Peer-to-Peer Networks

Game Theory
12th Week

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Peer to Peer Networks

Game Theoretic Aspects

Literature

- **Feldman, Chuang „Overcoming Free-Riding Behavior in Peer-to-Peer Systems“, 2005**
- **Feldman, Lai, Stoica, Chuang, „Robust Incentive Techniques for Peer-to-Peer Networks“, 2004**
- **Shneidman, Parkes, „Rationality and Self-Interest in Peer to Peer Networks“**

Motivation

- **Traditional system design**
  - assume obedient users
  - follow specific protocol without consideration
  - classes of nodes:
    - correct/obedient
    - faulty
      - fail-stop
      - message dropping
      - Byzantine failure

- **P2P**
  - have rational users
  - maximize own utility
  - may deviate from the protocol
  - classes of nodes
    - rational
      - optimize own utility
      - can include „tricky“ behavior
    - irrational
      - altruistic
      - malign cheating

Examples

- **Gnutella**
  - study by Adar & Huberman 2000
    - ~70% of peers provide no files (free-riders)
    - top 1% provide 37% of all files
  - similar patterns in studies of Napster
  - in 2005: 85% of all Gnutella users are free-riders

Selfish Behavior in P2P

- **Reasons**
  - Psychology of users
  - Lack of central authority
  - Highly dynamic memberships
  - Availability of cheap identities
  - Hidden or untraceable actions
  - Deceitful behavior
- **Implications**
  - Success of P2P networks must take into account economic behavior of users

Typical Features of Peer to Peer Systems

- **Social dilemma**
  - defective behavior (not uploading) is rational behavior, i.e. maximise the utility
- **Asymmetric transactions**
  - a peer wants a service
  - another provides this service
- **Untraceable defections**
  - it is not clear which peer declines a service
- **Dynamic population**
  - peers change the behavior
  - peers enter and leave the system

Incentives for Cooperation

- **Inherent generosity**
- **Monetary payment schemes**
- **Reciprocity-based schemes**

Inherent Generosity

- **Standard model of behavioral economics**
  - based on purely self-interest
  - does not explain all behavior of people
- **User generosity has a great impact on existing peer-to-peer systems**
  - can be determined analytically

Monetary Payment Schemes

- **Golle, Leyton-Brown, Mironov, Lillibridge 2001, „Incentives for Sharing in peer-to-peer Networks“**
  - consider free-rider problem in Napster
  - assume selfish behavior
  - if all peers are selfish this leads to the strict Nash equilibrium
  - introduce micro-payment system to overcome this problem
  - encourage positive behavior by virtual money

Basics of Game Theory

- **Prisoner's dilemma (Flood&Drescher 1950)**
  - two suspects arrested
  - if one testifies and the other remains silent then the witness is released the other serves 10 years prison
  - if both testify then both serve 5 years prison
  - if no one testify then they receive 1/2 year prison
- **Best social strategy**
  - no one testifies
- **Nash equilibrium**
  - for a constant choice of the other party each player optimizes his benefit
  - if both talk then there is a Nash equilibrium

	A talks	A is silent
B talks	A: -5 B: -5	A: -10 B: 0
B is silent	A: 0 B: -10	A: -1/2 B: -1/2

Dominant Strategy

- **Dominant strategy**
  - a strategy is dominant if it is always better than every other strategy
  - in the prisoner‘s dilemma every player has a dominant strategy
    - talk!
- **Nash equilibrium**
  - for a constant choice of the other party each player optimizes his benefit
  - if both talk then there is a Nash equilibrium
  - is not necessary Pareto-optimal

	A talks	A is silent
B talks	A: -5 B: -5	A: -10 B: 0
B is silent	A: 0 B: -10	A: -1/2 B: -1/2

Prisoner‘s Dilemma of Peer to Peer Filesharing

- **Rational strategy for downloading peer:**
  - Download
- **Rational strategy for uploading peer:**
  - Don‘t upload
- **Nash equilibrium**
  - Uploader rejects upload for downloader

	U: Peer uploads	**U: Peer rejects upload**
D: Peer downloads	**D: 10** **U: -1**	**D: 0** **U: 0**
D: Peer does not download	**D: 0** **U: 0**	**D: 0** **U: 0**

Monetary Payment Schemes

- **Advantage**
  - allow to use economic mechanisms
  - charge free-riders for misbehavior
- **Disadvantage**
  - require infrastructure for accounting and micropayments
- **Major problems**
  - how to encourage truthful relevation of costs
    - solution: Vickrey-Clarke-Groves (VCG-mechanisms)
    - strategyproof mechanism
      - encourage truthful revelation in dominant strategies
  - how to encourage cooperate behavior despite hidden actions
    - information asymmetry
    - use contracts
  - how to deliver the payment
    - e.g. the deliverer also receives some part of the payment

Mechanism Design

- **Define rules of the games**
  - such that rational behavior is good behavior
    - e.g. auction system: second best wins
- **Inverse game theory**
  - how to design the rules such that the desired outcome occurs
  - provide incentives
- **Obedient center**
  - the rule system must be enforced on all the nodes
  - altruistic rule maker
  - central control or distributed software control mechanism or cryptography
- **Mechanism design can be computationally hard**
  - calculating the optimal strategy can be difficult
  - not all the information may be available to each player
  - finding the best rule system poses an even more difficult problem
- **Algorithmic Mechanism Design**
  - Mechanism is carried out via a distributed computation

Reciprocity based Schemes

- **Reciprocity based schemes**
  - Users maintain histories of past behavior of other users
  - used for decision making
- **Direct-reprocity scheme**
  - A decides how to serve user B based solely on the service that B has provided
  - e.g. Bittorrent
  - still possibilities for manipulation
- **Indirect-reciprocity scheme**
  - aka. reputation based schemes
  - more scalable for
    - large population sizes
    - highly dynamic memberships
    - infrequent repeat transactions
- **Problems**
  - How to treat newcomers?
    - whitewashing attacks
    - irreplacable pseudonyms
    - penalty for newcomers
  - Indirect reciprocity is vulnerable to deceits, false accusations & false praises
    - sybil attacks
    - sybilproofness

Reciprocative Decision Functions

- **Discriminating Server Selection**
  - use history records to choose partners
- **Shared history**
  - communicate the history with other peers
    - problem: false praise or false accusations
- **Subjective reputation**
  - e.g. max-flow algorithm that collects the reputation be the combination of history of other users
  - e.g. page-rank algorithm
- **Adaptive stranger policy**
  - treat strangers like the previously seen strangers
    - arrest usual suspects only if the crime rate is high
- **Short-term history**
  - long history records allow peers to gather reputation and then turn into traitors
  - short-term history records will discipline all peers

Future Research Directions

- **How to overcome the prisoner‘s dilemma**
  - game theory the right tool?
- **What is rational behavior?**
  - Is Nash equilibrium the right model
- **Influence of different user behavior**
  - different grades of selfishness or altruism
- **Contracts can lead to desired behavior of peers**
  - computational complexity of optimal contracts unknown

PeerTrust

- **Xiong, Liu, „PeerTrust: Supporting Reputation-Based Trust for Peer-to-Peer Electronic Communities“**
- **suggest mechanism for reputation based trust management**
- **concentrate on trust not on the networks**

Trust Parameters

- **Feedback a peer obtains from other peers**
- **Feedback scope**
  - total number transactions a peer has with other ones
- **Credibility factor of the feedback source**
- **Transaction context factor**
  - for discriminating mission-criticial transaction from less critical ones
- **Community context factor**
  - for addressing community-related characteristics and vulnerabilities

Trust Metric

- **I(u,v): total number of transactions between peer u and v**
- **I(u): total number of transactions performed by u with all other peers**
- **S(u,i): normalized amount of satisfaction peer u receives from p(u,i) in its i-th transaction**
- **C_r(v): credibility of the feedback submitted byv**
- **TF(u,i): adaptive transaction context factor for peer‘s u‘s i-th transaction**
- **CF(u) denotes the adaptaive community context factor**
- **α, β are normalizing factors**

$$T(u) = \alpha * \sum_{i=1}^{I(u)} S(u,i) * Cr(p(u,i)) * TF(u,i) + \beta * CF(u),$$

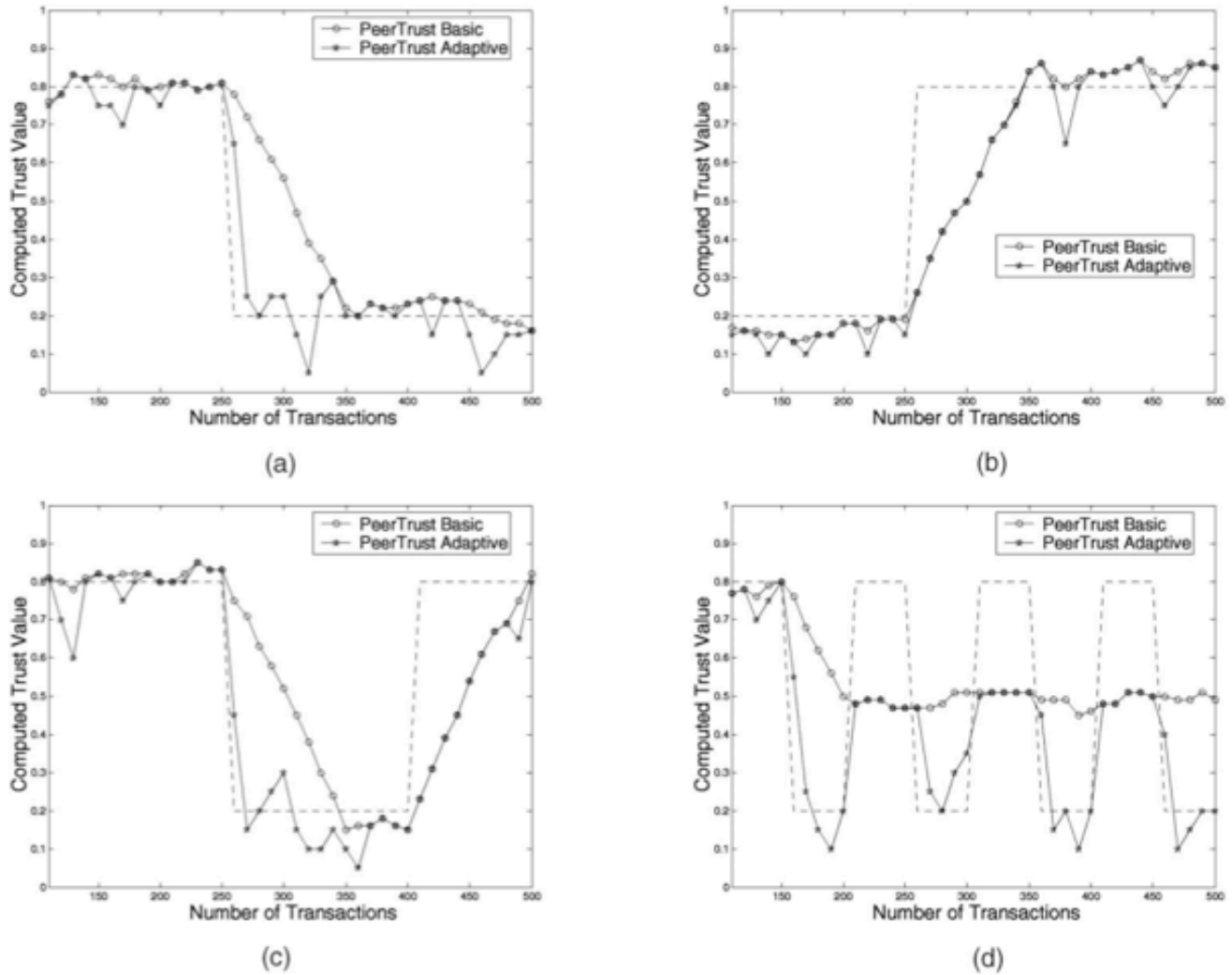

Fig. 5. Effectiveness against dynamic personality and reputation oscillation. (a) Peer milking reputation. (b) Peer building reputation. (c) Peer oscillating reputation. (d) Peer oscillating reputation.

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End of 12th Week

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