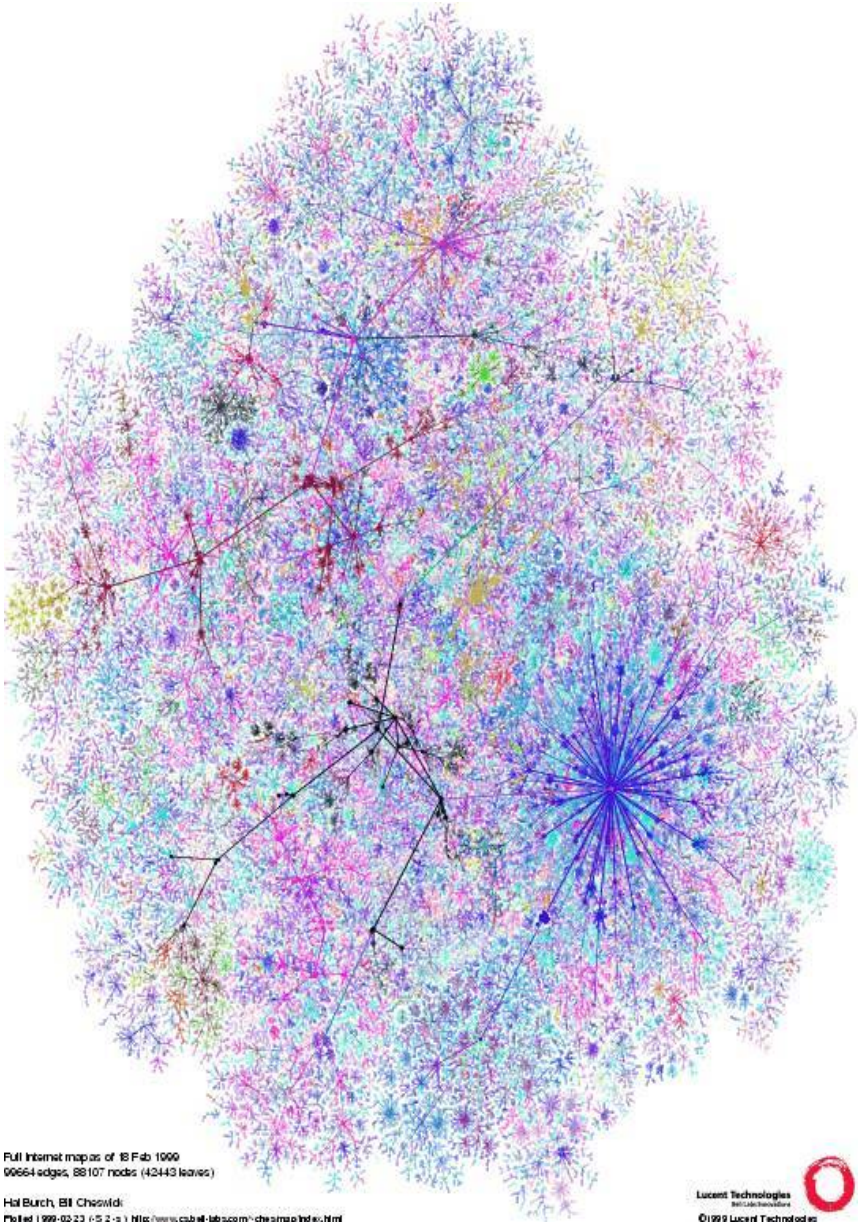
Networked Life
Networked and Social Systems Engineering (NETS) 112
Fall 2016
Prof. Michael Kearns

A Little Experiment

An Artificial Social Network

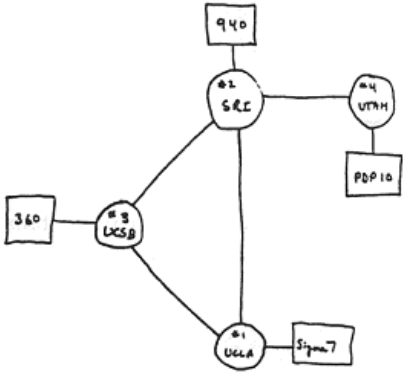
- Consider yourself "connected" to everyone in this room who:
  - Was born within a few hundred miles of the city or town you were born in
  - *Or* shares one of your favorite hobbies/interests/activities
  - Network is the aggregate of all these pairwise connections
- Some observations
  - Network is artificial, yet not unrelated to reality --- you really might meet people due to proximity or shared interests
  - Network definition has "knobs" or "parameters" we can fiddle with
    - Radius around your birthplace, strength of interest
    - But might expect certain qualitative properties to remain invariant (NYC density)
- Seems hard to guess at global structure
  - Might be quite complicated
  - None of us has a bird's eye view
- Let's experiment with *navigation* or *search* in this network
  - Communal goal: route a "message" from one part of the network to another
  - Try to do it in as few "hops" as possible
  - The Catch: everyone has only *local information* about the network
- Existence of short paths (structure) vs. finding them (algorithm)
- What happens when we go from 100 to 100 million to 7 billion?

Networks
(Social and Otherwise)



Internet, Router Level

- "Points" are physical machines
- "Links" are physical wires
- Interaction is electronic
- A purely technological network?

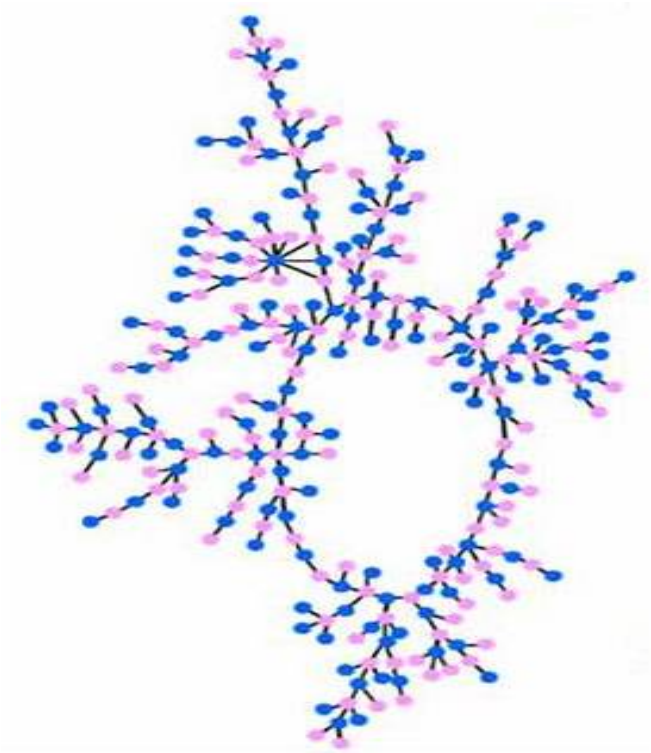


THE ARPA NETWORK

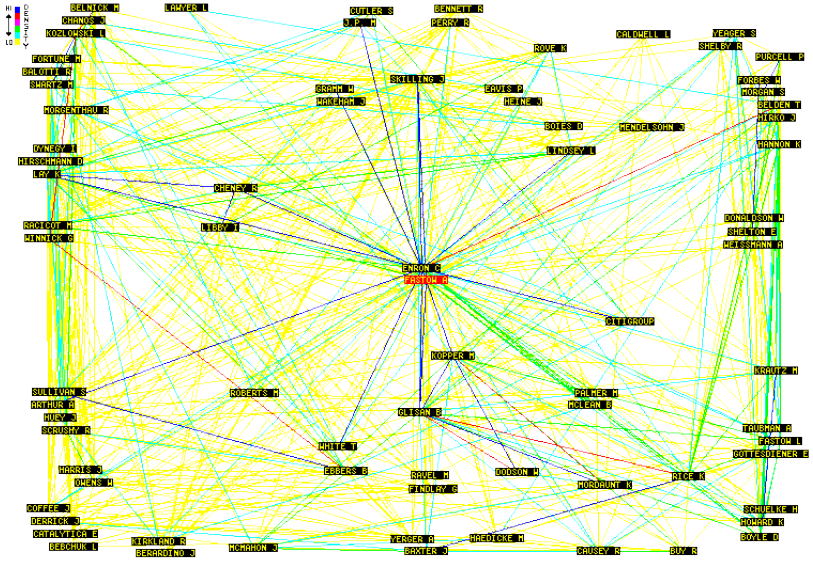
DEC 1969

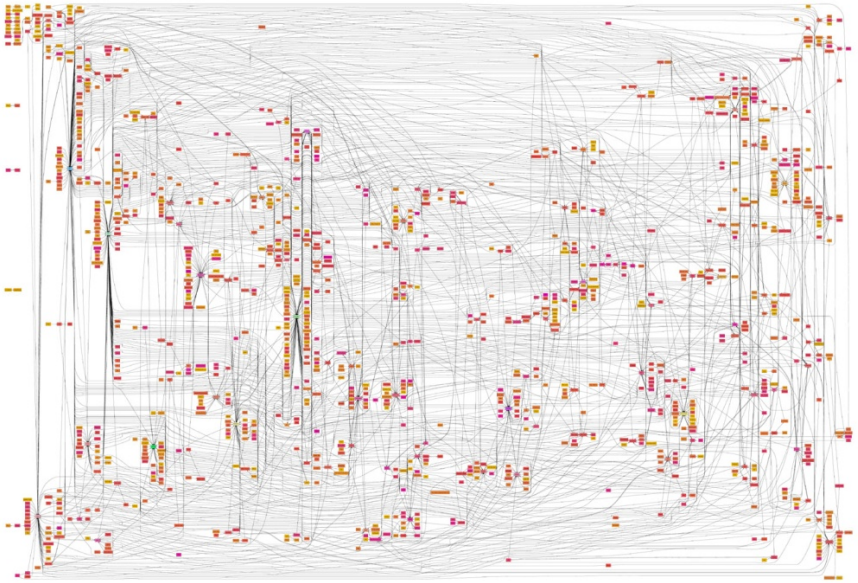
4 NODES

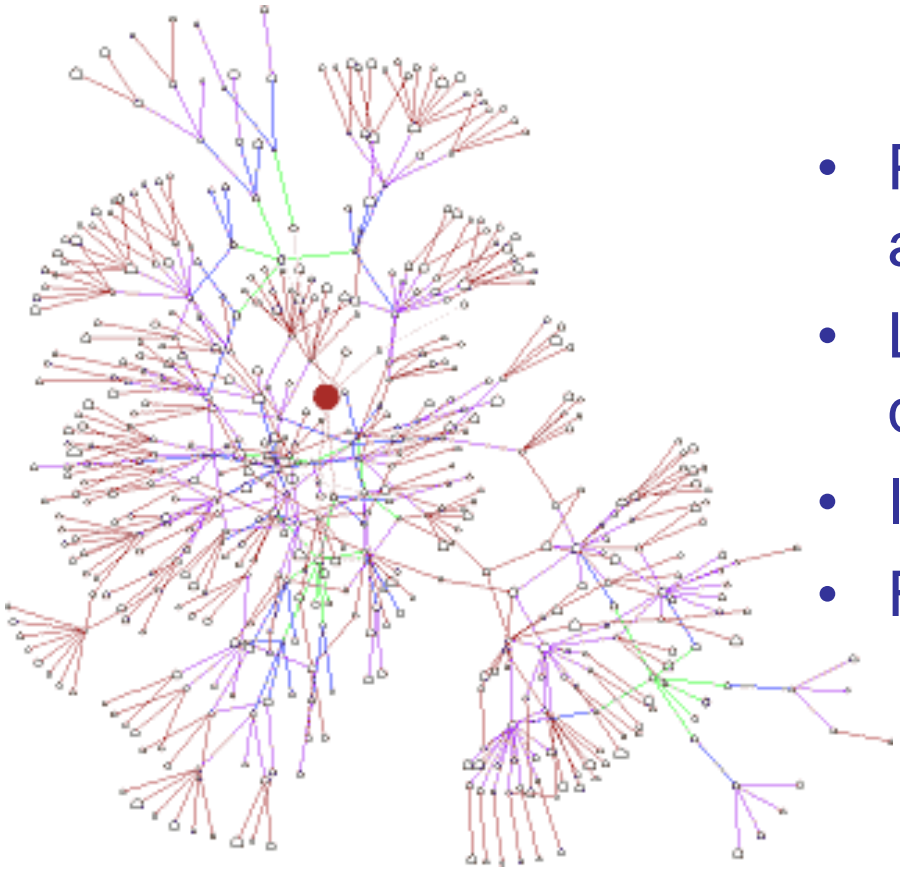
FIGURE 6.2 Drawing of 4 Node Network
(Courtesy of Alex McKenzie)



- Points are *people*
- Links are *social*
- Interactions: relationships, professional, virtual…
- How and why does *structure* form?



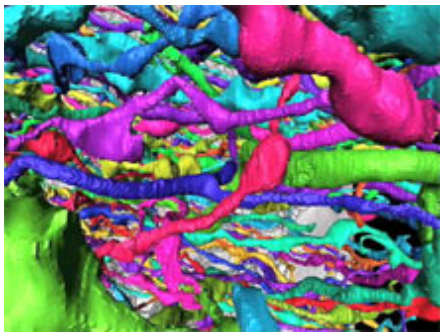


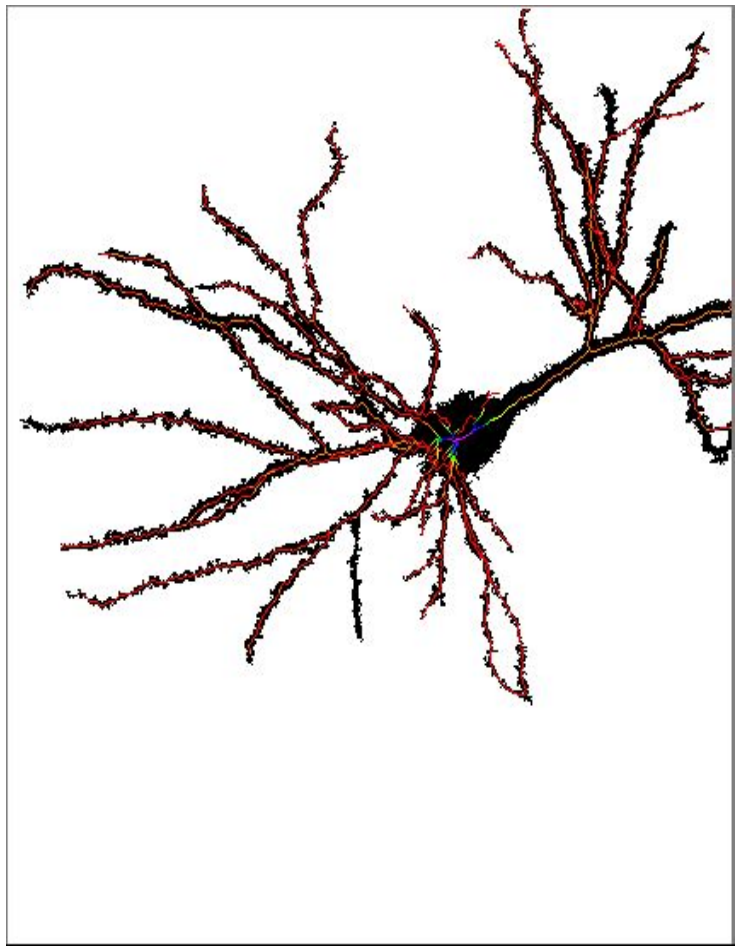


Gnutella Peers

- Points are machines… but are associated with *people*
- Links are physical… but may depend on *human preferences*
- Interaction: content exchange
- Food for thought: free riding

- Points are neurons
- Links are axons
- Interaction is electrical, but…
- New field: “Connectomics”
- Food for thought:
  - Do neurons *cooperate* or *compete?*





The Human Brain

The Premise of Networked Life

- *It makes sense to study these diverse networks together.*

- Commonalities:
  - Formation (distributed, bottom-up, “organic”,…)
  - Structure (individuals, groups, overall connectivity, robustness…)
  - Decentralization (control, administration, protection,…)
  - Strategic Behavior (economic, competition, free riding,…)
- An Emerging Science:
  - Examining apparent similarities (and differences) between many *social, economic, biological and technological* networked systems & organizations
  - Importance of *network effects* in such systems
    - How things are *connected* matters greatly
    - Details of *interaction* matter greatly
    - The metaphor of *contagion* in networks
    - Dynamics of *economic and strategic* interaction
  - Quantitative and qualitative; experimental and theoretical
  - Enabled by the revolution of instrumentation and measurement

Who's Doing All This?

- Computer Scientists
  - Understand and design complex, distributed networks
  - View "competitive" decentralized systems as economies
- Social Scientists, Behavioral Psychologists, Economists
  - Understand human behavior in "simple" settings
  - Revised views of economic rationality in humans
  - Theories and measurement of social networks
- Biologists
  - Neural networks, gene regulatory networks,…
- Physicists and Mathematicians
  - Interest and methods in complex systems
  - Theories of macroscopic behavior (phase transitions)
- Communities are *interacting* and *collaborating*

Course Mission

- A *network-centric* examination of a wide range of social, technological, biological, financial and political systems
- Examined via the tools and metaphors of:
  - computer science
  - economics and finance
  - psychology and sociology
  - biology
  - mathematics and physics
- Emphasize the common themes
- Develop a new way of examining the world

A Communal Experiment

- Few similar undergraduate courses
  - (e.g. Cornell)
- No formal technical prerequisites
  - greatly aided by recent books
  - publications in Science, Nature, popular press etc.
  - class demographics:
    - majors: cog sci, communications, linguistics, history, econ, finance, psych,…
    - freshmen through graduate students
- Extensive web visualizations and demos
- Participatory in-class and out-of-class social experiments
- Course was initial inspiration and basis for the Networked and Social Systems Engineering (NETS) program

Course Outline

What is a Network?

- Networks as a collection of pairwise relationships
- Measures: degree, diameter, clustering, centrality, expansion…
- Examples of (un)familiar and important types of networks
  - social networks
  - content networks
  - technological networks
  - biological networks
  - economic networks
- What makes a network *interesting?*
- The distinction between *structure* and *dynamics*

Contagion and Tipping in Networks

- The dynamics of *transmission*
- Viral spread and epidemic as metaphor
- Amplification of the incremental
- Connectors, hubs, and small worlds
- Travers and Milgram's famous experiment
- *Loosely* based on Gladwell's "The Tipping Point"

Network Structure

- "Universal" structural properties of networks
  - small diameter
  - clustering
  - mixtures of local and long-distance connectivity
  - heavy-tailed distributions
- Models of network formation
  - random graph models
  - preferential attachment
  - small-world models
  - affiliation networks
  - all will be stochastic or randomized… for now
- Loosely based on Watts' "Six Degrees"

The Web as Network

- Empirical structure of the web
  - connected components and directionality
  - diameter
  - robustness measures
- Web and blog communities
- Web search:
  - hubs and authorities
  - the PageRank algorithm and organic search
  - gaming Google and the SEO industry
  - later: sponsored search
- Web trust and network structure

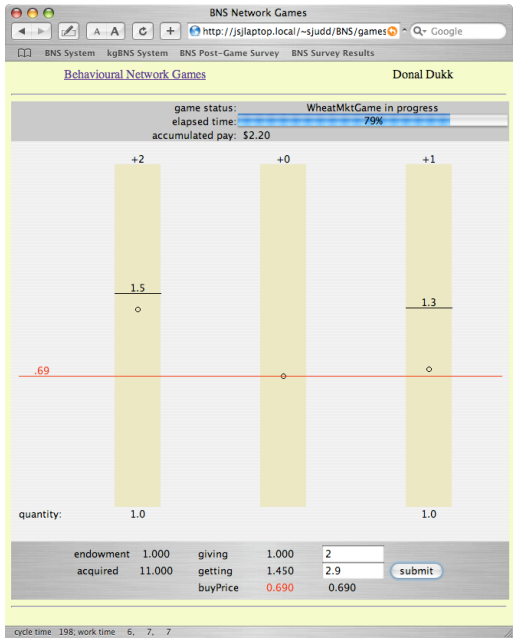
Towards Rational Dynamics

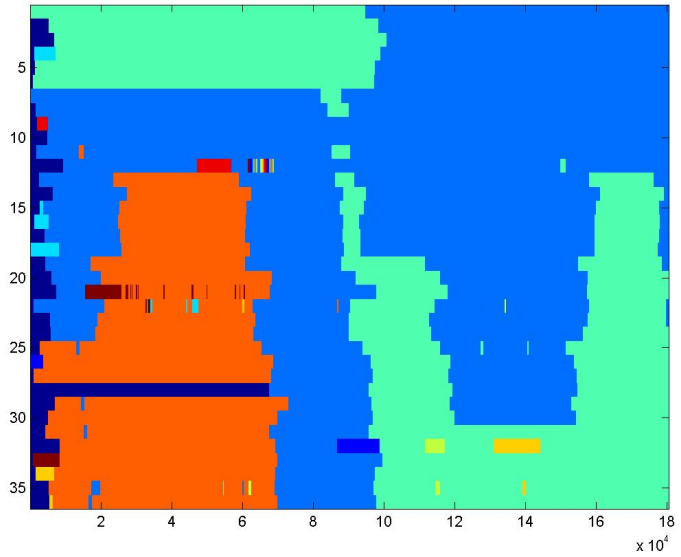
- Moving beyond the dynamics of contagion
- Dynamics of self-interest and optimization
- Introduction to equilibrium concepts
- Emergence of the global from the local
- The wisdom/madness of crowds:
  - thresholds and cascades
  - mathematical models of tipping
  - the market for lemons
  - private preferences and global segregation
- Loosely based on Schelling's "Micromotives and Macrobehavior"

Game Theory and Networks

- The mathematical language of strategic and economic behavior
- Notions of equilibrium
  - Nash, correlated, cooperative, market, bargaining
- Multi-player games and markets
- Evolutionary game theory
  - mimicking vs. optimizing
- Games and markets on networks
- How does network structure influence strategic behavior?
- Behavioral game theory and human subject studies
  - classic example: the Ultimatum game

Behavioral Experiments in Social Networks





- Analyses of recent years' experiments…
- … and hopefully some new ones of your own.

Strategic Network Formation

- Network Science: stochastic models of formation
- But networks form for a reason…
- Examine game-theoretic formation:
  - players must purchase the edges…
  - …but accrue “participation benefits”

Sponsored Web Search

- Web as Network: PageRank and “organic” search
- Sponsored search: formal markets in search phrases
- Mechanism design and auctions
- Competitive landscape (GOOG vs. MSFT vs. YHOO vs…)
- Equilibrium studies
- The economics of sponsored search
- SEO vs. SEM

Internet Economics

- Internet basics
- Selfish routing and The Price of Anarchy
- Peer-to-peer as competitive economy
- Paris Metro Pricing for QoS
- Economic views of network security and spam

Course Mechanics

- Will make heavy use of course web page:
  - www.cis.upenn.edu/~mkearns/teaching/NetworkedLife
  - You will need good Internet access!
- *No technical prerequisites!!!*
- Lectures:
  - slides provided; emphasis on concepts
  - frequent demos, visualizations, and in-class experiments
  - please be on time to lectures! (10:30)
- *No recitations*
- Readings: mixture of general audience writings and articles from the scientific literature
- Three texts:
  - "The Tipping Point", Gladwell (recommended)
  - "Six Degrees", Watts (required)
  - "Micromotives and Macrobehavior", Schelling (required)
- Assignments (~1/3 of grade)
  - occasional in-class quizzes
  - computer/web exercises, short essays, quantitative problems
  - collaboration is *not* permitted
- Midterm (~1/3 of grade)
- Final exam (~1/3 of grade)
- Possible we'll throw in a project/paper assignment

First Assignment

- Due *next lecture* (Thursday 9/1)
  - Simple background questionnaire
  - Last-names exercise