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Peer-to-Peer Networks

14 Game Theory

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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“

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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

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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

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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

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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

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Incentives for Cooperation

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

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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

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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

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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 7 years prison
  - if no one testify then they receive 2 years 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: -7 B: -7	A: -10 B: 0
B is silent	A: 0 B: -10	A: -2 B: -2

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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

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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

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Bittorrent

- Bram Cohen
- Bittorrent is a real (very successful) peer-to-peer network
  - concentrates on download
  - uses (implicitly) multicast trees for the distribution of the parts of a file
- Protocol is peer oriented and not data oriented
- Goals
  - efficient download of a file using the uploads of all participating peers
  - efficient usage of upload
    - usually upload is the bottleneck
    - e.g. asymmetric protocols like ISDN or DSL
  - fairness among peers
    - seeders against leeches
  - usage of several sources

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Bittorrent Coordination and File

- Central coordination
  - by tracker host
  - for each file the tracker outputs a set of random peers from the set of participating peers
    - in addition hash-code of the file contents and other control information
  - tracker hosts to not store files
    - yet, providing a tracker file on a tracker host can have legal consequences
- File
  - is partitions in smaller pieces
    - as described in tracker file
  - every participating peer can redistribute downloaded parts as soon as he received it
  - Bittorrent aims at the Split-Stream idea
- Interaction between the peers
  - two peers exchange their information about existing parts
  - according to the policy of Bittorrent outstanding parts are transmitted to the other peer

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Bittorrent Part Selection

- Problem
  - The Coupon-Collector-Problem is the reason for a uneven distribution of parts if a completely random choice is used
- Measures
  - Rarest First
    - Every peer tries to download the parts which are rarest
      - density is deduced from the comunication with other peers (or tracker host)
    - in case the source is not available this increases the chances the peers can complete the download
  - Random First (exception for new peers)
    - When peer starts it asks for a random part
    - Then the demand for seldom peers is reduced
      - especially when peers only shortly join
  - Endgame Mode
    - if nearly all parts have been loaded the downloading peers asks more connected peers for the missing parts
    - then a slow peer can not stall the last download

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Bittorrent Policy

- Goal
  - self organizing system
  - good (uploading, seeding) peers are rewarded
  - bad (downloading, leeching) peers are penalized
- Reward
  - good download speed
  - un-choking
- Penalty
  - Choking of the bandwidth
- Evaluation
  - Every peers Peers evaluates his environment from his past experiences

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Bittorrent Choking

- Every peer has a choke list
  - requests of choked peers are not served for some time
  - peers can be unchoked after some time
- Adding to the choke list
  - Each peer has a fixed minimum amount of choked peers (e.g. 4)
  - Peers with the worst upload are added to the choke list
    - and replace better peers
- Optimistic Unchoking
  - Arbitrarily a candidate is removed from the list of choking candidates
    - the prevents maltreating a peer with a bad bandwidth

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Alternatives for BitTorrent

- Rational strategy for downloading peer:
  - Download
- Rational strategy for uploading peer:
  - Now: upload
- Nash equilibrium
  - Uploading and Downloading

	U: Peer uploads	U: Peer rejects upload
D: Peer downloads	D: 7 U: 3	D: 0 U: 0
D: Peer does not download	D: 0 U: 0	D: 0 U: 0

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Other Possible Mechanisms: 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

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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

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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

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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

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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

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