



Peer-to-Peer Networks

15 Game Theory

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- 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“

- 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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- 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 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

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: -7 B: -7	A: -10 B: 0
B is silent	A: 0 B: -10	A: -2 B: -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

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

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

- 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 communication 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

- 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

- 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

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

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 revelation 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

- 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-reciprocity 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
 - irreplaceable 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



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