Promoting sustainability:
Electronic markets for peer production and spectrum sharing

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Hutong Karma. Peter Hessler, The New Yorker

By midmorning, the vendors are out. They pedal through the alley on three-wheeled carts, each announcing his product with a trademark cry. The beer woman is the loudest, singing out again and again, "Maaaaiiiii piiiiijiuuuuuuu!"... The rice man's refrain is higher-pitched; the vinegar dealer occupies the lower registers. ... The sounds are soothing, a reminder that even if I never left my doorway again life would be sustainable, albeit imbalanced. I would have cooking oil, soy sauce, and certain vegetables and fruit in season. In winter, I could buy strings of garlic. ...

On an average day, a recycler passes through every half hour, riding a flat-bed tricycle. ... Not long ago, I piled some useless possessions in the entryway of my apartment ... A stack of old magazines sold for sixty-two cents; a burned-out computer cord went for a nickel. Two broken lamps were seven cents, total. A worn-out pair of shoes: twelve cents. Two broken Palm Pilots: thirty-seven cents.

— *Hutong Karma. The many incarnations of a Beijing alleyway*, by Peter Hessler, The New Yorker, February 13, 2006.

Essence of sustainability

- Multitude of small transactions
- Shared resources
- Coordination
- No waste

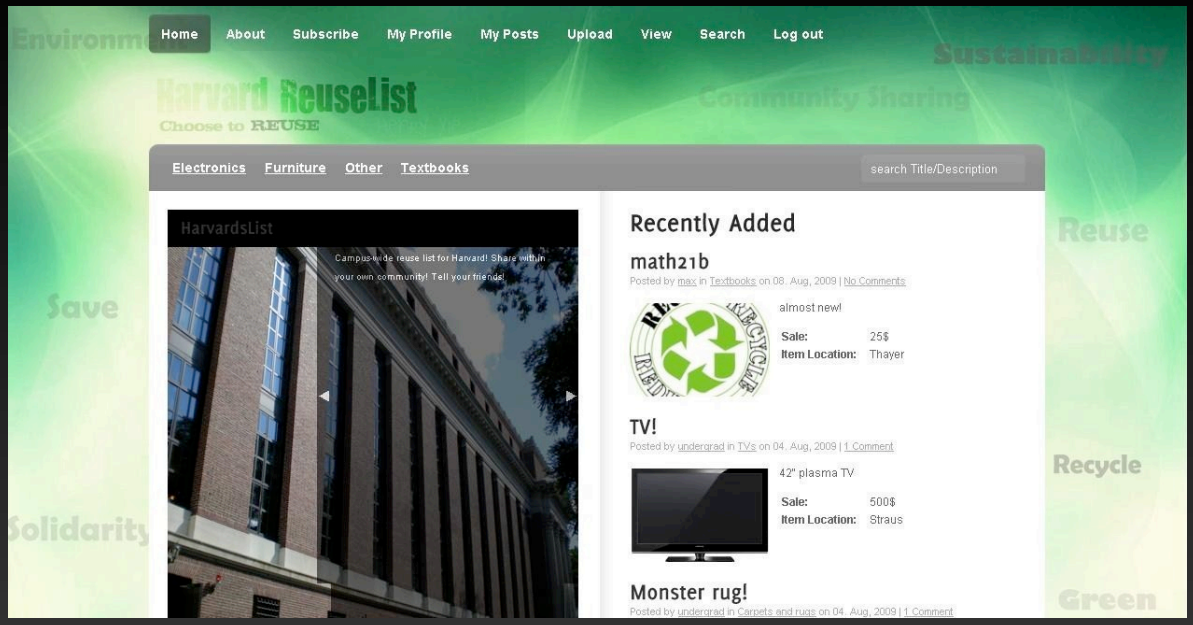
Enabling New Transactions

- AirBnB: rooms over a social network
- Casual commute in Bay Area
- SnapGoods (bikes, ipads, roomba's)
- Zipcar/Zimride
- Bike sharing, e.g. Velib
- CouchSurfing

Example: Harvard Reuse List

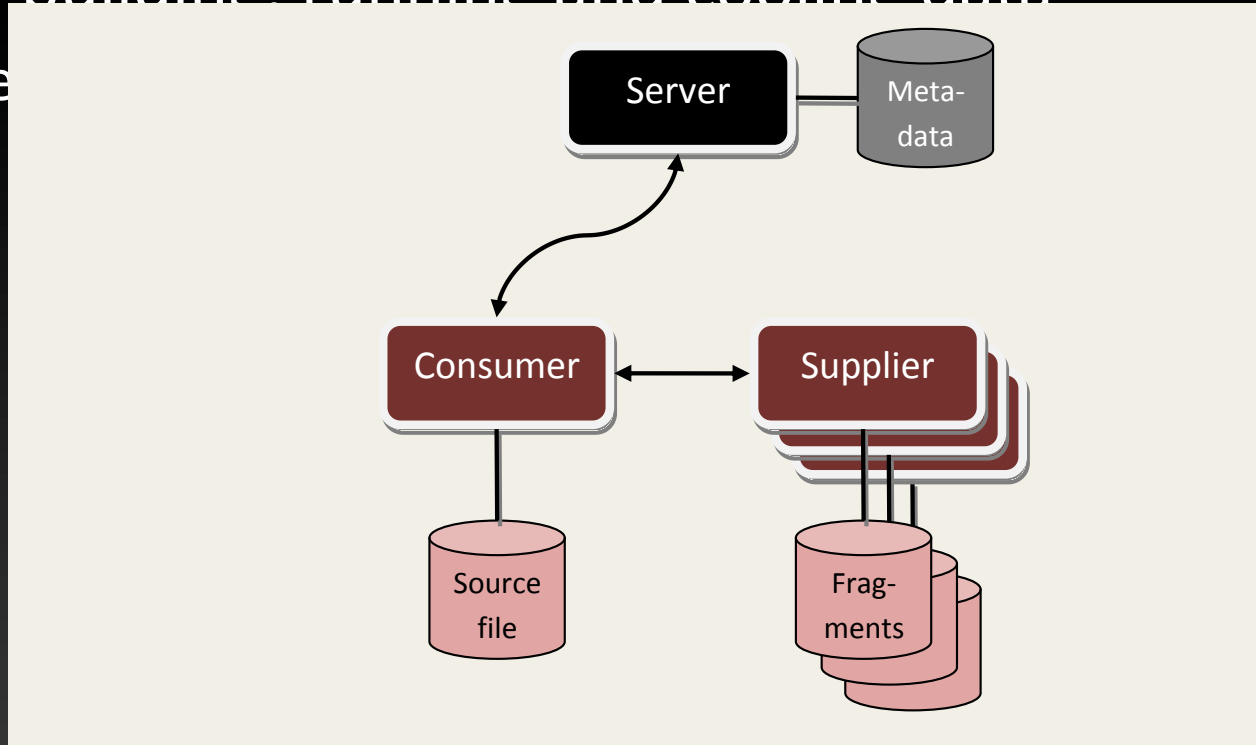
(Henry Xie, College'11, Harvard Strategic Procurement, Harvard Office for Sustainability)

- Many college goods are only desired temporarily (e.g., furniture, books, etc.)
- Enable *swaps* office supplies, furniture and other unused items (operate without money)



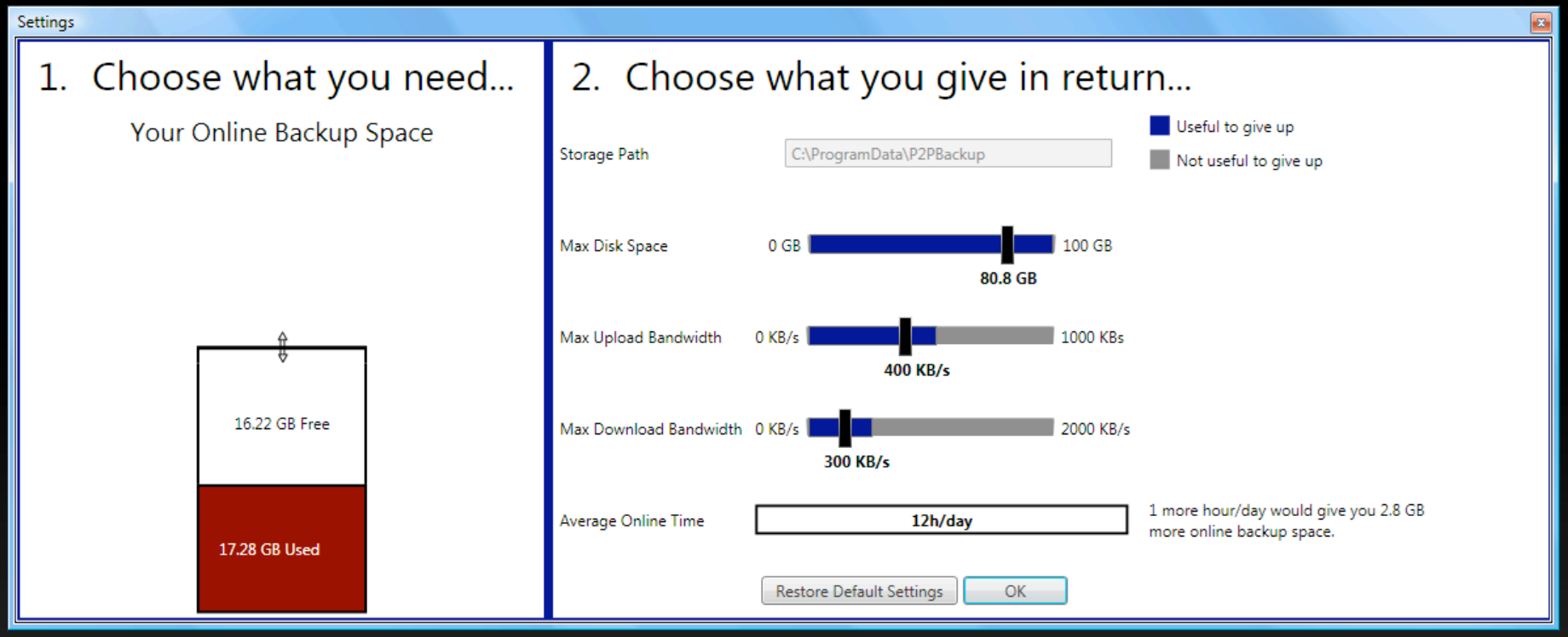
Example: P2P Backup

- In 2006, CO_2 produced in generating power to run US data centers $\approx$ 16% of that produced by burning jet fuel. In 2008, 3% of US energy consumption.
- P2P Backup: Use wasted free disk space, avoid energy costs for building, running and cooling data centers (Seuken e



Hidden Market Interface

[Sven Seuken, Kamal Jain, Desney Tan, Mary Czerwinski; CHI'10]



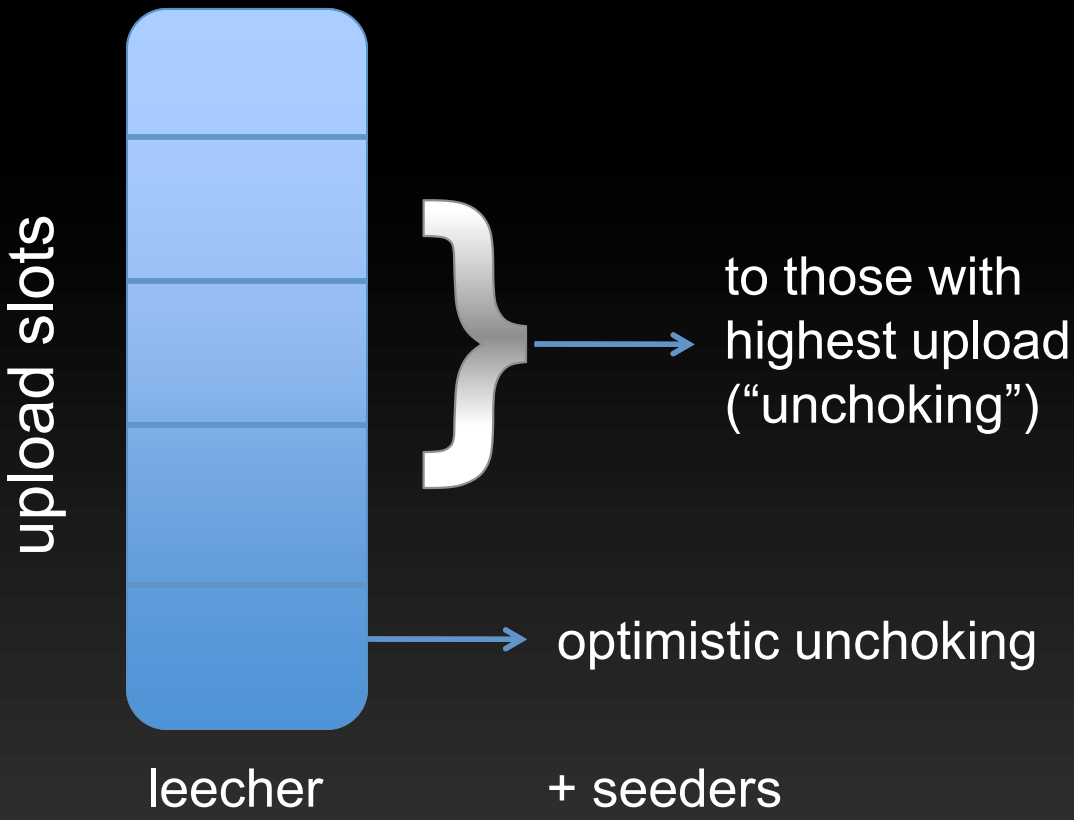
Hidden prices on disk space, upload, download, service

Hidden budget constraint.

Example: P2P File sharing

Example: P2P File sharing

- Rip file into chunks. Join a swarm of people trading
- BitTorrent protocol: tit-for-tat, mitigate free-riding



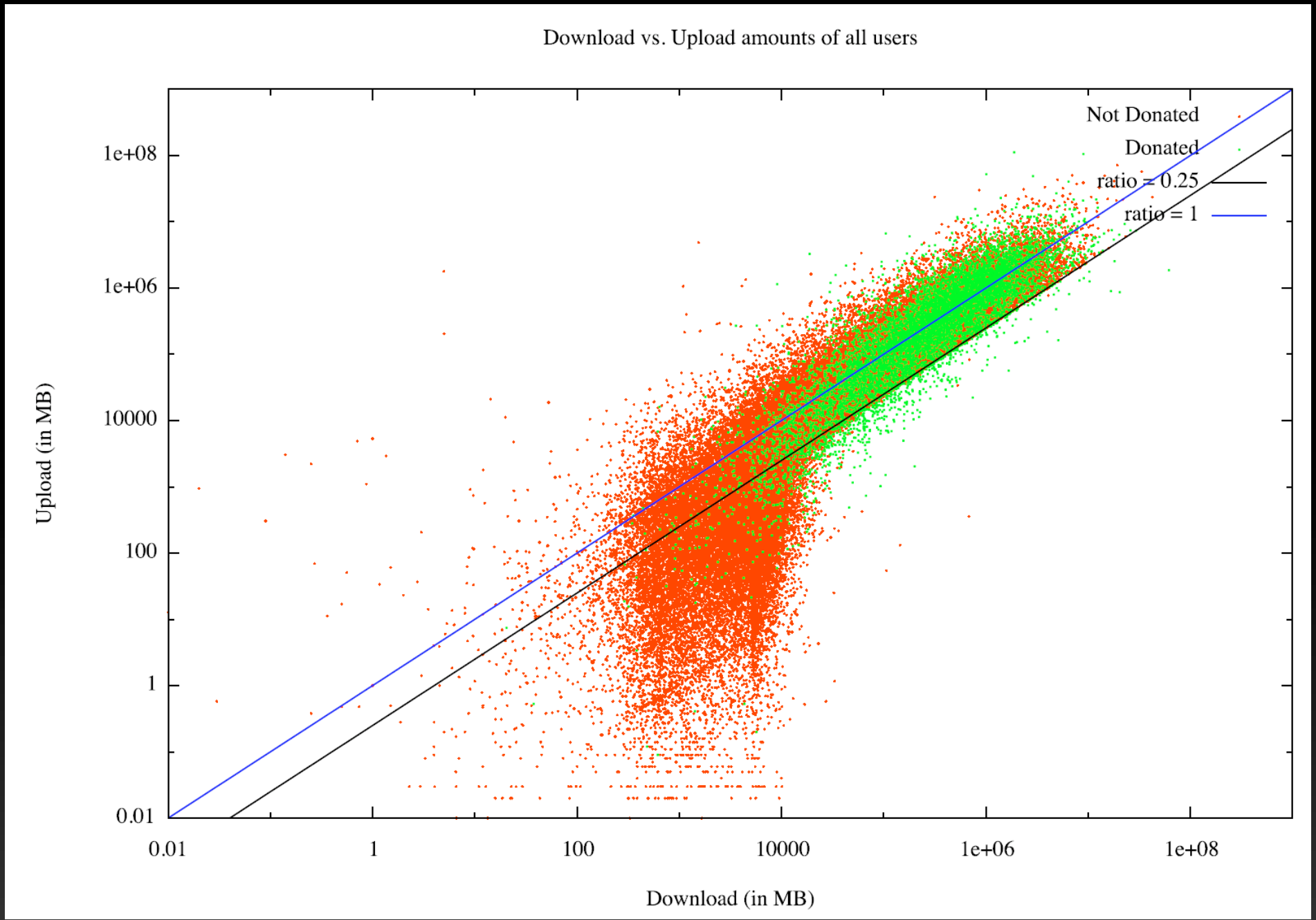
no incentive for long-term sharing (or seeding)

inefficiency w/ asymmetric connections

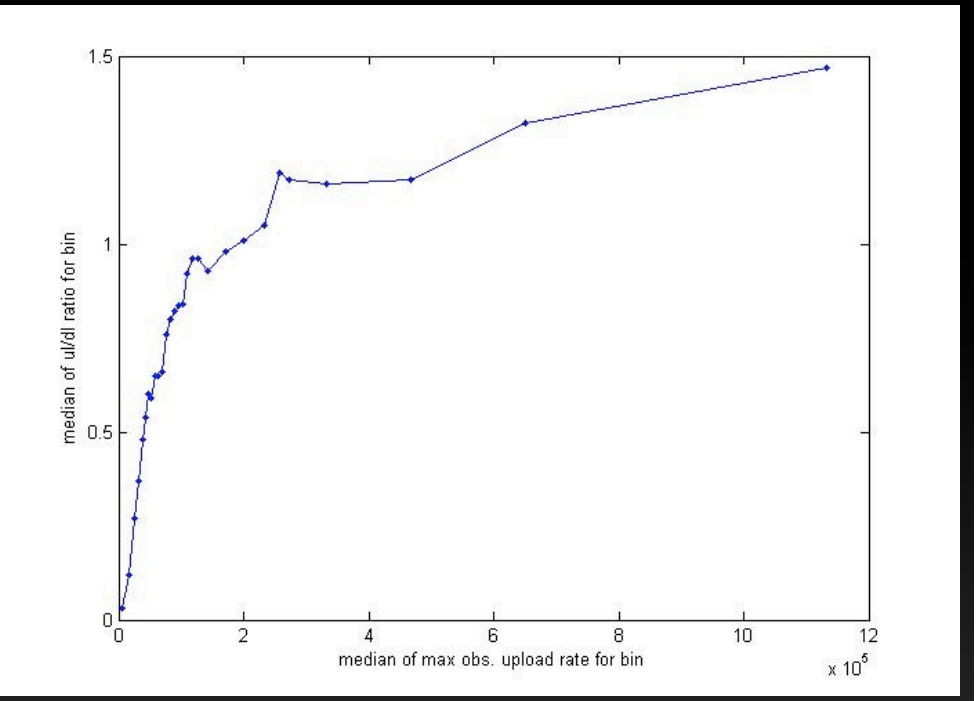
Communities: Private Trackers

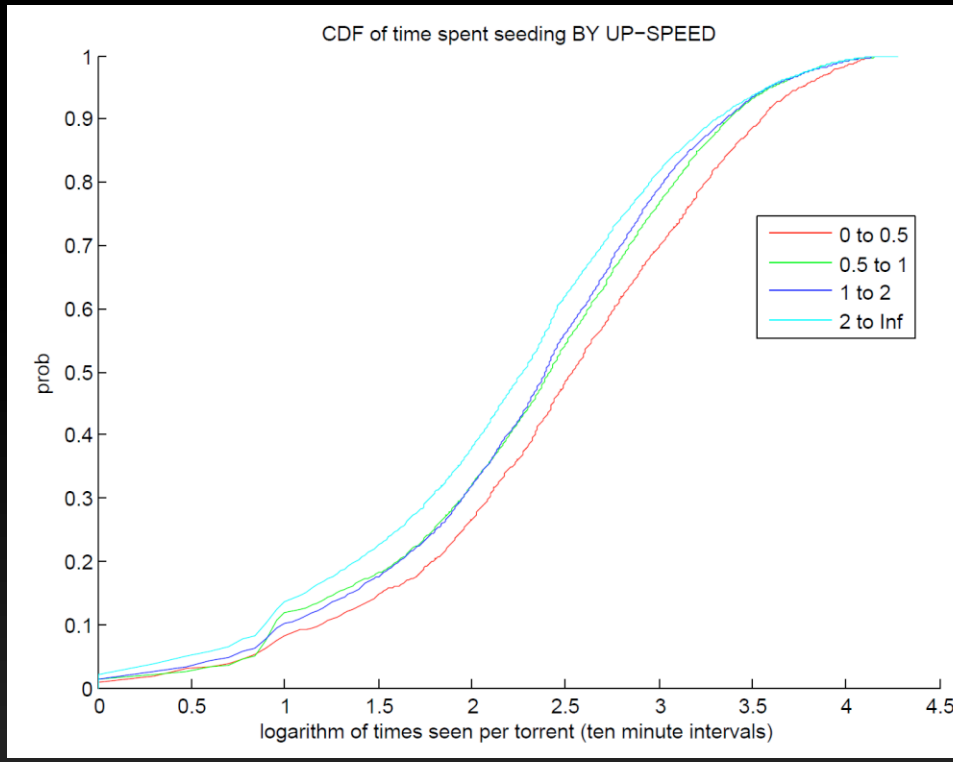
(Kash, Lai, Zhang, Zohar)

- Enforce sharing ratios, promote cooperation
  - upload / download
  - *cycle enforcement* (5GB intervals)
- Example: DIME
  - records meta-information on torrents, IP's of sharers and tracks *work contributions*
  - audio content
  - accepts donations
  - maintains a "do not share" list
- 4-5 months of user activity in 200 torrents


Download vs. Upload amounts of all users
Not Donated
Donated
ratio = 0.25
ratio = 1
Upload (in MB)
Download (in MB)
0.01
1
100
10000
1e+06
1e+08

Low upspeed → hard to work





Principle

- People want to be collaborative and find more efficient use of resources
- Role of electronic market design in making this transparent and in enforcing norms, curating and sharing meta-information; e.g.,
  - reputation
  - credit accounting
  - matching algorithms

Two market design challenges

- Accounting mechanism for distributed work systems: Seuken, Tang and Parkes, AAAI'10
- Enabling Spectrum Sharing in Secondary Market Auctions: Kash, Murty and Parkes, submitted to INFOCOM'10

The “Accounting Mechanism” problem

(Seuken, Tang & P.)

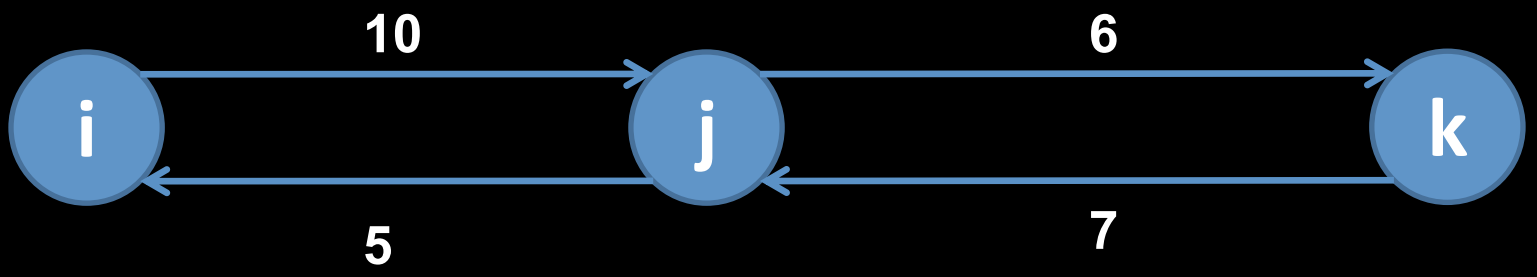
- Matching (e.g., services -> people)
  - based on meta-information and policy
  - algorithmically, or by people
- Private bilateral transaction w/out monitoring
- Reports about work performed
  - e.g., time Alice worked in my garden
  - e.g., time Bob borrowed by roomba
  - e.g., number of boxes Carol carried for me
- Challenge: truthful reports + informative feedback

Accounting vs. Reputation Mechanisms

- Reputation Mechanisms (e.g., eBay)
  - How well did an agent complete a task?
  - Average all individuals reports to get full picture

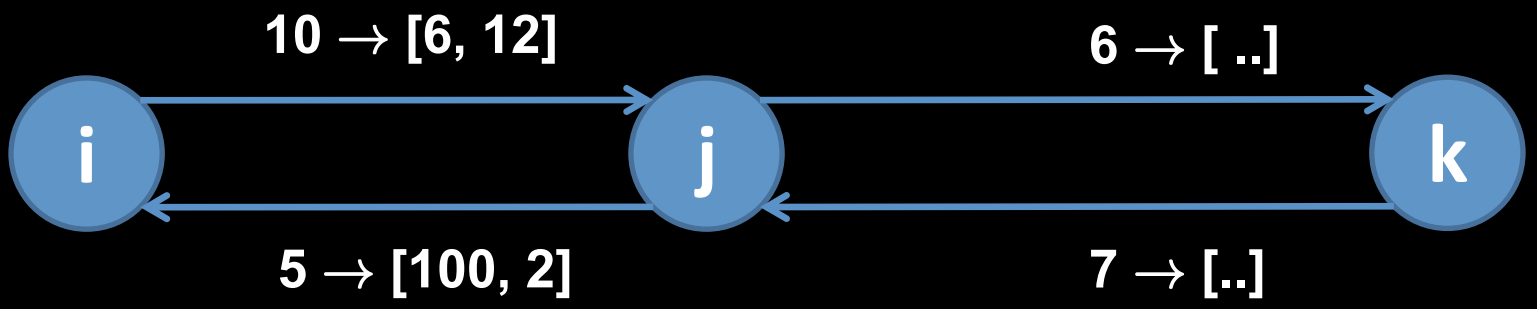
- Most important difference:
  - **Reputation Mechanisms**: *Positive reports about another agent says nothing about myself*
  - **Accounting Mechanisms**: *Positive reports about other agents are negative about myself*

Omniscient Work Graph



work(j,G): net weighted outflow from agent j

Subjective Work Graph



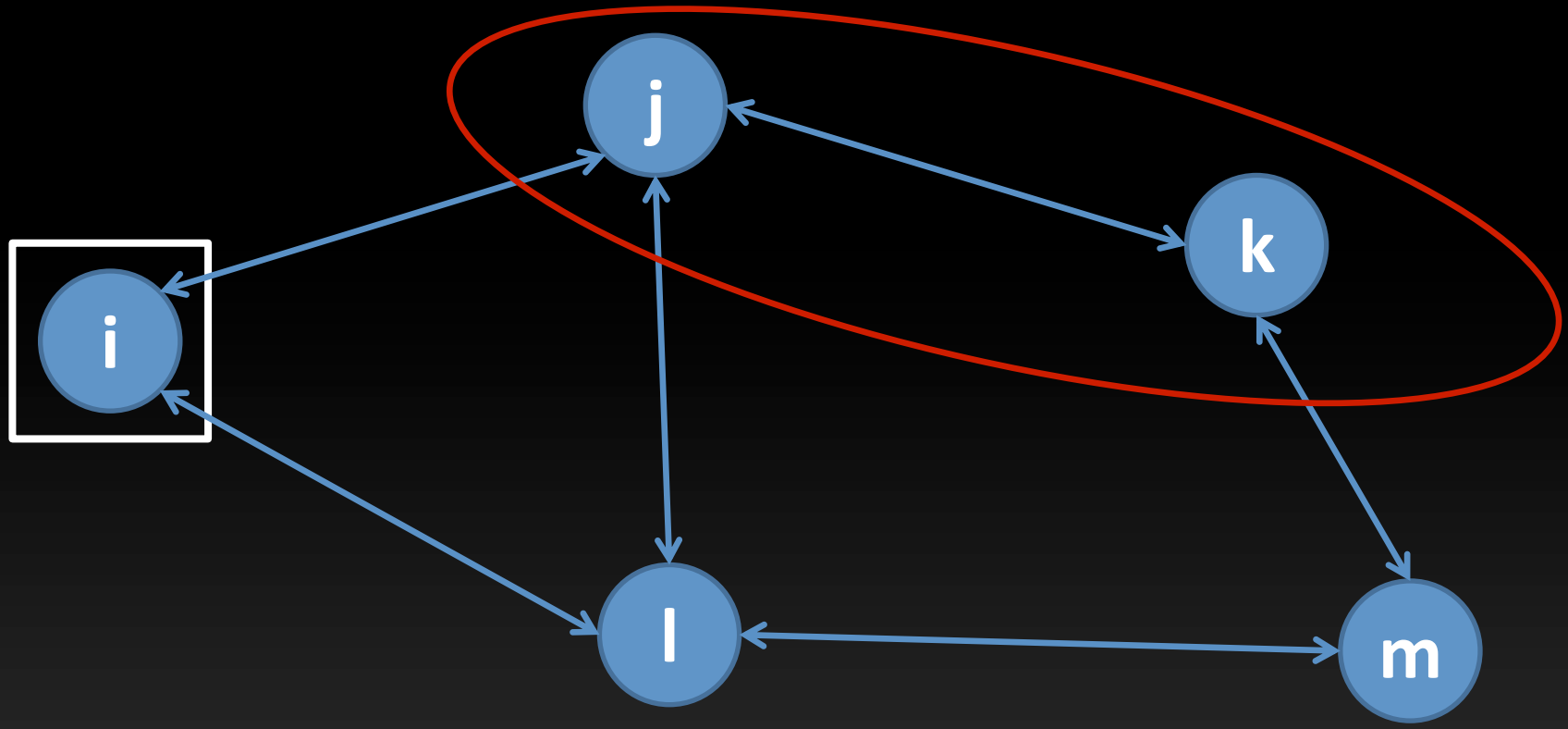
Each edge annotated with claims by both parties

$score_i(j, G')$: measure of j's net contribution from i's perspective

needs to be robust to attacks

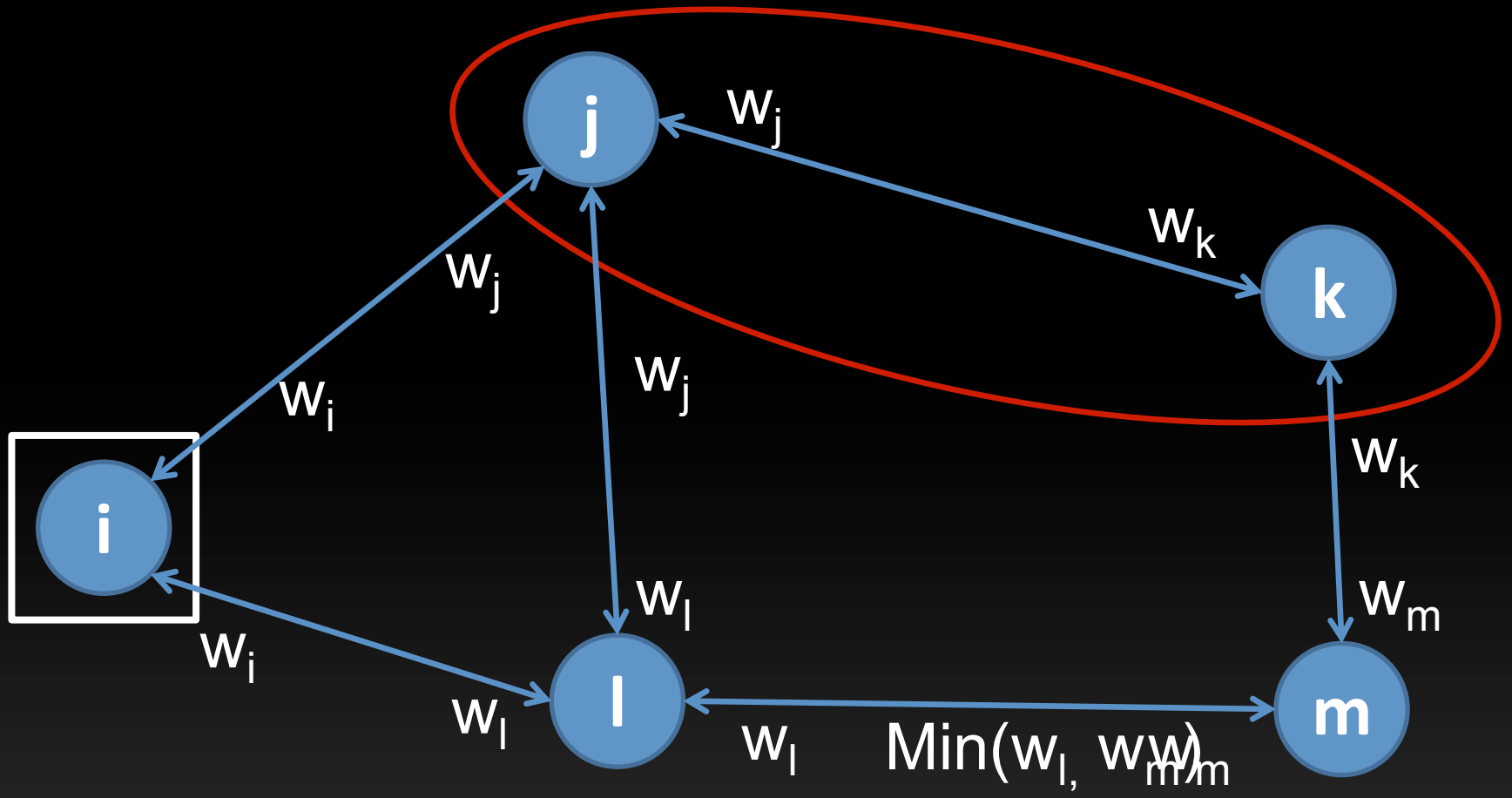
Idea: Context dependence

"choice set" = agents interested in receiving work



misreport proof: can't increase own score or decrease score of others in choice set

DropEdge Mechanism



$score_i(j,G') = MF(j,i) – MF(i,j)$

Theoretical properties

- Misreport proof (!)

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- work(j,G): net outflow from j

- G: graph, G^D: graph with edges dropped
- Choice set uniform random;|C|=m, |N|=n
- $E[work(j,G^D)] / work(j,G) = 1 – m(m-1)/n(n-1)$

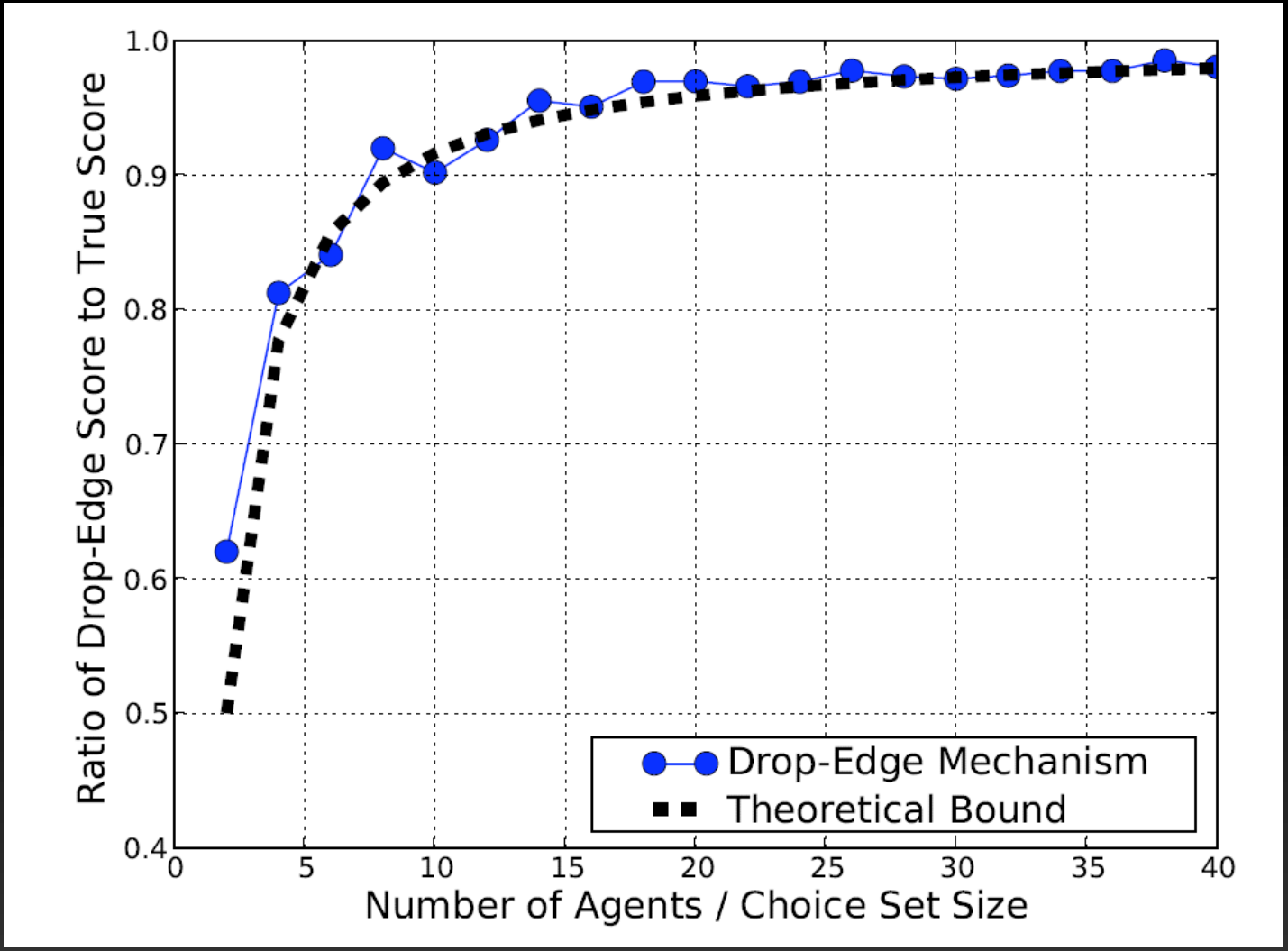
Theoretical properties

- Misreport proof (!)

- work(j,G): net outflow from j
- $score_i(j,G)$: score viewed by i via max-flow
- G: graph, G^D: graph with edges dropped
- Choice set uniform random;|C|=m, |N|=n
- $E[work(j,G^D)] / work(j,G) = 1 - m(m-1)/n(n-1)$

- $E[score_i(j,G^D)] / score_i(j,G) \geq (n-m-1)/(n-2)$

Accuracy of Score in Simulation

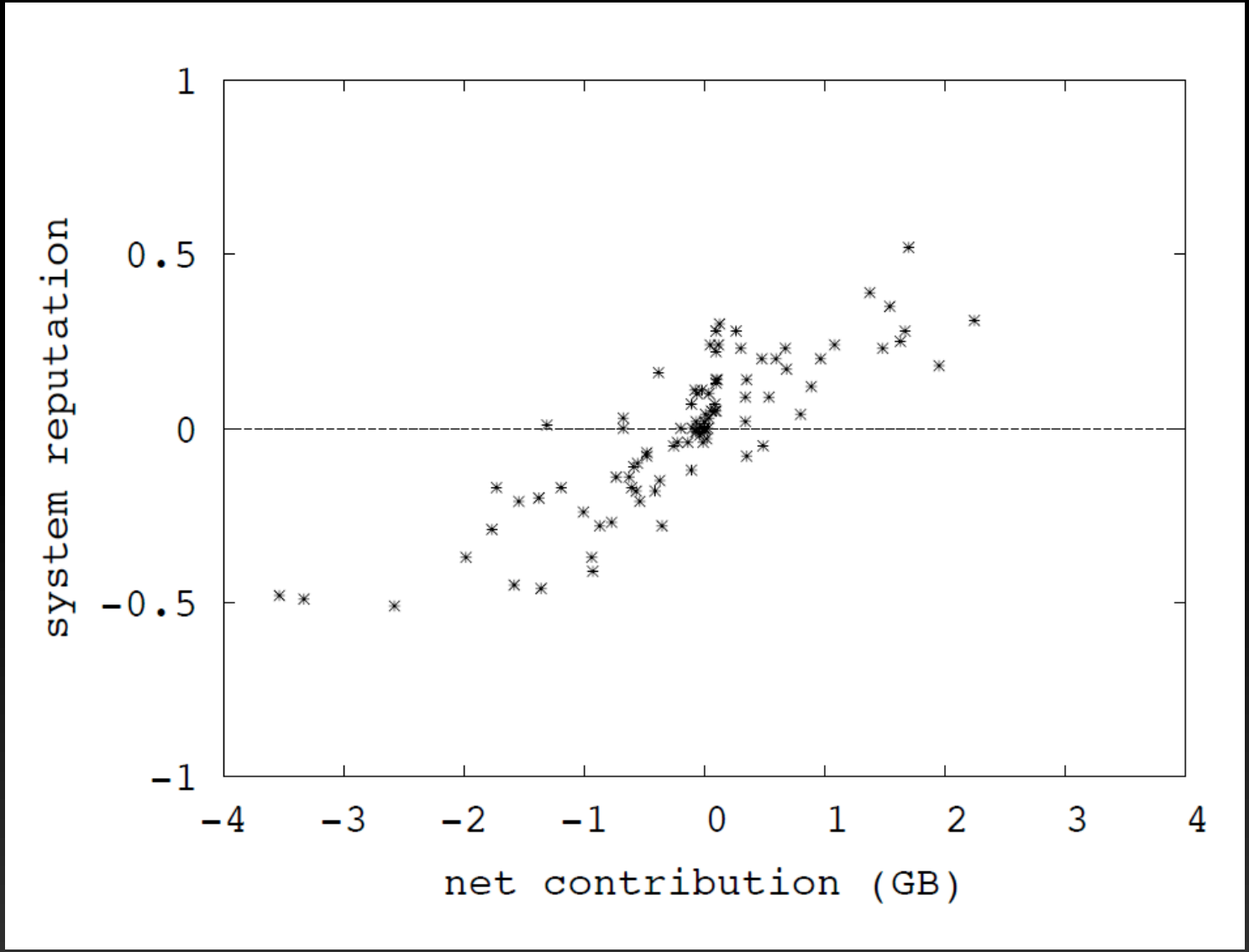


BitTorrent Experiment

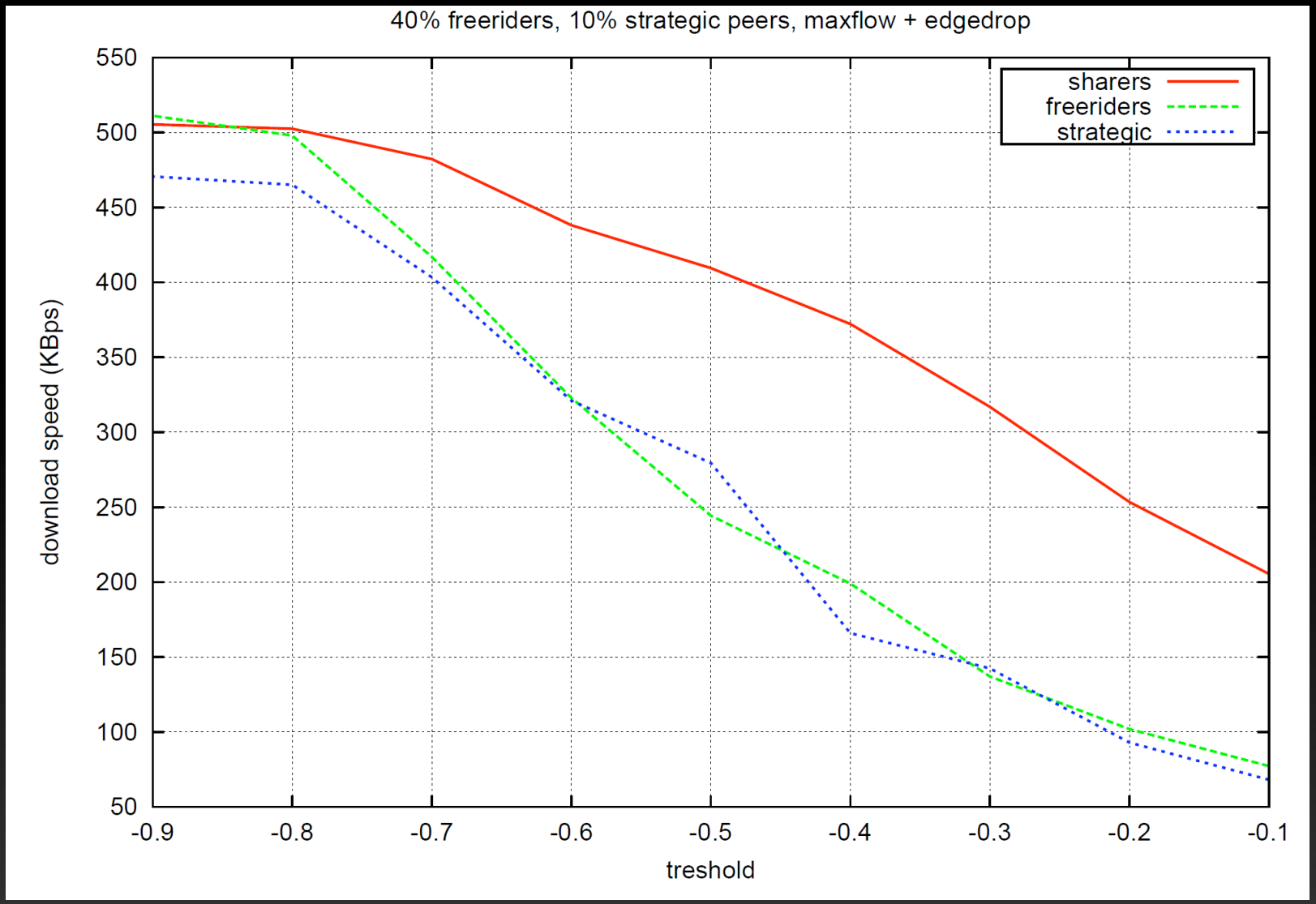
(Meulpolder, Seuken & Parkes)

- Piece-level simulation of BitTorrent
- Score used for optimistic unchoking
  - block any peer with score below a threshold
  - still use T4T for rest of upload slots
- 100 agents, 10 swarms, 1 week, MB-GB files, 3MBps/512kBps down/up
- Agent types:
  - cooperative (share for 10 hrs)
  - free-ride (some fraction also “strategic”)

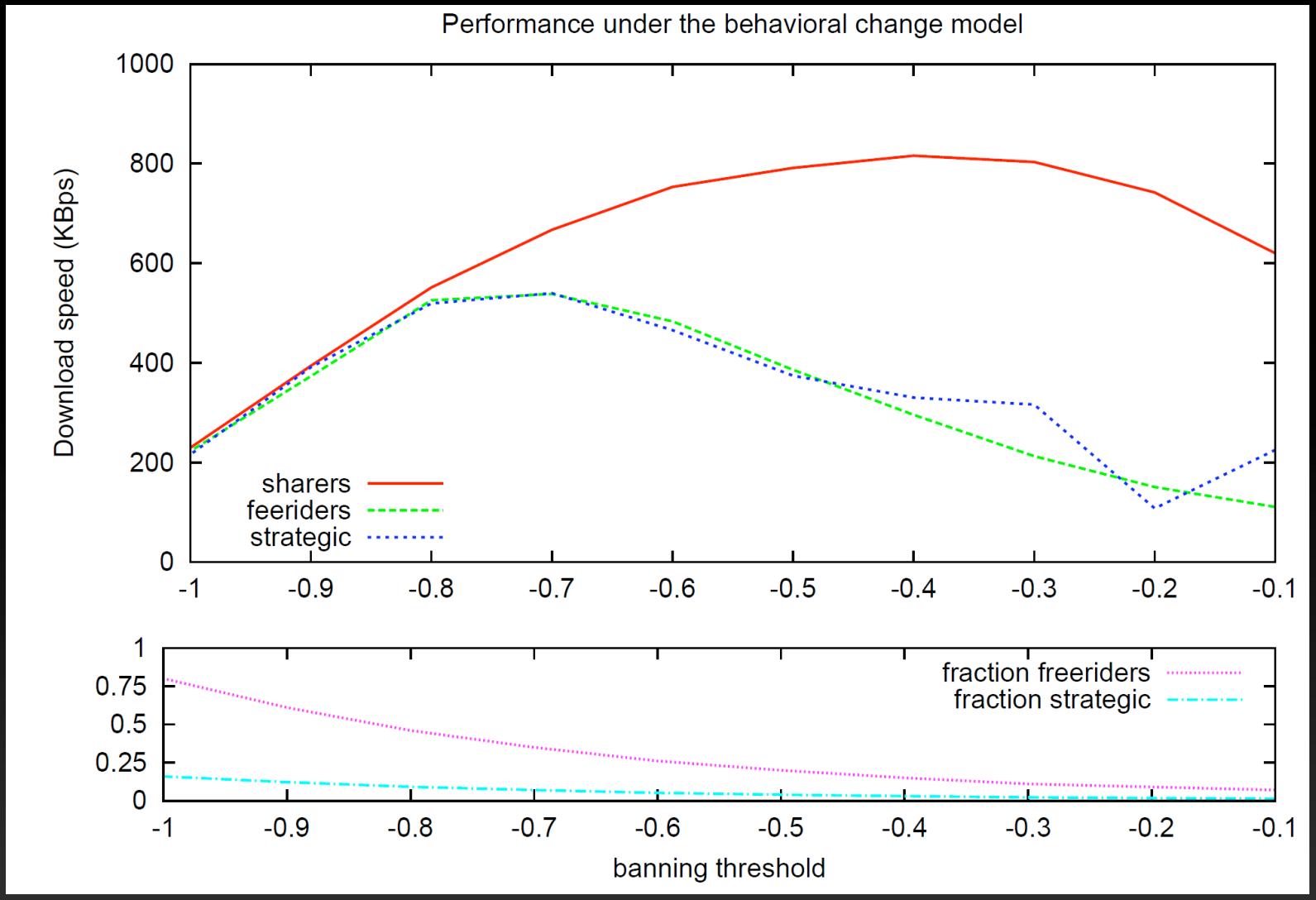
Score vs. Net Work



Effect of more banning



Coupling with Endogeneous Cooperation



Continuing Limitations

- Vulnerable to sybil attacks
- Vulnerable to cross-period attacks

Related work

- Sum of us: Truthful Self-selection (Alon, Fischer, Procaccia and Tennenholtz)
- Moulin (this workshop)
- Liquidity in credit networks: A little trust goes a long way (Dandekar, Goel, Govindan and Post)

Two market design challenges

- Accounting mechanism for distributed work systems: Seuken, Tang and Parkes, AAAI'10

- Enabling Spectrum Sharing in Secondary Market Auctions: Kash, Murty and Parkes, submitted to INFOCOM'10

Spectrum allocation

- Licensed spectrum auctions
  - exclusive licenses, e.g. $19B in 2006 FCC
  - high barrier to entry
- Unlicensed WiFi
  - significantly enhanced consumer welfare, but subject to tragedy of commons (Bykowsky et al. FCC office of strategic planning)
- What else can be done?
  - enable primary owner to sell short-term, shared leases

Example buyer types

- Low power local TV
  - can’t share when active, always active, high penalty if conflict
- Wireless microphone
  - can’t share when active, only active occasionally, moderate penalty if conflict
- Wireless network
  - can share when active (MAC), fairly constant activation, use 90% of channel, large penalty if conflict w/ an exclusive use device
- Opportunistic data
  - can share, intermittent activation and small use when active, small penalty

Model

- ability to share $x_i \in \{0,1\}$
- demand $d_i \in (0,1]$
- activation probability $a_i \in (0,1]$
- normalized value (per epoch) $v_i \in R_{>0}$
- normalized penalty (per epoch) $p_i \in R_{>0}$

- Channels C
- Constraint graph G=(V,E)
  - edge when devices conflict if share channel

Induces an allocation problem

$$b(A,i) = \begin{cases} 0 \text{ if } A_i = \perp, \text{ otherwise} \\ B_i \Pr_i(F|A) E_A[S_i|F] - p_i(1 - \Pr_i(F|A)) \end{cases}$$

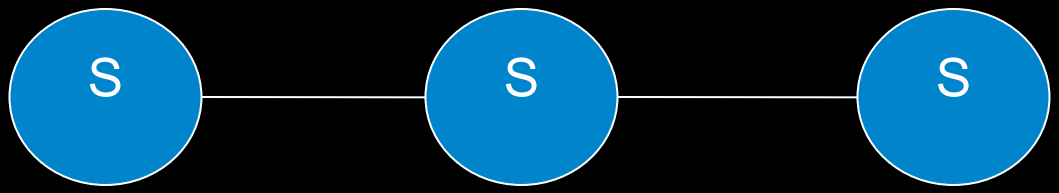
bid value

prob. channel free

expected share given
active and free
(via fair-share MAC model,
equal alloc s.t. no greater than demand)

prob channel not free

How much do I get?



d_i =	0.3	0.5	0.7
Share =	0.3	0.35	0.35

Induces an allocation problem

$$b(A,i) = \begin{cases} 0 \text{ if } A_i = \perp, \text{ otherwise} \\ B_i \Pr_i(F|A) E_A[S_i|F] - p_i(1 - \Pr_i(F|A)) \end{cases}$$

bid value

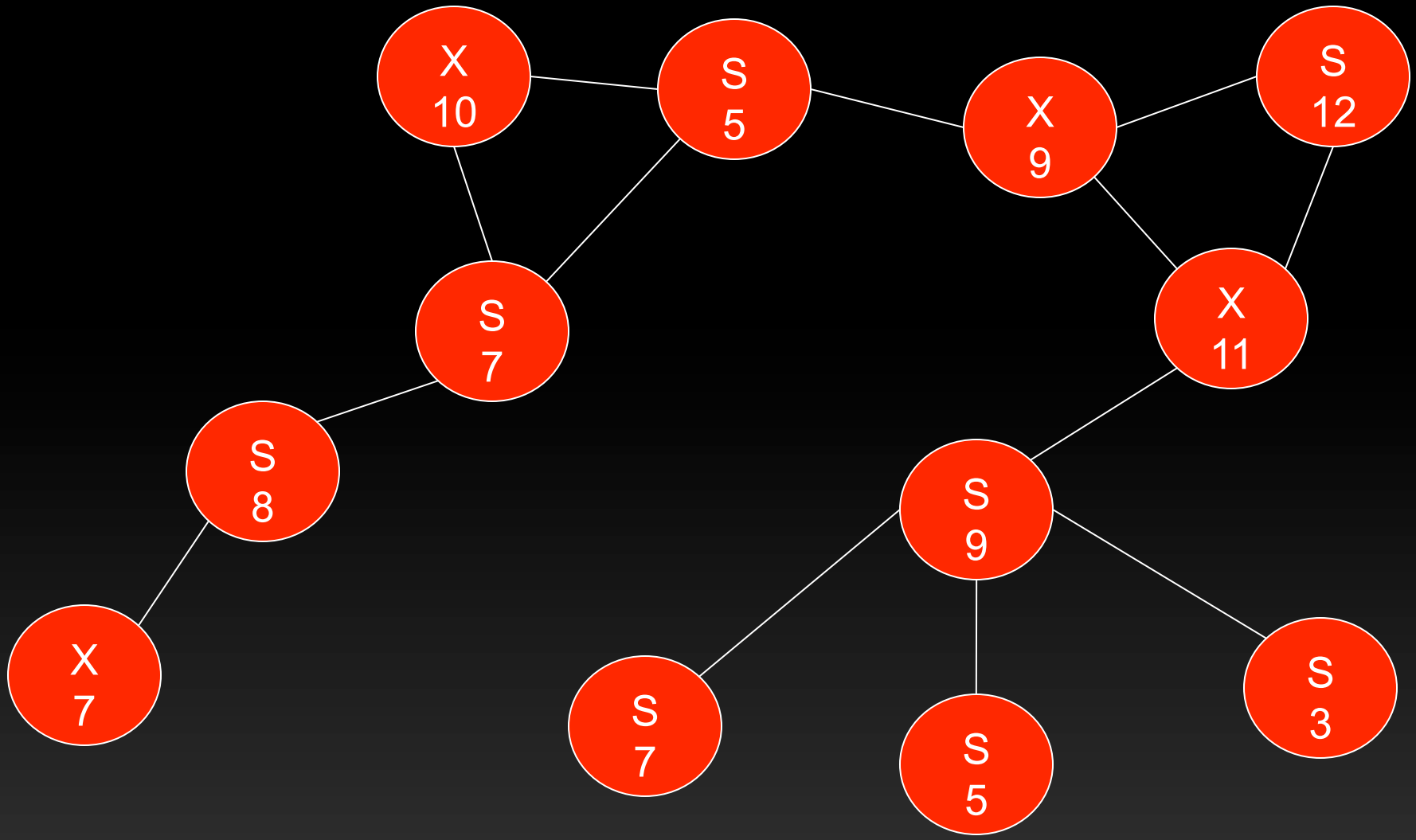
prob. channel free

expected share given
active and free
(via fair-share MAC model,
equal alloc s.t. no greater than demand)

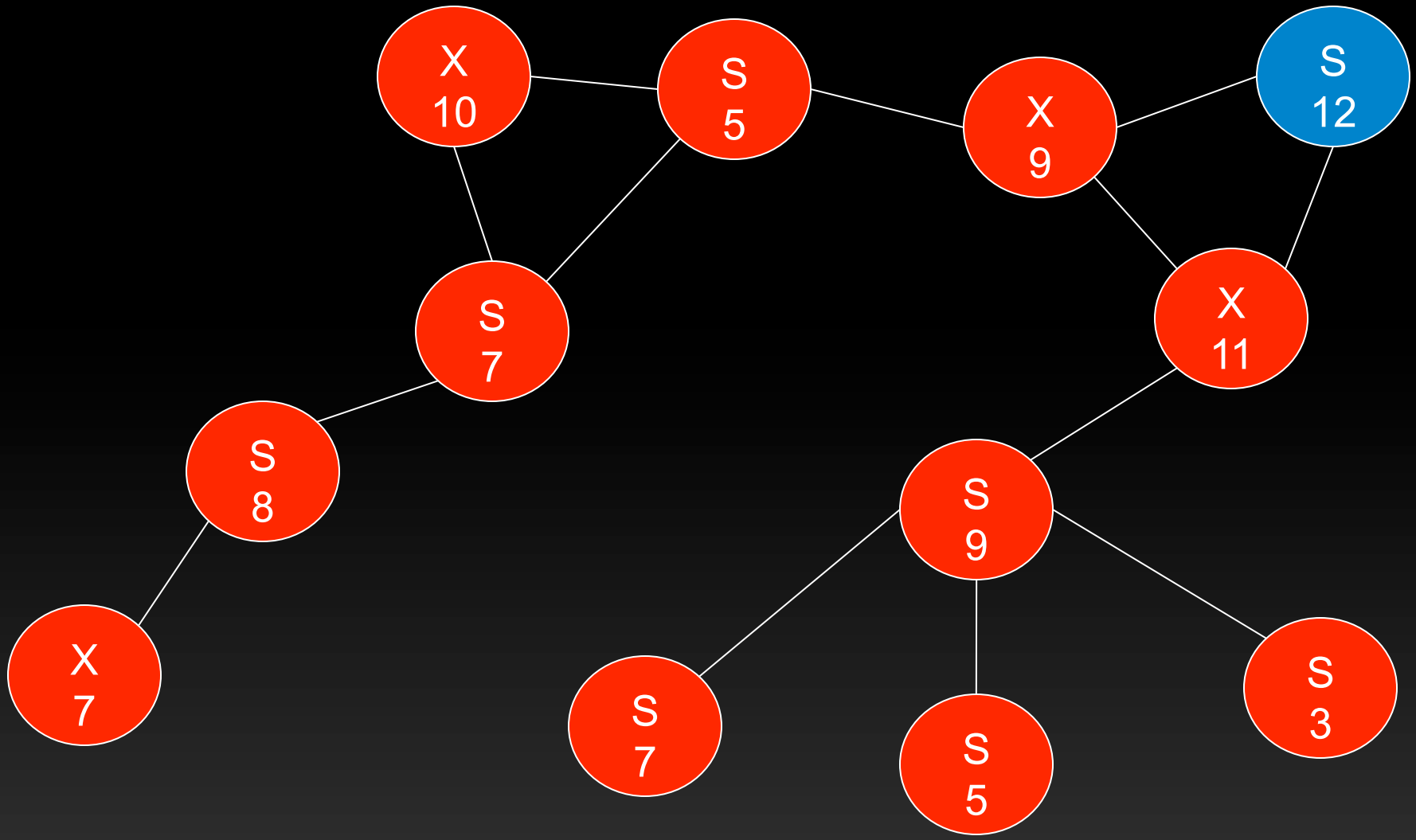
prob channel not free

But, NP hard even without sharing (Jain et al.'03)
$\rightarrow$ consider greedy heuristic

Greedy Algorithm



Greedy Algorithm



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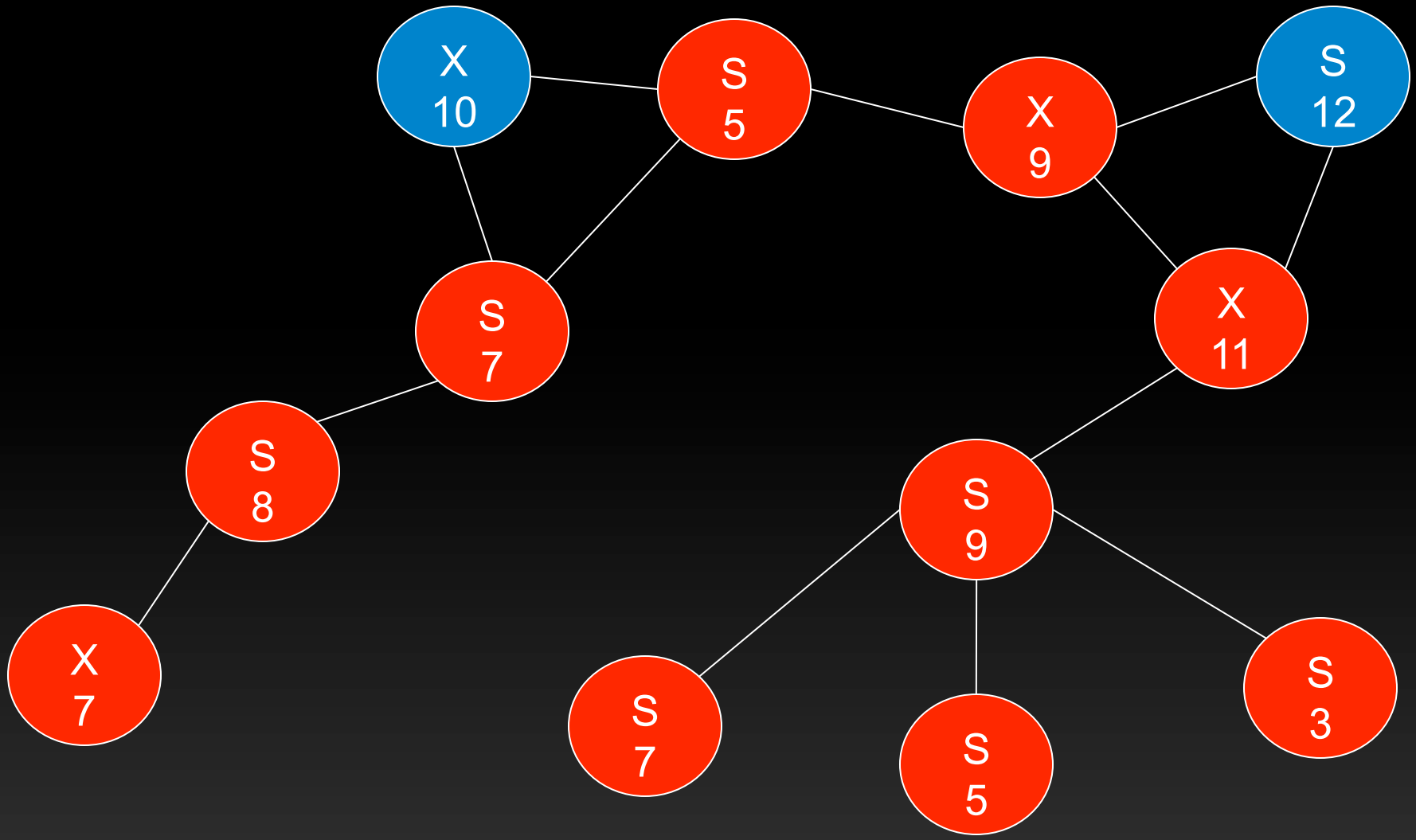

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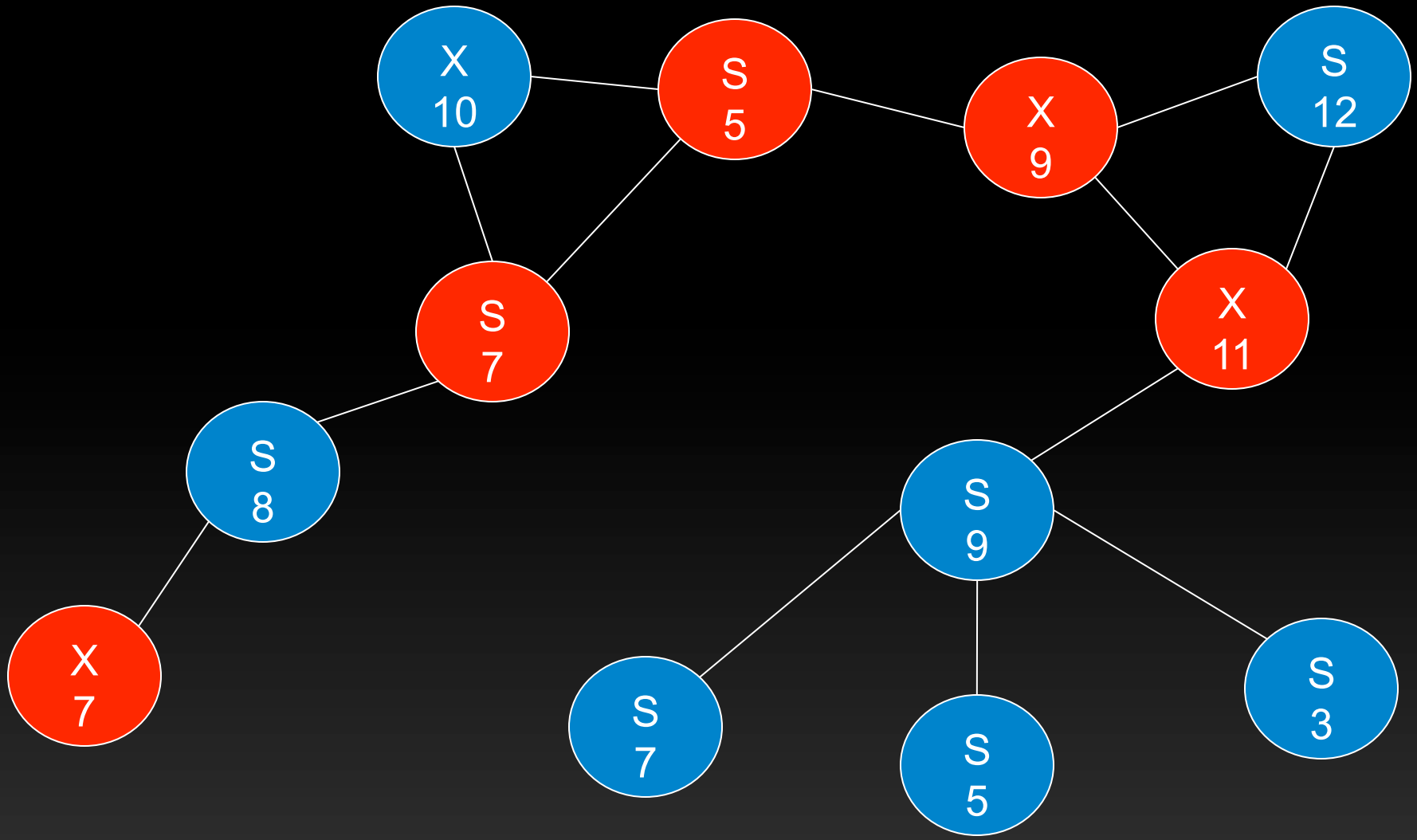


A few more details

- Allocate agent values into buckets
- Go from high to low buckets
  - within a bucket, select agents at random
  - allocate a channel greedily from those available
    - available: in C_i and impose no externality on higher buckets (so, higher is better in this sense)
    - note: can interfere within same bucket
- Additional correction step

Why? Greedy Is Not Monotone!

Channels: 1,2

Channels: 1

(c.f., with no sharing greedy is monotone; Zhou et al.'06)

Why? Greedy Is Not Monotone!

(c.f., with no sharing greedy is monotone; Zhou et al.'06)

Why? Greedy Is Not Monotone!

(c.f., with no sharing greedy is monotone; Zhou et al.'06)

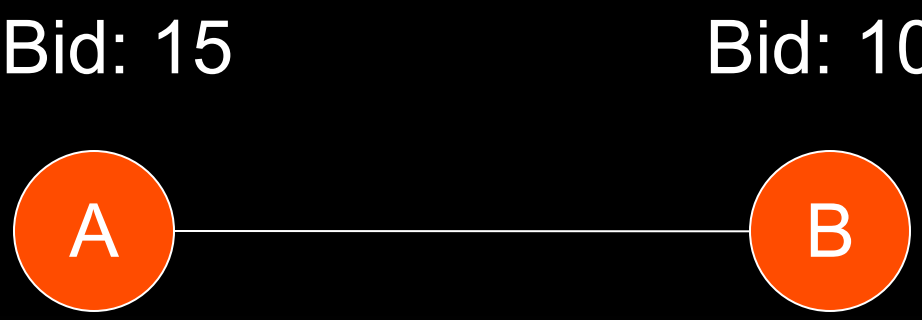
Monotone $\Rightarrow$ SP

- Useful , e.g.
  - avoids wasteful counterspeculation
  - provide stability
  - provide simplicity

Making Greedy Monotone

- A. Bucketing (“Input Ironing”)
  - Partition bidders into buckets by their bid.
  - Treat all bidders in a bucket the same.
  - E.g. all bids in 11-20 are treated as 11.
  - Sharing only allowed within bucket.
- B. “Output Ironing”
  - Cancel assignments as needed to maintain monotonicity.

A. Bucketing



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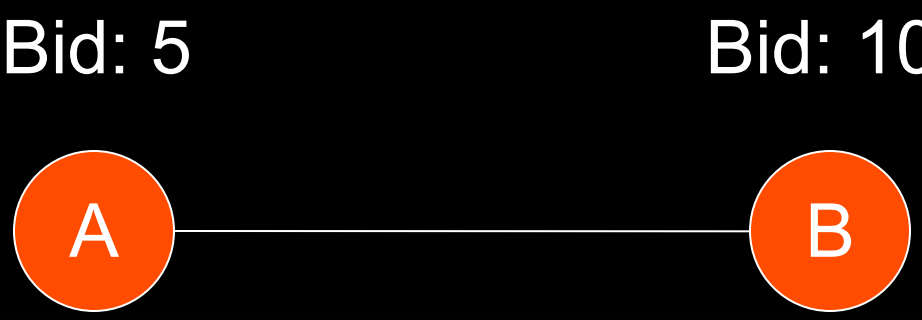
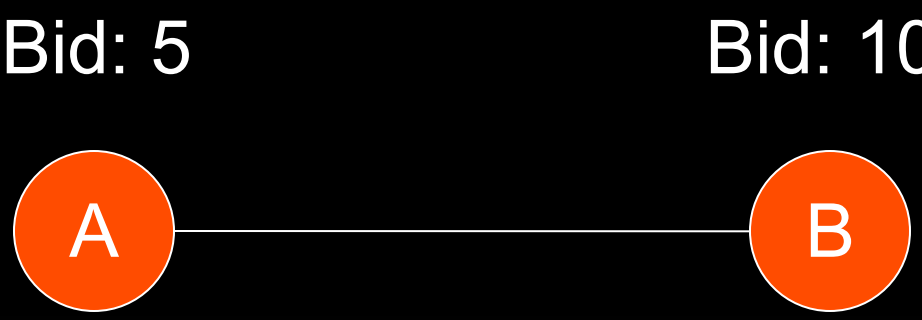


B. Output Ironing



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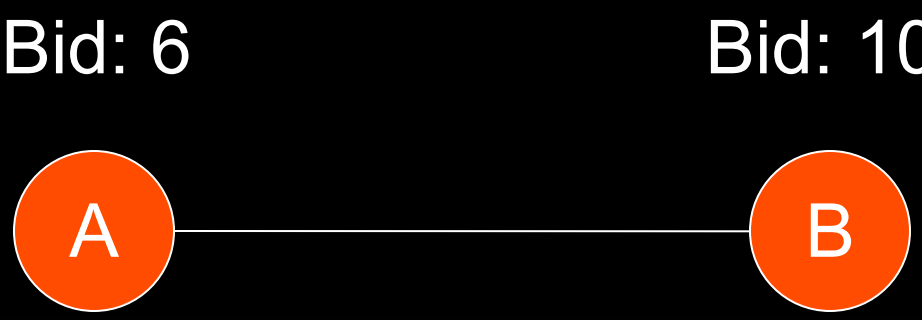


B. Output Ironing

Bid: 6

Bid: 10

Channels: 1,2
Bucket: 6-10

Channels:
Bucket: 6-10

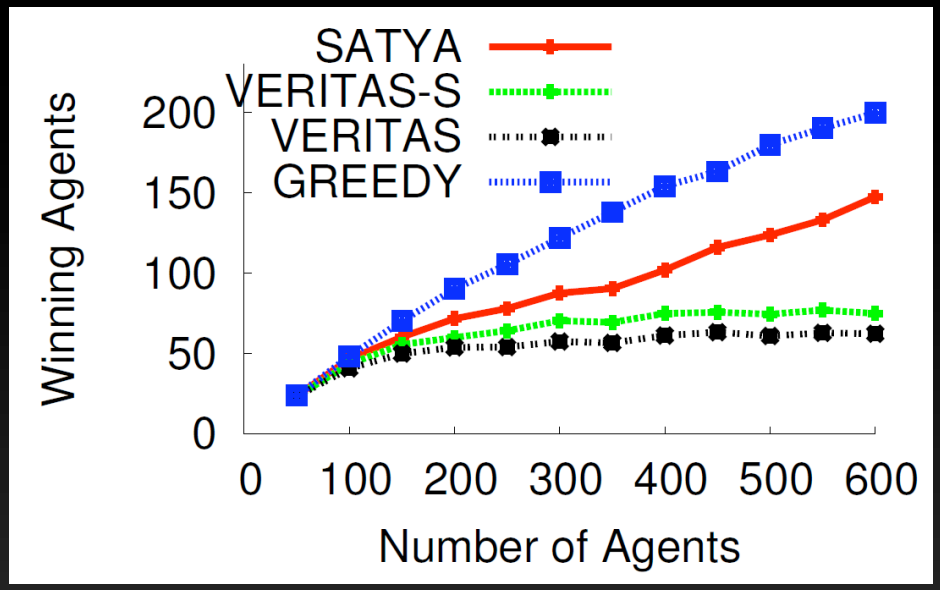
Simulation Parameters

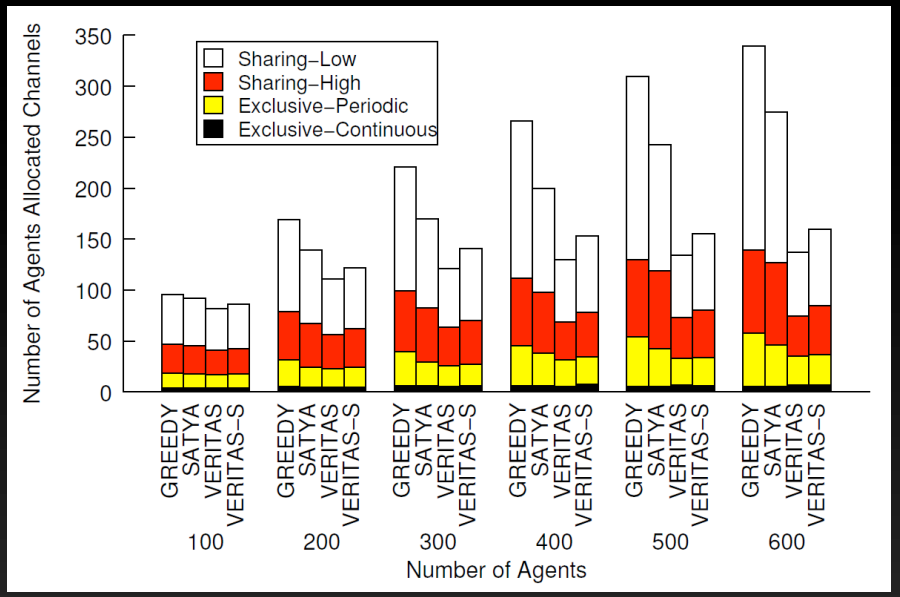
- Assigned bidder types based on current applications:

Agent Type	*Act. Prob.*	*Bid*	*Penalty*	*Demand*
Exclusive-Continuous	1	[0, 1000]	10000	1
Exclusive-Periodic	[0.05, 0.15]	[0, 1000]	5000	1
Sharing-High	1	[0, 1000]	10000	[0.3, 1]
Sharing-Low	[0, 1]	[0, 1000]	5000	[0.3, 1]

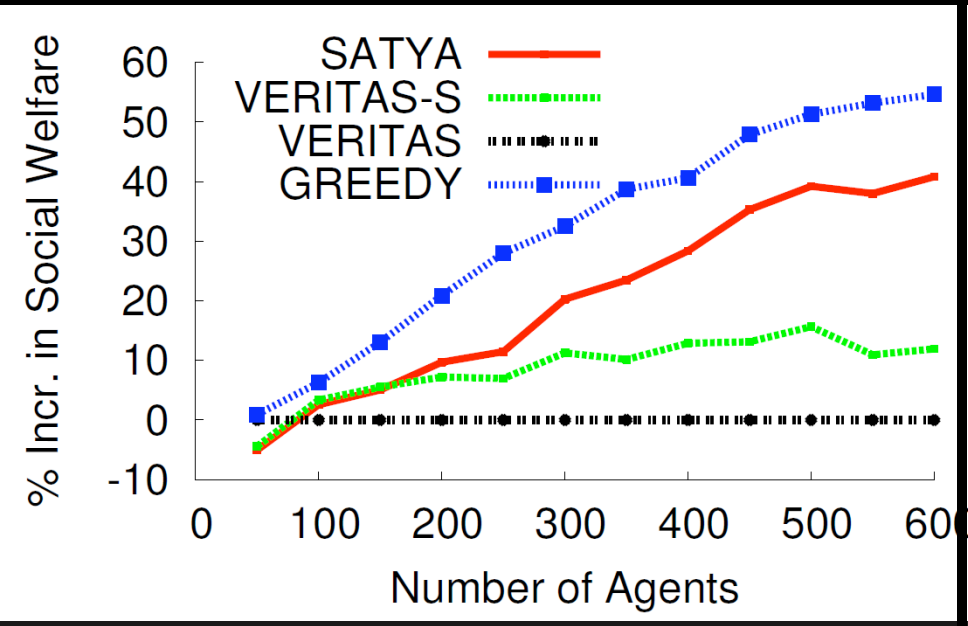
- Randomly located in 25 x 25 mile area around a city according to population density.
- Did propagation modeling to generate conflict graph.

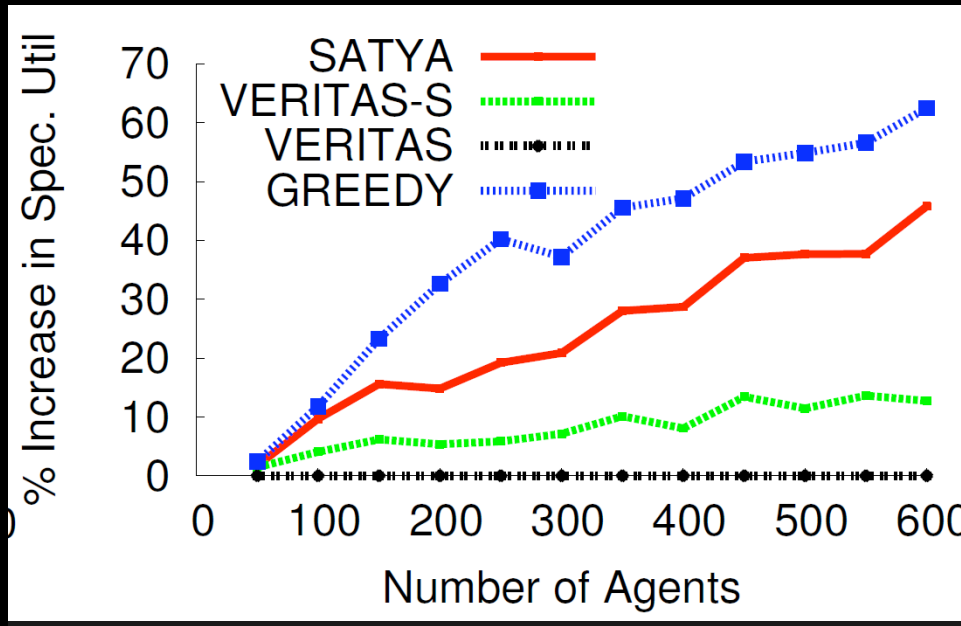
Results I: # and Distr. Winners





Results II: Efficiency Gains





Conclusions

- Agenda: electronic markets to support lots of micro-transactions
- Some challenges:
  - easy for users, hidden
  - align incentives with information sharing
  - sustain community norms
- This talk:
  - incentive compatible accounting and application to P2P file sharing systems
  - auctions for dynamic sharing w/ externalities

Thanks!

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