In Search of *Homo Swappus* : Evolution of Cooperation in Peer-to-Peer Systems

John Chuang

School of Information Management and Systems
University of California at Berkeley
chuang@sims.berkeley.edu
http://p2pecon.berkeley.edu/

IEEE Conference on P2P Computing, September 2005

http://www.modernhumorist.com/

Exhibit A. *Homo Swappus*

http://www.modernhumorist.com/

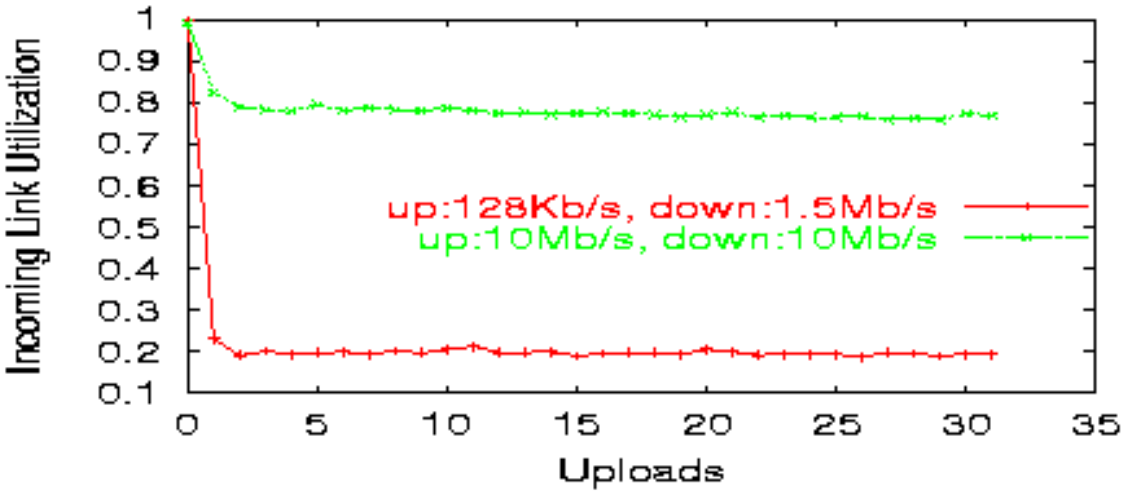
Exhibit B. *Homo Swappusnot* ?

Outline

- Evolution of cooperation: from murderous apes to P2P file-swappers
- The evolution continues: white-washers, roving vagabonds, liars and shirkers
- Beyond *homo economicus* : BitTorrent and rationality revisited

The P2P Dilemma

- P2P systems rely on grassroots contribution of resources
- Contributions can be costly
  - e.g., incoming link utilization degrades by 20-80% when simultaneously uploading due to TCP Data/Ack contention



[Feldman et al., 2003]

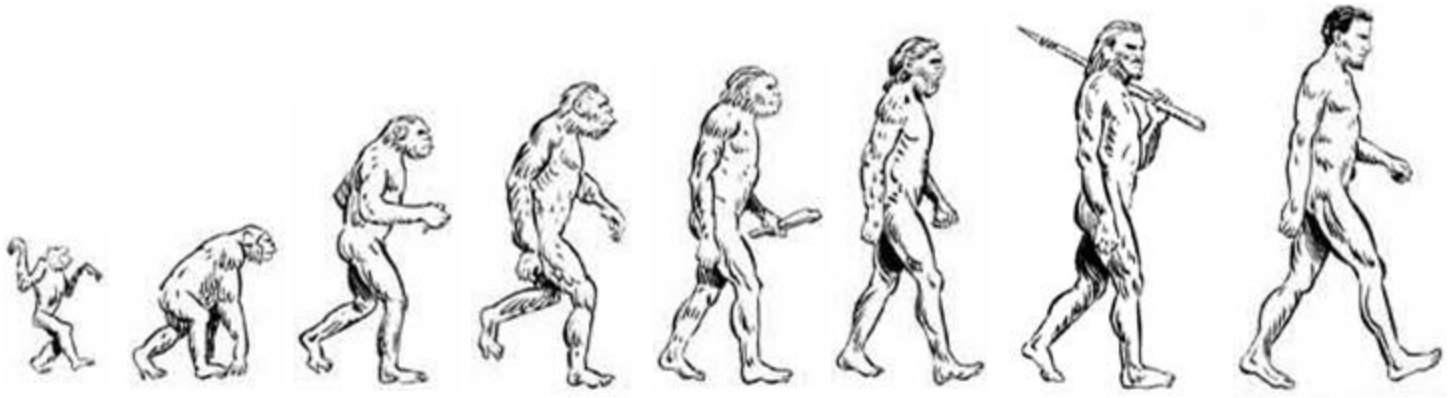
- Fundamental tension between individual rationality and collective welfare

The P2P Dilemma

- Rational users (a.k.a. *homo economicus*) choose to free-ride
  - Consume but not contribute
  - May lead to system collapse ("Tragedy of the Commons")

- How to encourage cooperation among strangers?
  - Challenges: large, dynamic groups with anonymity, hidden action, hidden information, and asymmetries of interest

Evolution of Human Cooperation

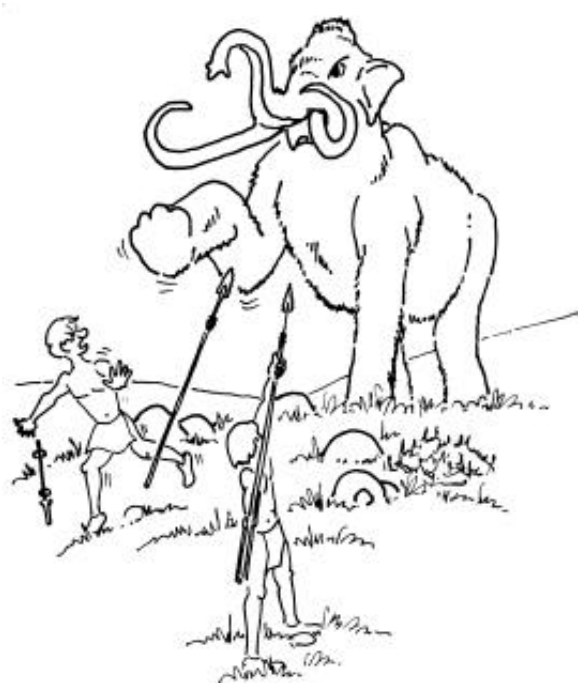


Adapted from: http://pharyngula.org/images/lay_evo_obesity.jpg

Kin selection: survival and propagation of genes

- Altruism towards genetic relatives
- Hostility, murder of non-related males

Evolution of Human Cooperation



Formation of hunter-gatherer groups beyond family ties:

- Economies of scale
- Specialization
- Risk management

⇨ Reciprocity

Evolution of Human Cooperation

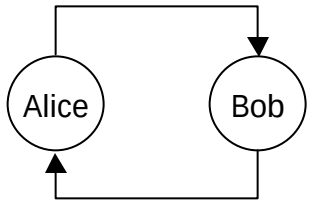
Reciprocity

Reputation and Trust

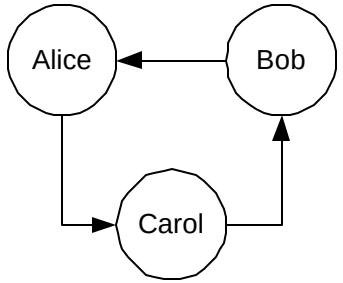
Money and Markets

Incentives for P2P Cooperation

- Barter
  - BitTorrent (tit-for-tat; direct reciprocity)
  - End System Multicast (taxation)



- Reputation (indirect reciprocity)
  - KaZaA, Eigentrust, CONFIDANT, ...
  - EBay: 3 billion feedback comments



- Currency
  - Tokens, stamps, claims, mojos, karma, nuglets, ...

Evolution of P2P Cooperation

1999 2000 2001 2002 2003 2004 2005

Hughes et al., Freeriding in Gnutella Revisited: The Bell Tolls? → 85% FR

Andrade et al., Influences on Cooperation in BitTorrent Communities (p2pecon'05) → 5-6% FR

Cohen, Incentives Build Robustness in BitTorrent (p2pecon'03)
"Give and ye shall receive!"

Golle et al., Incentives for Sharing in P2P networks

Adar and Huberman, Freeriding on Gnutella → 66% FR

Outline

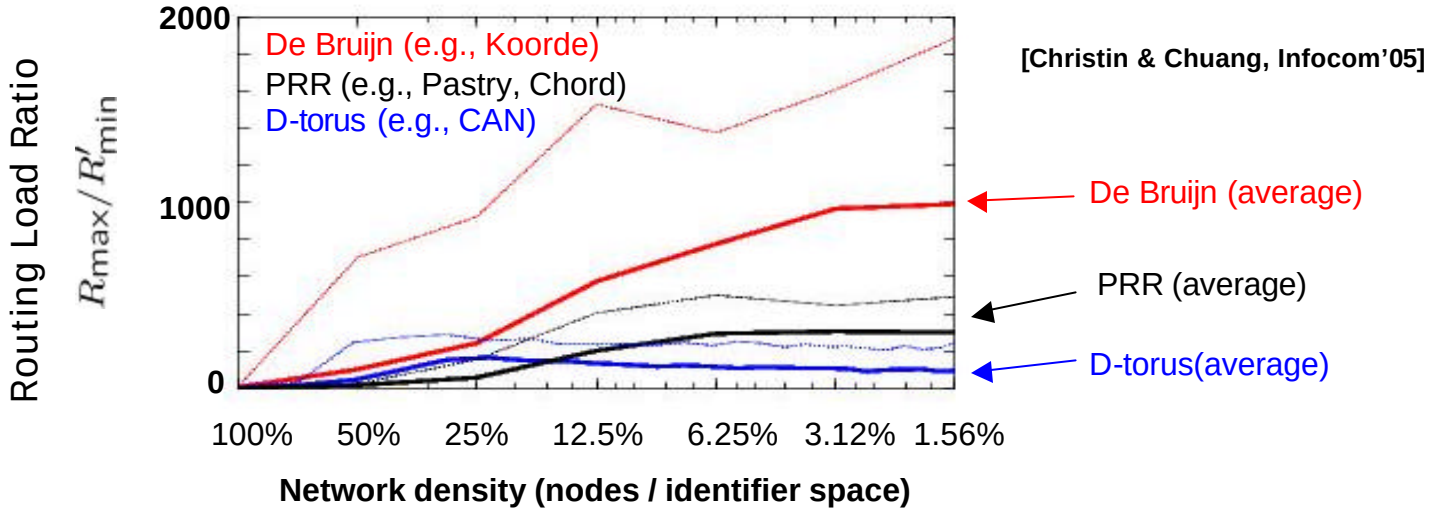
- Evolution of cooperation: from murderous apes to P2P file-swappers
- The evolution (arms-race?) continues: white-washers, roving vagabonds, liars and shirkers
- Beyond *homo economicus* : BitTorrent and rationality revisited

Whitewashers

- Cheap (or free) pseudonyms
  - Sybil attack, sock puppetry (collusion)
  - Whitewashing attack
- Whitewash: always defect, and continuously change identity
  - Whitewashers indistinguishable from legitimate newcomers
  - *Tit-for-tat (TFT)* no longer *evolutionary stable* in the presence of whitewashers [Feldman and Chuang, 2005]
    - TFT always cooperates with stranger
  - Reputation-based mechanisms circumvented
- Response 1: increase cost of acquiring new identities
- Response 2: punish all newcomers
  - Social cost of cheap pseudonyms (Friedman & Resnick, 1998)
  - Stranger-adaptive strategy (Feldman et al., 2004)

Roving Vagabonds

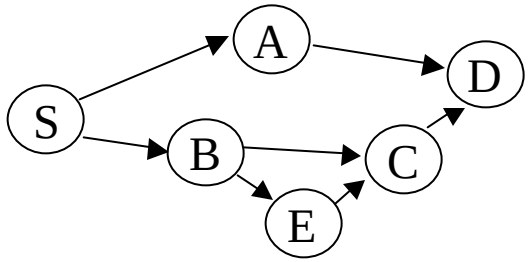
- Real Estate Lesson #1: Location! Location! Location!
- Structured DHT topologies: excluding object popularity, some locations route 100x to 1000x more traffic than others



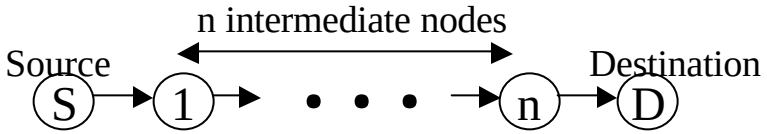
- Rational node response: strategic churning
  - repeatedly exit and re-enter P2P network in hopes of finding better location in the network

Liars and Shirkers

- Two types of information asymmetries:
- Hidden information
  - Players possess private information (e.g., transit costs in routing [Feigenbaum et al., 2003])



- Hidden action
  - Players' actions unobservable to others (e.g., multi-hop routing [Feldman et al., 2004])



- Mechanism design and agency theory
  - Use of incentives to induce truth revelation or good behavior
  - Recent advances (e.g., distributed algorithmic MD) considers algorithmic complexity and communications complexity of mechanisms

Outline

- Evolution of cooperation: from murderous apes to P2P file-swappers
- The evolution continues: white-washers, roving vagabonds, liars and shirkers
- Beyond *homo economicus* : BitTorrent and rationality revisited

BitTorrent Revisited

- Andrade et al. (p2pecon 2005) found free-riding as low as 5-6% in some BitTorrent communities (*etree* and *easytree*)
- Is the tit-for-tat mechanism in BitTorrent really responsible for reduced free-riding?
  - BitTorrent mechanism not strategy-proof
    - Shneidman et al. (PINS 2004) identify multiple "rational manipulation points"
    - Hales and Patarin (2005): subvert with multiple fake IDs
    - Jun and Ahamad (p2pecon 2005) show free-rider obtained same download completion time
- Andrade et al. also found 27-52% of peers (across four communities) act as seeders

Alternate Explanations?

- Near rationality (e.g., ε–equilibrium)
  - Switching cost: not costless to modify client code or default configuration
- Tribe formation and evolutionary group selection
  - Due to lack of meta-search capabilities [Hales & Patarin]
- MPAA hasn't filed any lawsuits yet
- Social norm: "When complete, keep your window open to contribute bandwidth"
  - *Contingent* cooperation: contribute only if prevailing contribution level is perceived to be high
- Modus operandi:
  - Initiate movie download before bedtime
  - Broadcatching: automatic download via RSS + regex

Beyond *Homo Economicus*
(Rationality Revisited)

- Altruism
  - Information gift economies
    - e.g., linux, creative commons, wikipedia, ...
  - Warm-glow (Andreoni, 1990)
  - "Digital Robin Hoods"
- Strong reciprocity
  - Reciprocate (reward cooperators and/or punish defectors) even if action reduces own utility
    - Ultimatum, Dictator, and Public Goods games: ~50-60% of subjects exhibit reciprocal behavior, ~20% exhibit selfish behavior
    - Considerations of fairness and social norms
- Even selfish individuals may not be *perfectly* selfish
  - bounded rationality or near rationality vs. hyper rationality
  - Imperfect knowledge; imperfect execution (e.g., trembling hand)

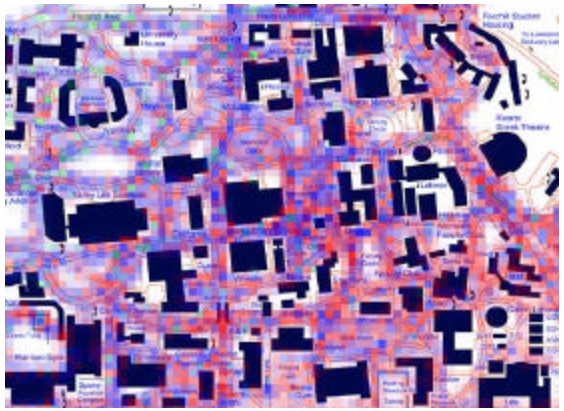
Implications/Open Questions

- How to design P2P systems when population is a mixture of altruists, reciprocators, and selfish rascals?
  - Now throw in faulty peers and malicious attackers
  - Now consider peers with imperfect information, and possibly *trembling hands*?
- May not need 100% cooperation, but how much is optimal or sufficient?
- Might explicit incentives *crowd out* voluntary good behavior?
  - e.g., incentives gone awry at Haifa daycare centers

In Search of *Homo Swappus*...

- P2P systems as virtual microcosm of physical world
  - Rational peers respond to incentives ...
  - ... but not all peers are rational
- P2P systems mediate interactions in/with physical world
  - E.g., P2P as underlay to “layer 8” social networks

http://fusion.sims.berkeley.edu/GarageCinema/images/MMM1.gif



http://www.wired.com/news/images/full/campus_strength_f.jpg

- *Homo swappus* → *homo sapiens* in a P2P world

Thank you!

John Chuang
School of Information Management and Systems
University of California at Berkeley
chuang@sims.berkeley.edu
http://p2pecon.berkeley.edu/

IEEE Conference on P2P Computing, September 2005