Course Introduction and Overview

Networked Life
Networked and Social Systems Engineering (NETS) 112
Fall 2018
Prof. Michael Kearns

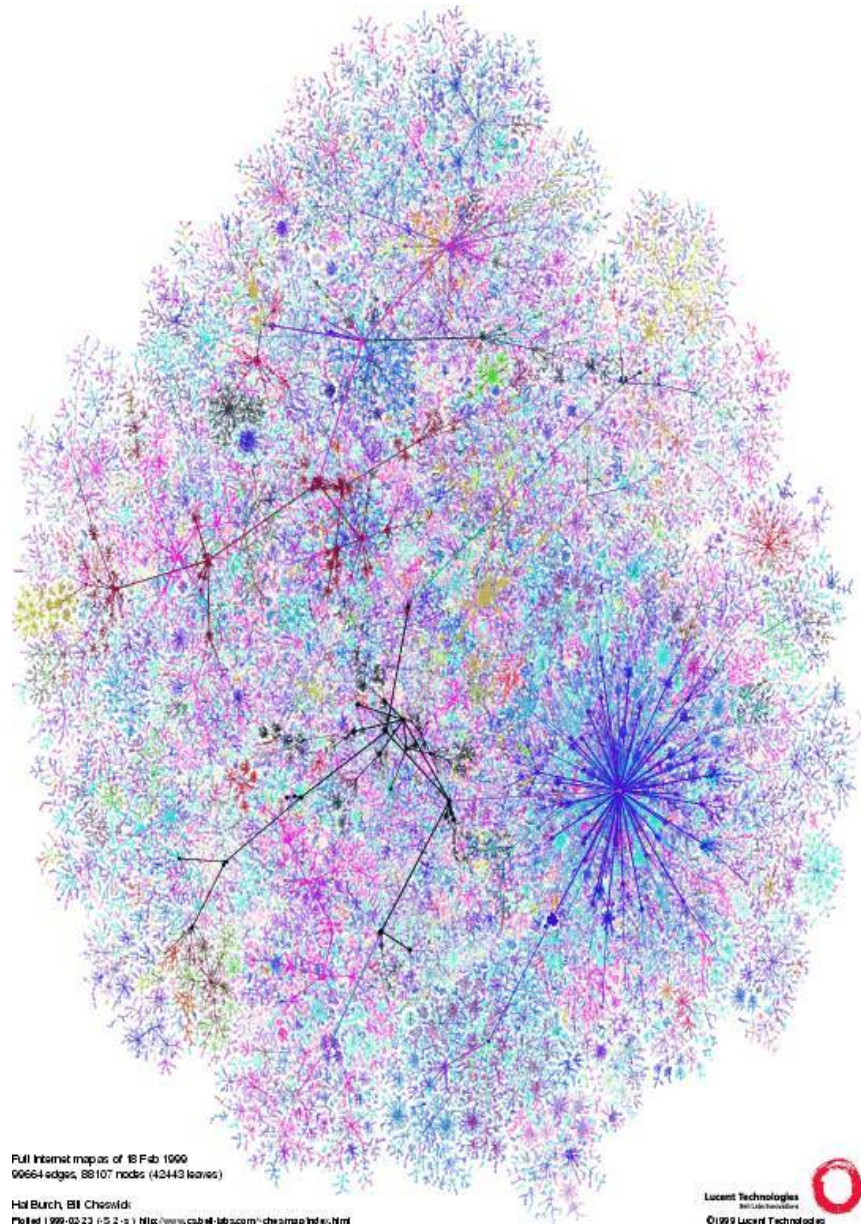# A Little Communal Experiment

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)

Full internet maps of 18 Feb 1999
99664 edges, 88107 nodes (42443 leaves)

Hal Burch, Bill Cheswick
Plotted 1999-03-23 (v5 2-s) http://www.cs.bell-labs.com/~ches/map/index.html

©1999 Lucent Technologies

Internet, Router Level

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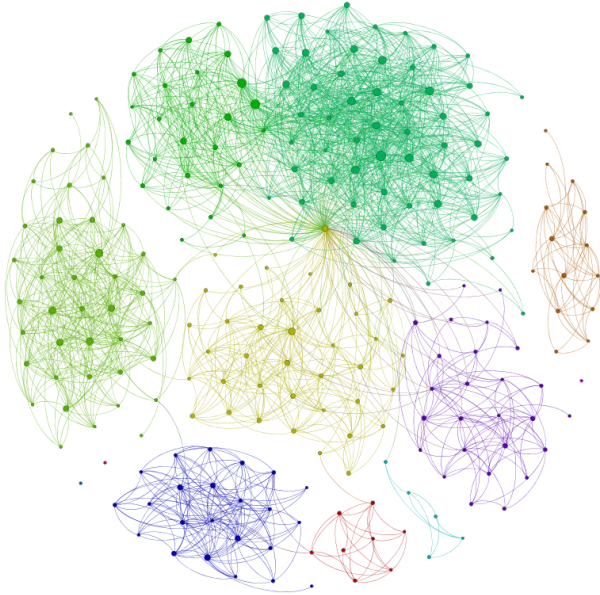- A purely technological network?
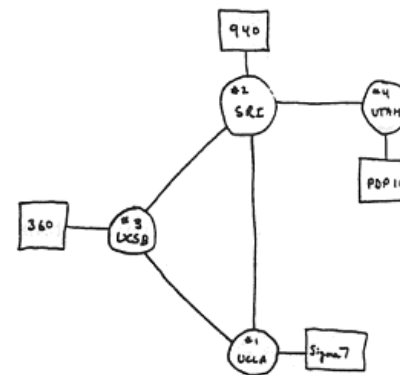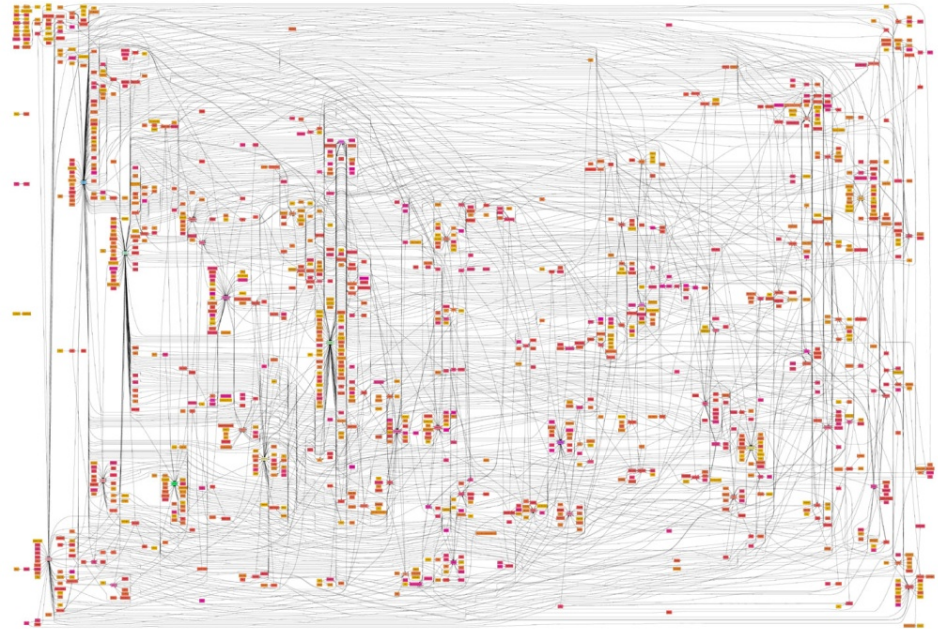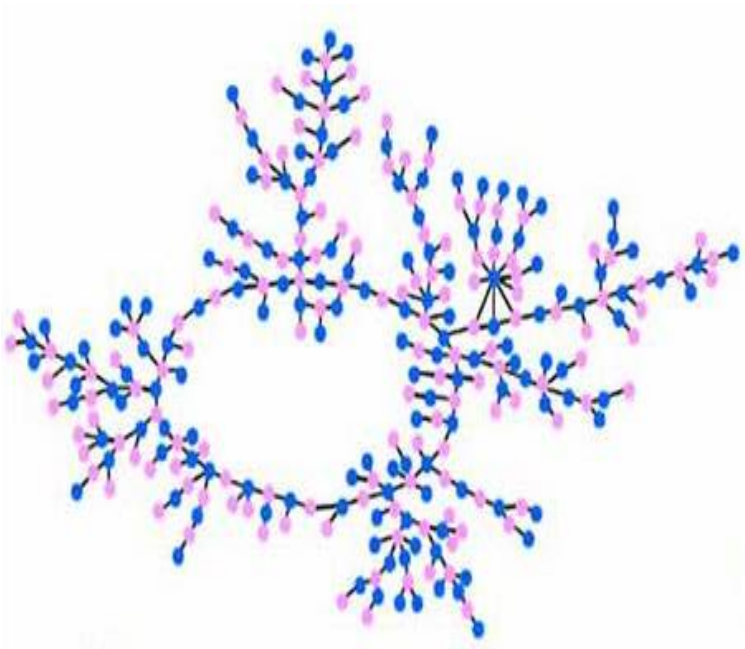

THE ARPA NETWORK

DEC 1969

4 NODES

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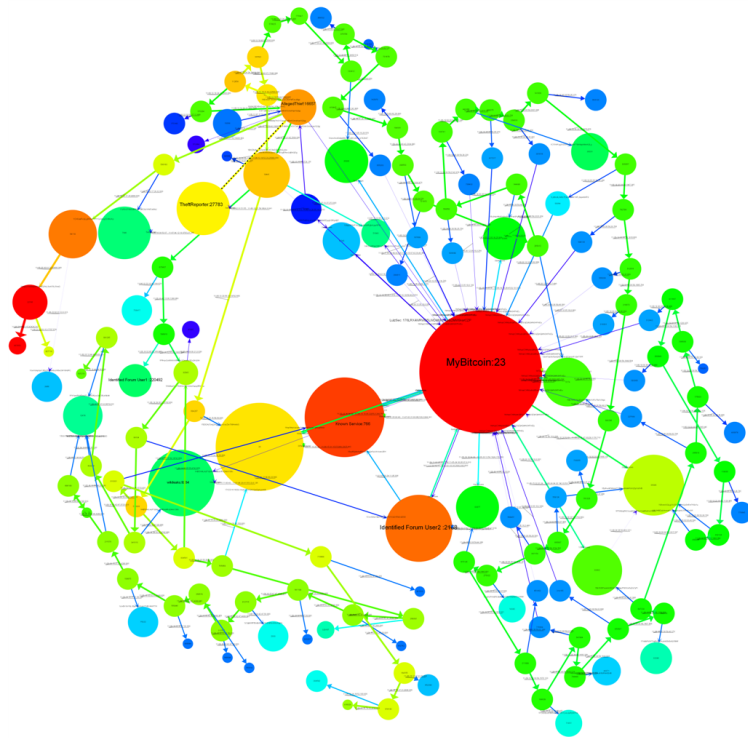(Courtesy of Alex McKenzie)

- Points are *people*

- Links are *social*

- Interactions: relationships, professional, virtual…

- How and why does *structure* form?

Bitcoin Exchanges
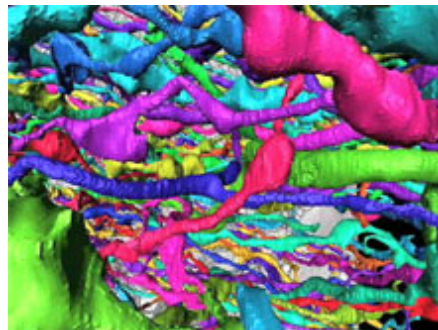
- Points are machines or accounts… but are associated with *people*
- Links are physical or virtual… but may depend on *human preferences*
- Interaction: content exchange
- Food for thought: <u>free riding</u>

- Points are neurons

- Links are axons

- Interaction is electrical, but…

- New field: "Connectomics"

- Food for thought:
  – Do neurons *cooperate* or *compete?*
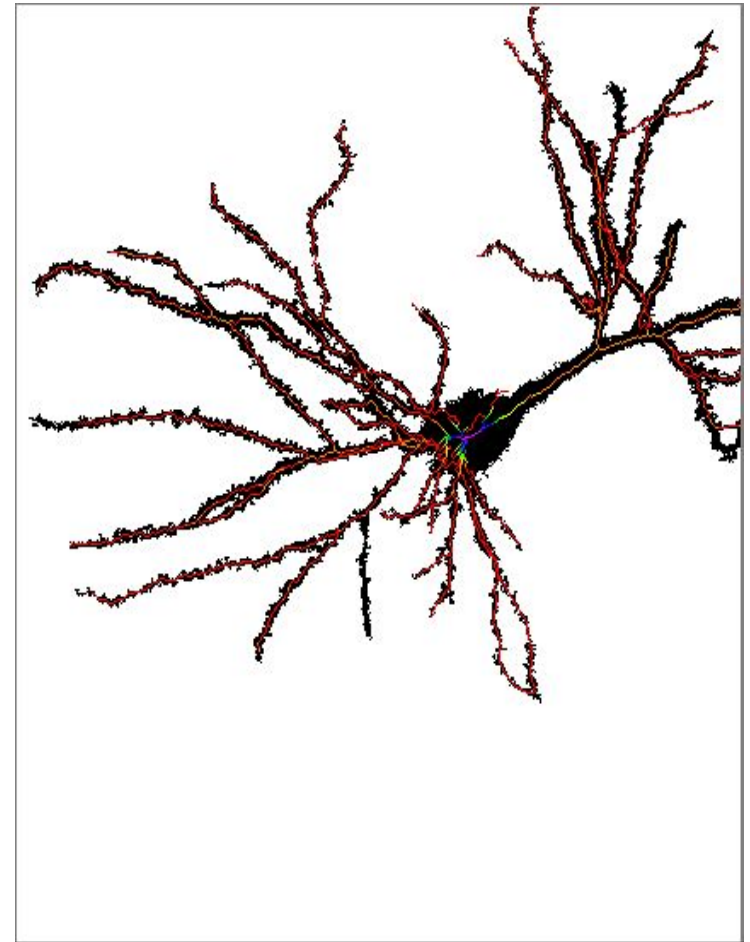
The Human Brain

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*

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
- Loosely accompanied by Watts' "Six Degrees"

Contagion and Tipping in Networks

- The dynamics of *transmission*
- Viral spread and epidemic as metaphor
- Amplification of the incremental: "sudden" contagion
- Relationship to structure

Search and Navigation in Networks

- How do we "find" each other in a large network?
- Travers and Milgram's famous experiment
- Modern variants and models
- Relationship to 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
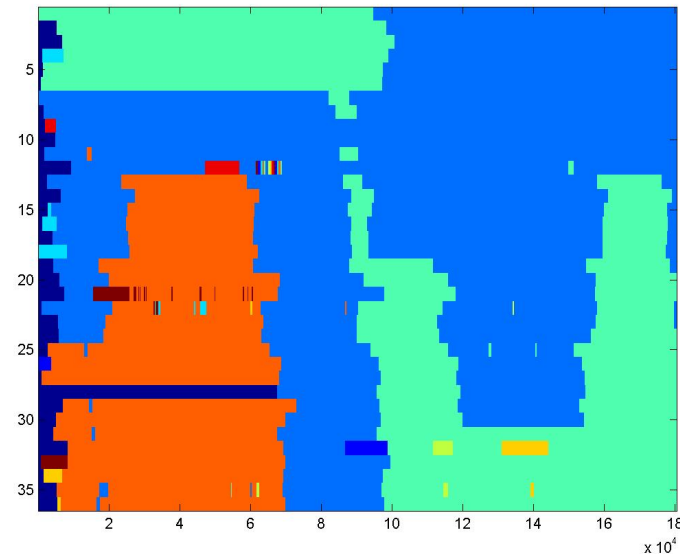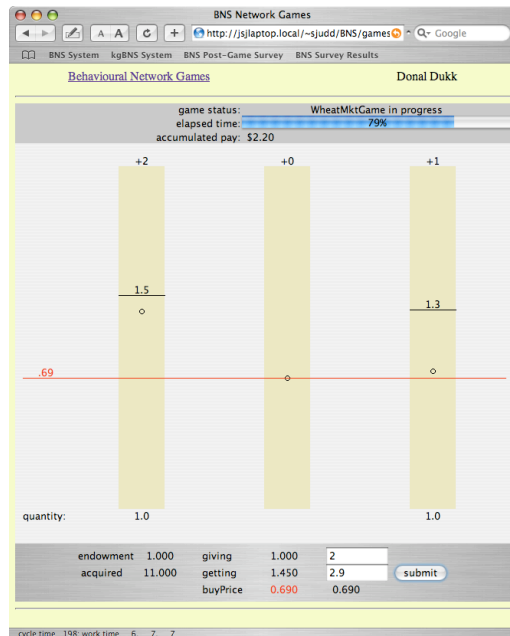
– Analyses of recent years' experiments…
– … and maybe some new ones of our own.

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"

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
- Sponsored search and Internet advertising

Networks and Algorithms vs. Social Norms

- New for 2017! (and 2018)
- "Big data", machine learning, models and algos…
- Privacy, fairness, transparency, accountability, morality…
- Accompanied by Schneier's "Data and Goliath" and O'Neil's "Weapons of Math Destruction"

Course Mechanics

- Will make heavy use of course web page:
  - www.cis.upenn.edu/~mkearns/teaching/NetworkedLife
- *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
- Five required texts:
  - "Six Degrees", Watts
  - "Micromotives and Macrobehavior", Schelling
  - "Data and Goliath", Schneier
  - "Weapons of Math Destruction", O'Neil
  - "The Ethical Algorithm", Kearns/Roth
- 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/experiment//paper assignment

First Assignment

- Due *next lecture* (Thursday 8/30)
    - Simple background questionnaire
    - Last-names exercise