Incentives in Peer-to-Peer Systems

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Outline

What is Peer-to-Peer?

Peer-to-Peer (P2P) is a network architecture allowing network nodes (peers) to share resources (such as files) by making part of their resources available to other nodes.

- Each node is both a client and a server.
- Management can be cetralized or decentralized.
- Connection pattern may be structures (DHT) or unstructured (arbitrary connections).

Example of a Peer-to-Peer System

The Gnutella network introduced in March 2000.

Millions of individuals participated.

Six months later 2/3 users are free riding*.

* E.Adar and B.A. Huberman. Free Riding on Gnutella. *First Monday*, Oct. 2000.

Issues with P2P Systems

The Gnutella experience lead to push in incentive systems.
These systems try to address the following issues:

- Anonymous, on-time interactions.
- Free-riding (leeching) problem.
- Hidden actions (undetectable defections).

Incentives in P2P Systems

Possible incentive strategies proposed for P2P networks:

- Direct reciprocity
- Barter (BitTorrent)
- Reputation (KaZaA)
- Currency (MojoNation, Karma)

Attacks Against Reputation Systems

Possible strategies agaist incentive systems:

- Cybil attack (multiple personalities)
- Whitewashing attack (leech, flee, repeat)

P2P System as a PD Game

With one time interactions between strangers, there is no incentive to cooperate.

		Server: Cooperate	Server: Defect
Client	Cooperate	R_c / R_s	S_c / T_s
	Defect	T_c / S_s	P_c / P_s

Figure: GPD Payoff matrix

		Server: Provide Service	Server: Ignore Request
Client	Request Service	7 / -1	0 / 0
	Don't Request	0 / 0	0 / 0

Figure: Payoff matrix used in experiments

Payoff matrix for Generalized Prisoner's Dilemma:

- R - reward
- T - temptation
- P - punishment
- S - sucker

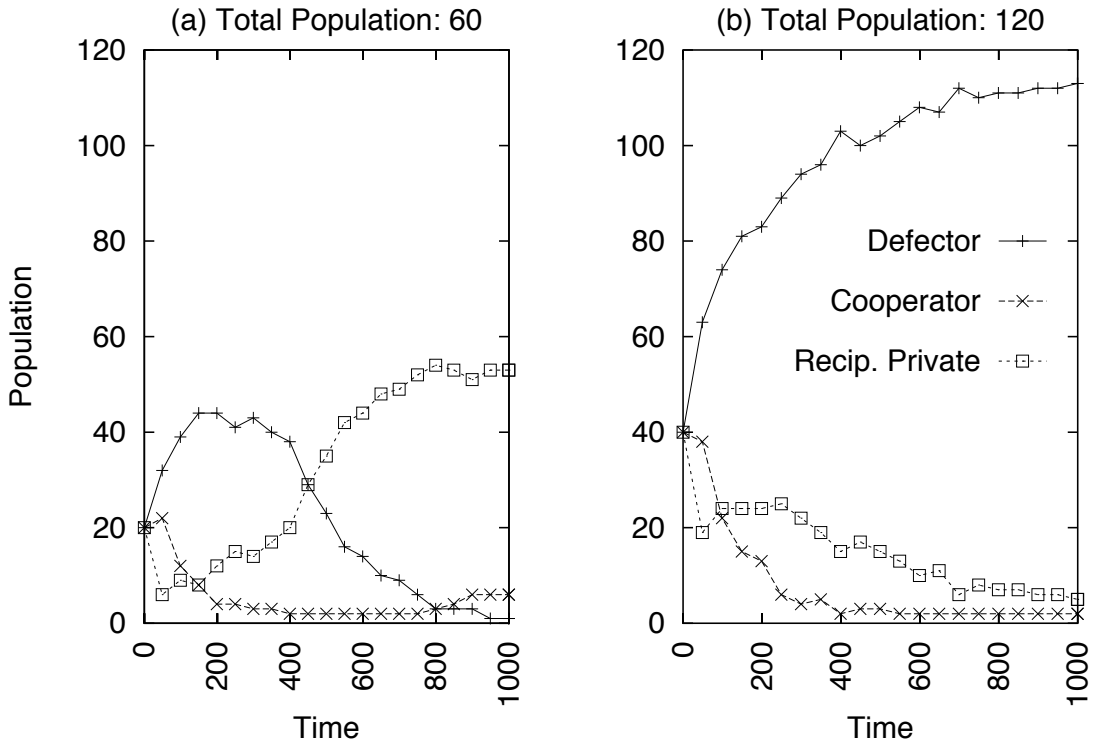
Payoffs are asymmetric.

Iterated game

- Game is conducted in rounds.
- Players use one of the strategies:
  - Cooperate
  - Defect
  - Reciprocate
- At the end of the round:
  - Mutate - random switch
  - Learn - compute utility of each strategy
  - Turnover - leave the game
  - Stay the same
- Use a *Reciprocative* decision

Mitigation Via Direct Reciprocity

If there are enough peers, interaction tend to one-shot PD games. Free riding becomes dominant*.



* Feldman et al. Robust incentive techniques for peer-to-peer networks. Proceedings of the 5th ACM conference on Electronic commerce (2004) pp. 102-111

Another Model of a P2P system *

Given a population of rational peers,

- Peer *i* has "generosity" (willingness to contribute) θ_i
- There are *x* peers contributing at any time.
- The contribution cost is $1/x$.

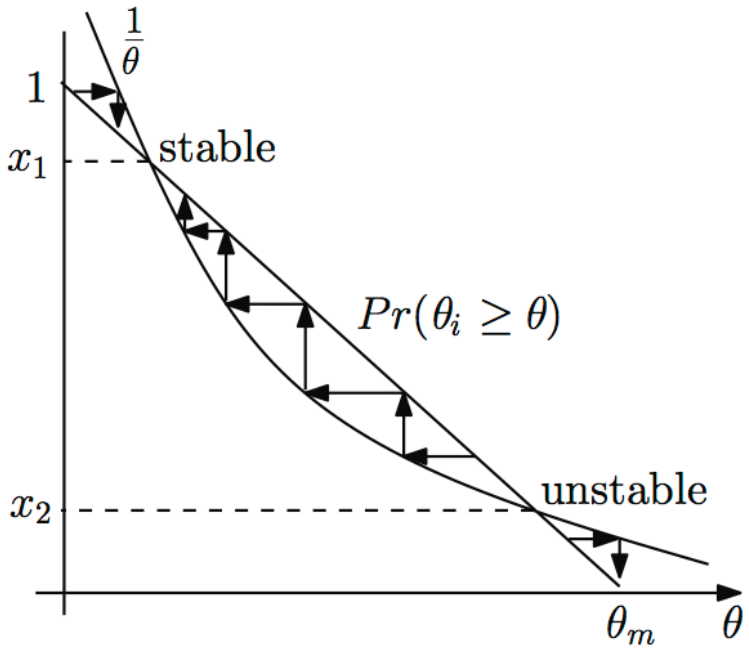
The rational peer in this "free market" will:

- Contribute, if $\theta_i > 1/x$;
- Free-ride, otherwise.

* Feldman et al. Free-riding and whitewashing in peer-to-peer systems. IEEE journal on selected areas in communications (2006) vol. 24 (5) pp. 1010-1019

Equilibria in Free Market Model

The equilibria are observed from the intersection of the type distribution with curve $1/\theta$.
Assuming uniform generosity distribution:



There are three equilibria.

Performance of the Free Market Model

Utility for a peer is αx for some $\alpha > 1$.
System utility (contribution minus cost) becomes

$$W_S = \alpha x - (1/x)x = \alpha x - 1,$$

if network size is normalized to 1.

Reputation System

In free market model, performance can be limited by low contribution level.
To address that, we want to detect and exclude free-riders.

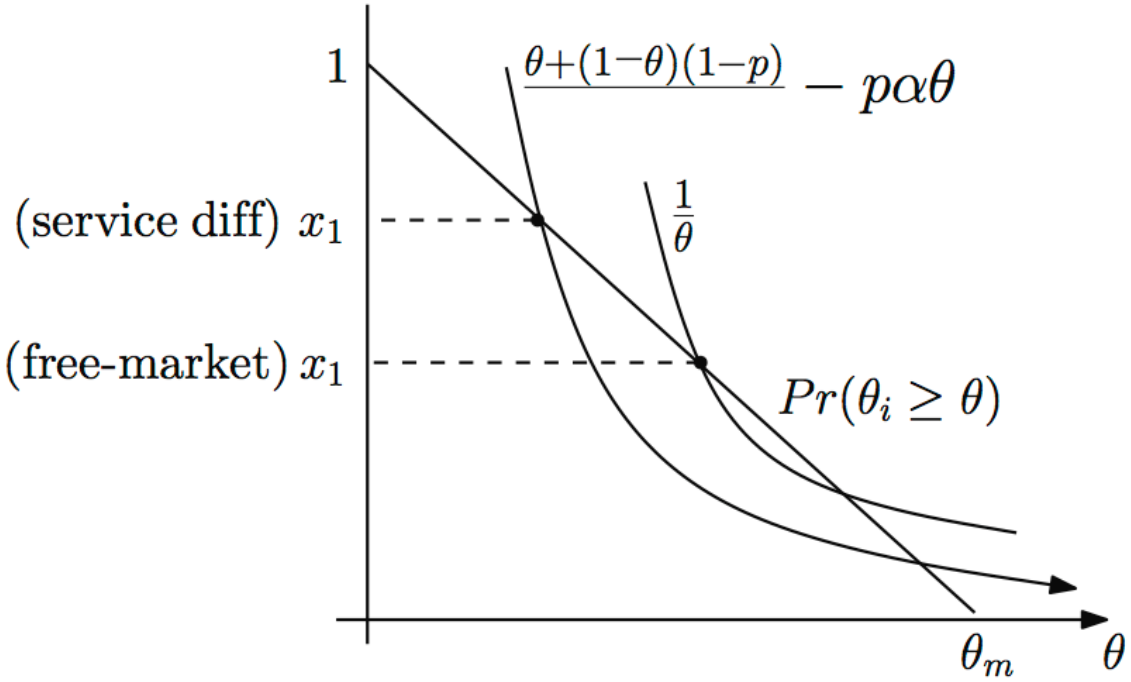
- **Reputation:** detect and exclude free-riders with probability p.
- **Service Differentiation:** detect all free riders, reduce their level of service by $1 - p$ times contributor level.

Cost and Utility

- Free riders now get $1 - p$ of the benifits, so contribution cost is
$$\frac{x + (1 - x)(1 - p)}{p}$$
- Utility for contributor:
$$Q - R = \alpha x - \frac{x + (1 - x)(1 - p)}{p}.$$
- Utility for free rider:
$$Q - T = \alpha x - p\alpha x$$
- System Utility: $W_S(p) = x(Q - R) + (1 - x)(Q - T) = (\alpha x - 1)(x + (1 - x)(1 - p))$

Some social loss is imposed by the reputation system, but participation level increases.

Equilibria in Service Differentiation Model



Claim: for a penalty level $p \geq 1/\alpha$, there exists an equilibrium for $x = 1$.