

Course Introduction and Overview

Networked Life

Networked and Social Systems Engineering (NETS) 112

Fall 2019

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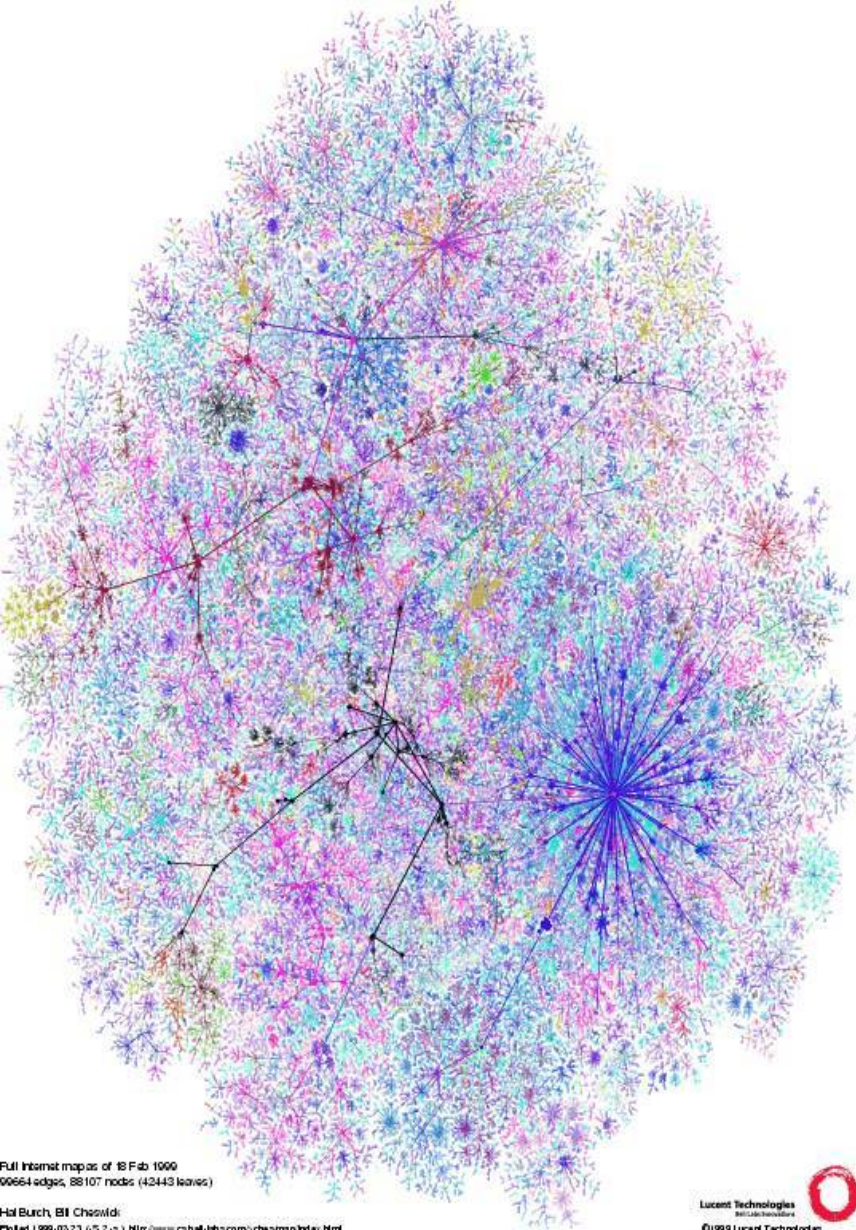
A Little Communal Experiment

An Artificial Social Network

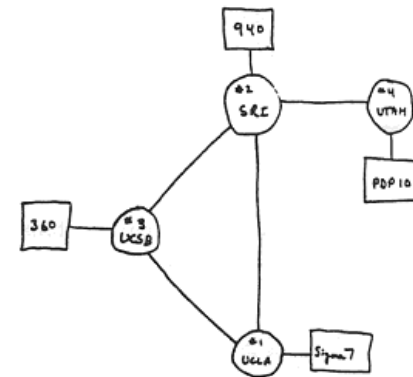
- Consider yourself “connected” to everyone in this room who:
 - Was born within a few hundred miles of the city or town you were born in
 - *Or* shares one of your favorite hobbies/interests/activities
 - Network is the aggregate of all these pairwise connections
- Some observations
 - Network is artificial, 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)



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



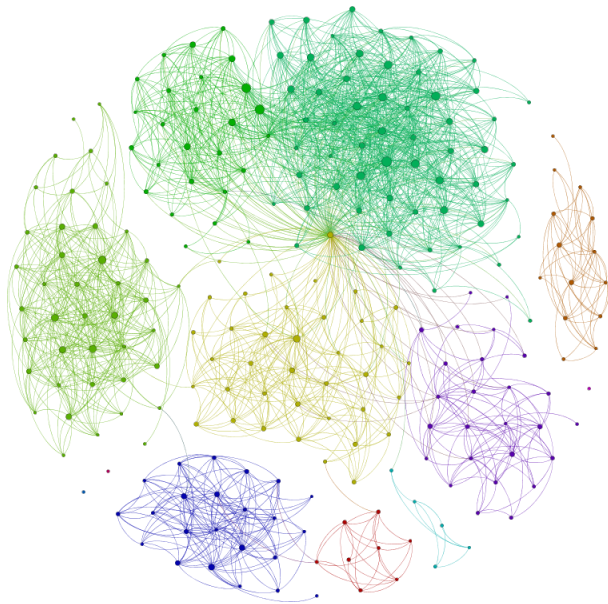
THE ARPA NETWORK

DEC 1969

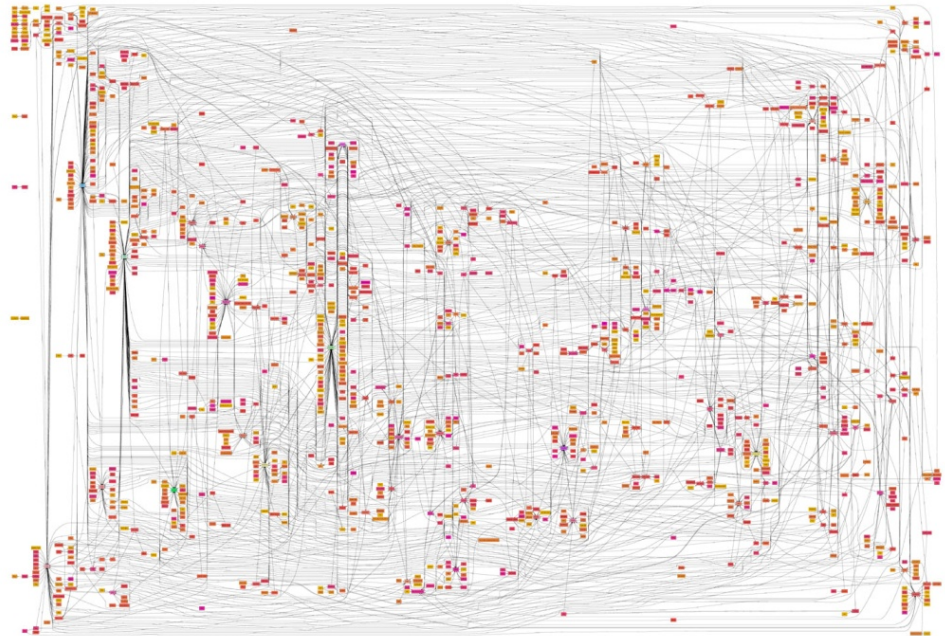
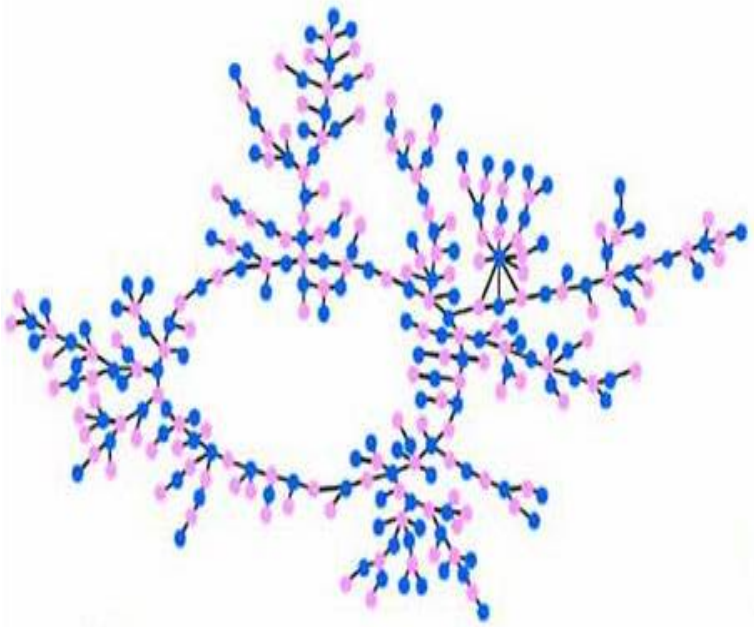
4 Nodes

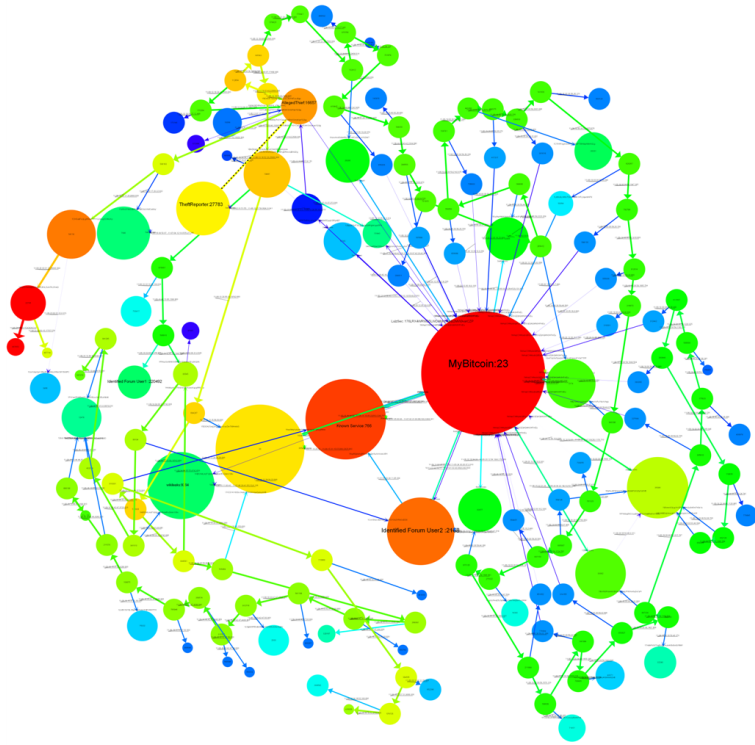
FIGURE 6.2 Drawing of 4 Node Network
 (Courtesy of Alex McKenzie)

Internet, Router Level



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

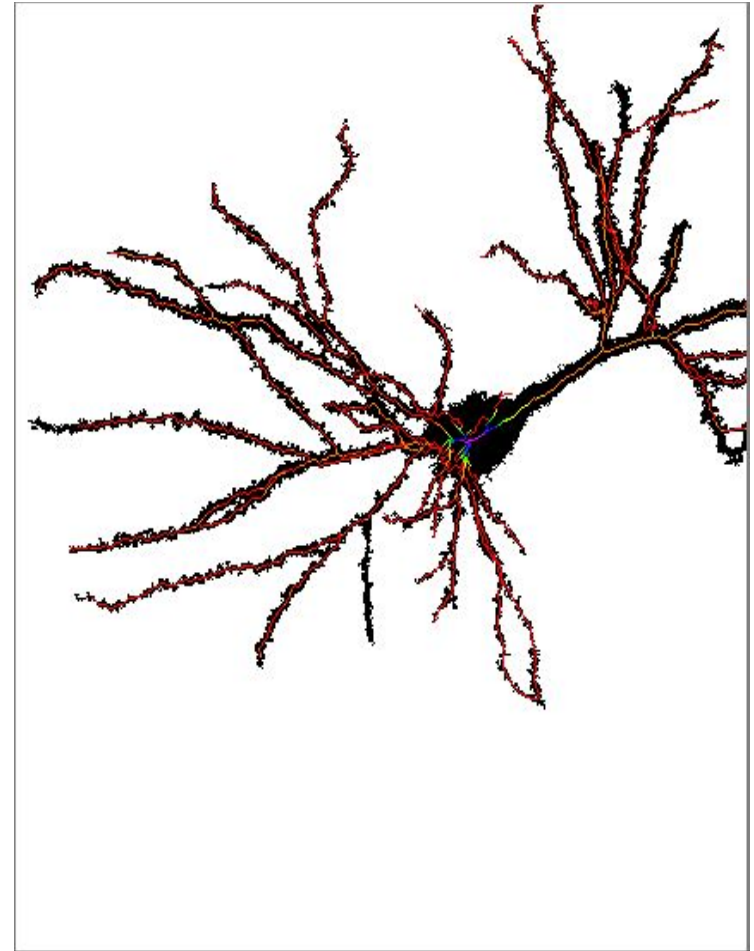
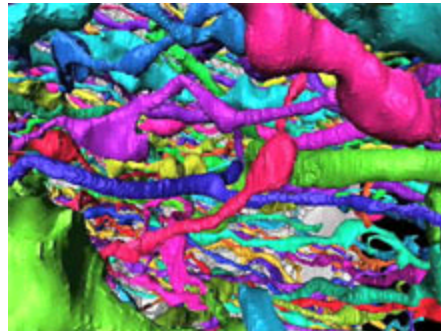




Bitcoin Exchanges

- 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: 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*

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

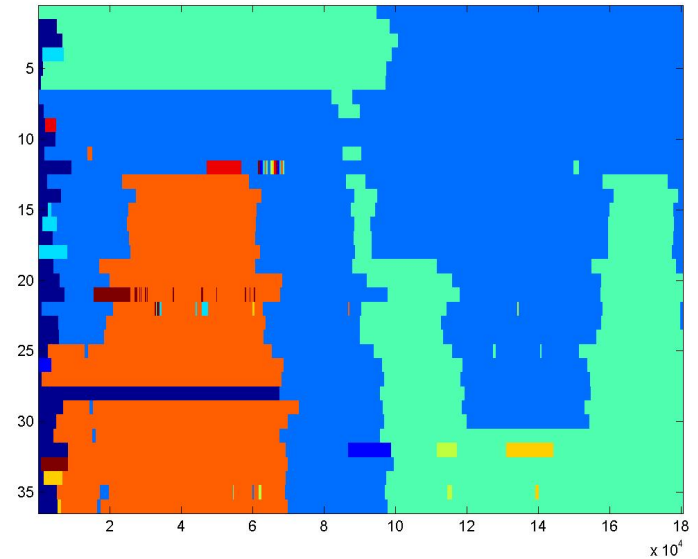
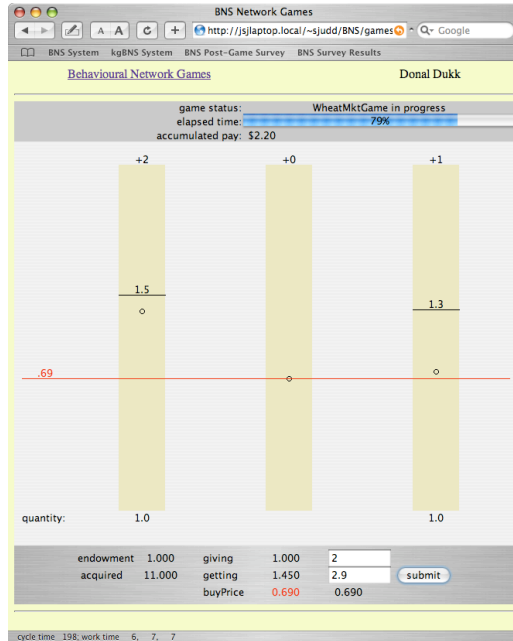
Towards Rational Dynamics

- 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

- A recent addition to the course
- Data science, machine learning, models and algos...
- Privacy, fairness, transparency, accountability, morality...
- Accompanied by O'Neil's "Weapons of Math Destruction", and MK and Aaron Roth's "The Ethical Algorithm"

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
- Four required texts:
 - “Six Degrees”, Watts
 - “Micromotives and Macrobehavior”, Schelling
 - “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 8/29)
 - Simple background questionnaire
 - Last-names exercise