Boosting Market Liquidity of Peer-to-Peer Systems Through Cyclic Trading

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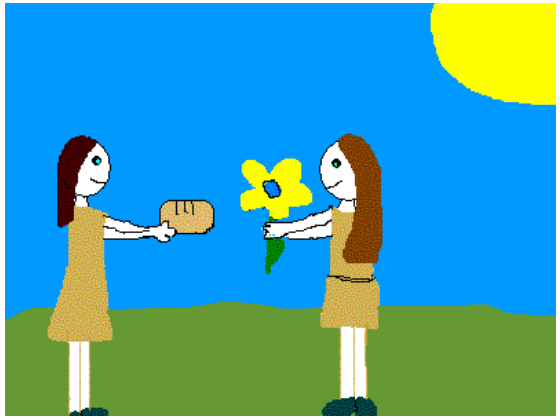
A Renaissance of Barter?

- **Most economical systems today are money-based**

- **Advantages of monetary systems**
  - Money overcomes problems and inefficiencies of barter markets!
  - More flexible: do not have to find matching good (and amount) for trade
  - Temporal flexibility (can store money)

- **But barter markets continue to exist**
  - Neighborhood barter markets in Barcelona
  - Apartment barter (switch cycles of «assigned apartments» in 80ies in Russia)
  - Organ donation markets
  - And above all: Internet-based barter!



Example 1: Barter Markets near Tarragona!

People in Barcelona meet regularly to trade stuff!

Kirsten Dirksen
Co-founder, faircompanies.com

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Barter Markets: Can Trading Beef for a Backpack Keep Consumption in Check?

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Blame it on the recession, the Internet, or a rejection of consumerism, barter markets are no longer fringe in Barcelona (see video Barcelona's barter markets: an antidote to overconsumption).

I first heard about this world without money a couple years ago from a friend who had just exchanged a head of lettuce for a baby backpack.

How to buy without money

"So they didn't want money for it?," I asked staring at the hard-framed baby carrier -- worth about $100 new -- that she'd swapped for just a piece of produce.

"No, you have to exchange things," she explained for the fourth or fifth time that afternoon. "That's the point. It's an exchange market."

She was talking about the seasonal barter market that goes on in her neighborhood in Barcelona.

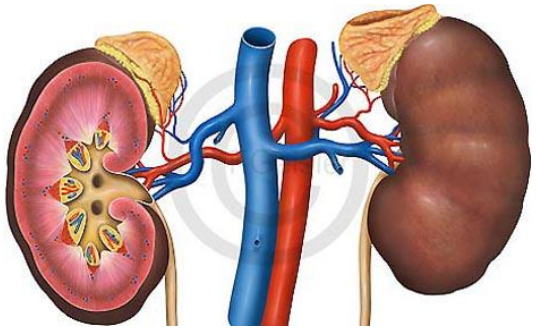
Example 2: Organ Donation Market

- Monetary trade with organs forbidden by law!
- But what if you do not have a relative who is able to donate?
- Mechanism design: organ market!
  - Today, bilateral or even multilateral trades take place!
  - Multiple transplantation must occur concurrently! (No money allowed...)
  - 2007 Nobel Memorial Prize in Economics
  - According to Michel Goemans (MIT), surgeries for up to 7 patients (= 14 people) simultaneously! Gammoid theory to maximize number of survivors.

A. brother ⇢ B

B. daughter ⇢ C

C. nephew ⇢ A



Peer-to-Peer Content Distribution

- Largest barter however today: Internet!

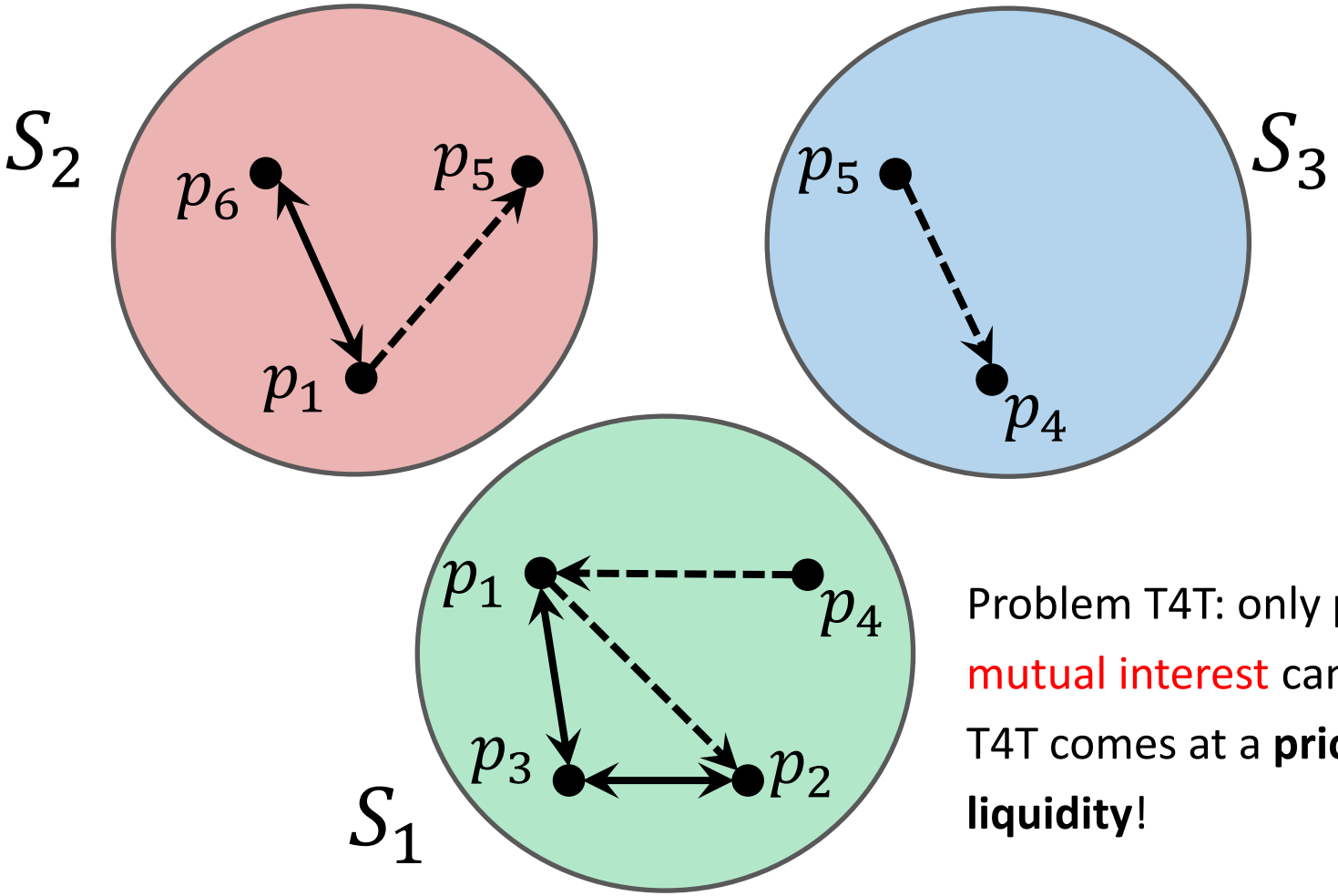
- For example: peer-to-peer computing
  - Monetary solution too complex (virtual money, anonymous context, ...)

- Peer-to-peer content distibution attractive for its scalability
  - More peers = more uploaders («cake grows with the number of eaters»)
  - For example, used in BitTorrent, Wuala (other talk) in a hybrid manner, ...

- But how to prevent free-riding?
  - Bram Cohen: fairness can be achieved on a single file by trading blocks!
  - «Tit-for-tat» like schemes: instantaneous fairness (no money!)
  - But how to solve the bootstrap problem?
  - Optimistic unchoking exploited by BitThief client (bitthief.ethz.ch)
  - Strategic clients such as BitTyrant

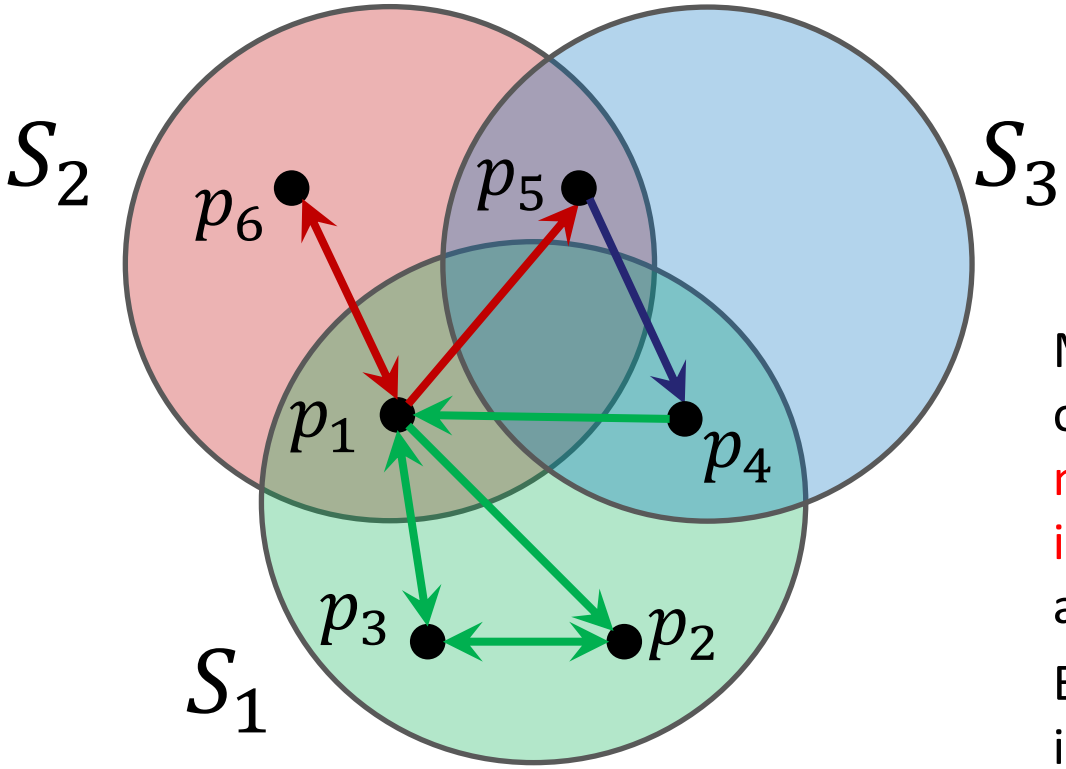
Tit-for-Tat Trading in Swarms

- Usually, trades in different swarms are independent:



Problem T4T: only peers with mutual interest can trade! Thus, T4T comes at a **price of market liquidity**!

Inter-Swarm and Cyclic T4T Trading



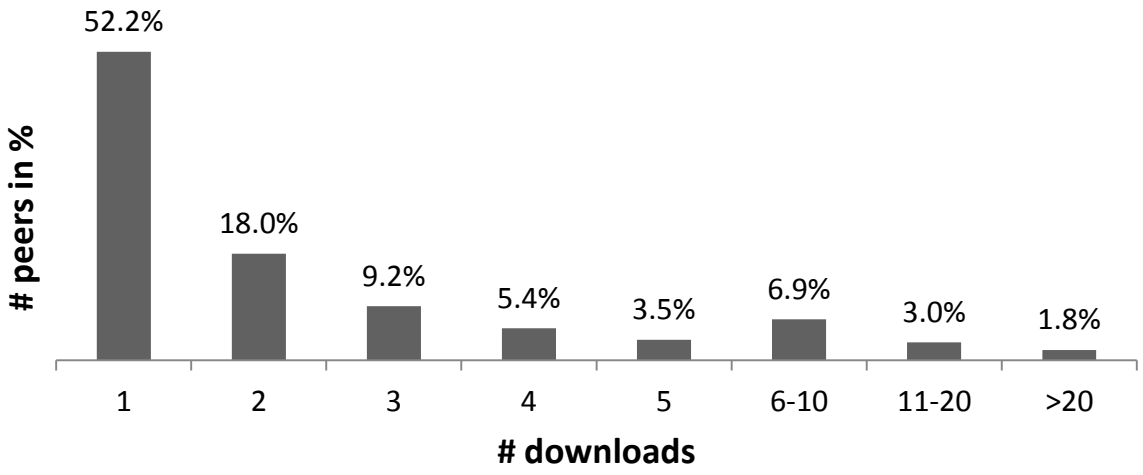
Many unused trading opportunities! Idea: improve market liquidity by allowing inter-swarm trades and trades along cycles (see organ market)!

Example: **p1->p5->p4->p1** interest cycle!

Idea: Cycle(k) looks in k-neighborhood for cycles, trade T4T along cycle!

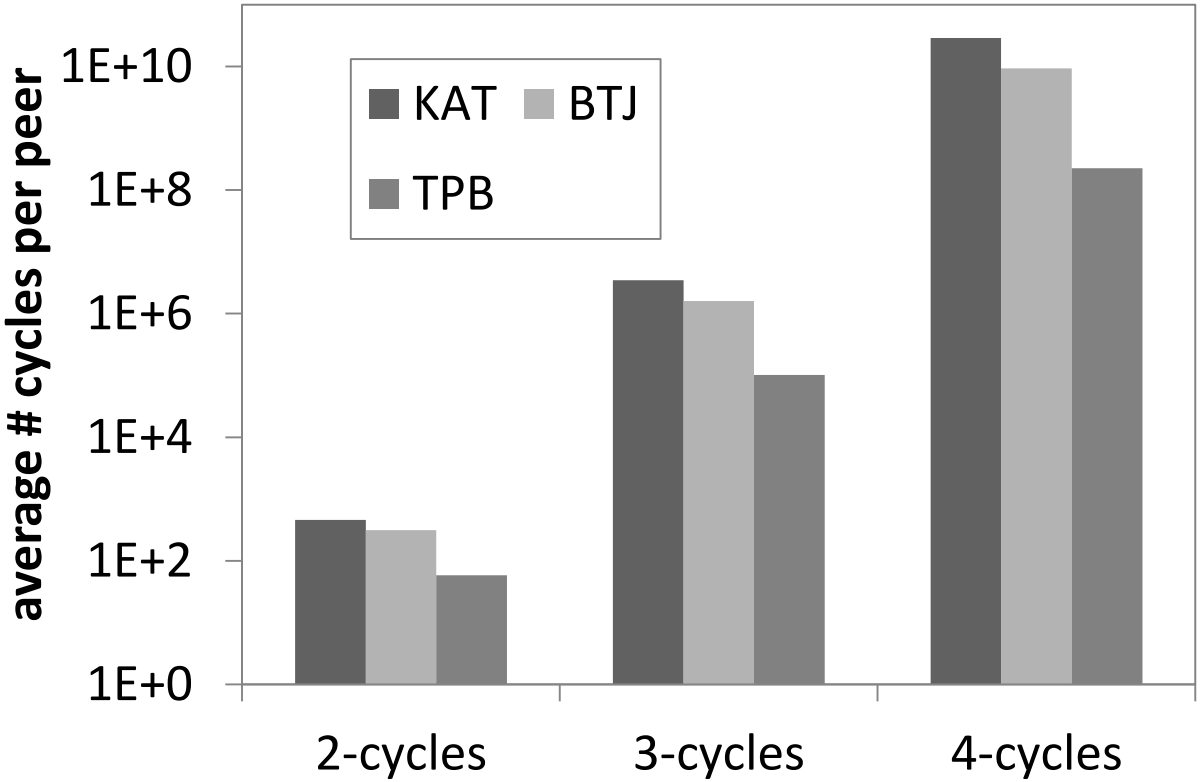
BitTorrent: Downloads per Peer

Motivation: almost 50% of peers are active in multiple swarms simultaneously => lots of opportunities?



Data source: C. Zhang, P. Dhungel, D. Wu, and K. W. Ross, "Unraveling the BitTorrent Ecosystem" IEEE Transactions on Parallel and Distributed Systems, vol. 22, no. 7, 2010.

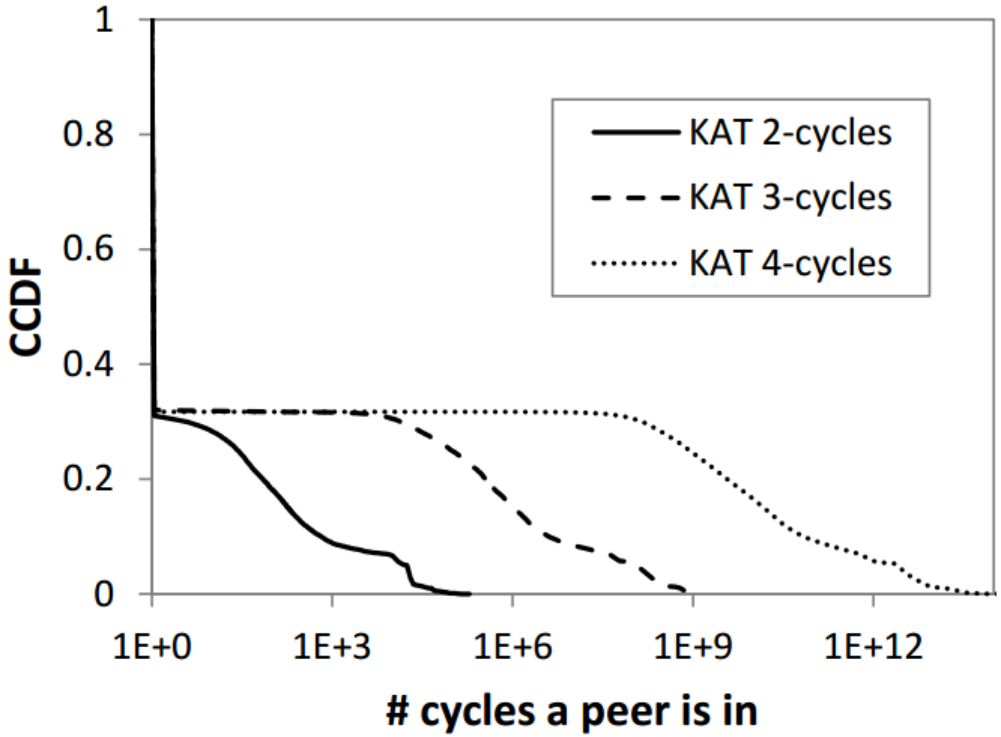
Motivation: number of (interest) cycles grows significantly with k.



Data source: Top 100 video torrents (highest Alexa rank)
Kat.ph, Btjunkie.org, Piratebay.org

Cross-Swarm Cycles in BitTorrent

Motivation: peers take part in many cycles.

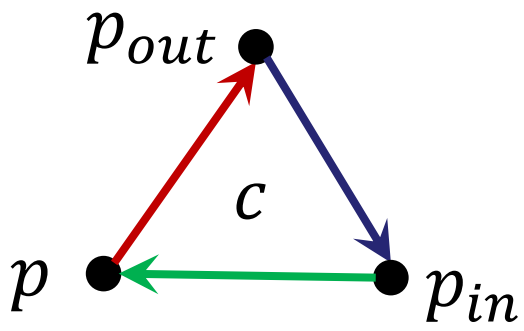


Paper Overview

- Empirical study of number of cycles in different p2p networks
- Algorithm to exploit cycles
- Study of performance benefits (the «Price of Tit-for-Tat Mechanism»)
- Extensive simulations (based on observed distributions, with realistic latencies, using active sets, etc.)
- New model for peers' download preferences combining *preferential attachment* with *co-occurrence principles*
- Discussion of possible pitfalls, such as redundant downloads (and solutions)

Algorithm Cycle(k)

- At each peer p
  - Keep track of k-neighborhood in demand/interest graph
  - Compute possible trading cycles (brute force)
  - Trade in tit-for-tat manner on any cycle of length at most k as long as it exists (use cycle ID): local decision



T4T on cycle c

$\Delta = 0$;
loop
    if($\Delta \geq 0$)
        send file block to p_{in};
        $\Delta --$;

    if(receive block on c)
        $\Delta ++$;

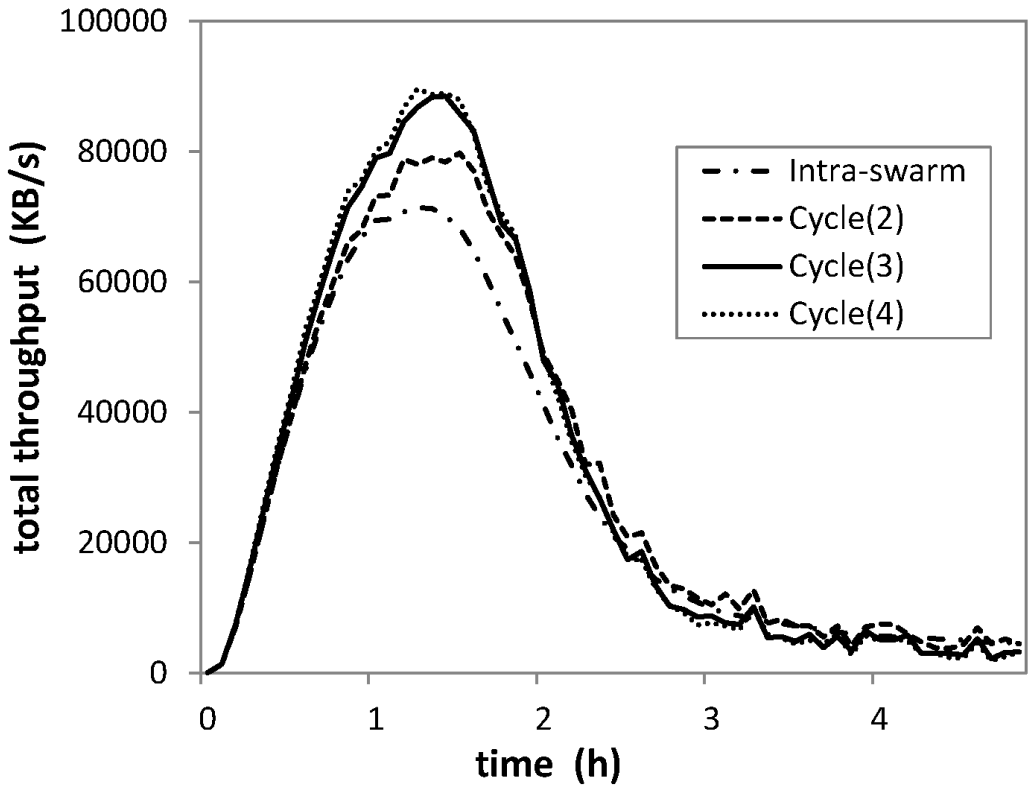
Simulation

- Event-driven simulator in Java

- Base scenario
  - 365 peers, 100 swarms
  - 512 MB files, 500 KB blocks
  - Upload bandwidth $\leq$ 500 KB/s, download bandwidth unlimited
  - 1 publisher/seeder per swarm
    - Seeds at 10 KB/s
  - Constant and multi-modal / Gauss latencies

- 10 simulation runs for `Intra-swarm`, `Cycle`(k) with $k = 2,3,4$
  - Sample all $D_p = |\#\text{ downloads}|$ at p from BitTorrent data
  - Choose D_p swarms for each peer u.a.r.
  - p starts downloads in a Poisson process with $\frac{1}{\lambda} = 10\text{ min}$

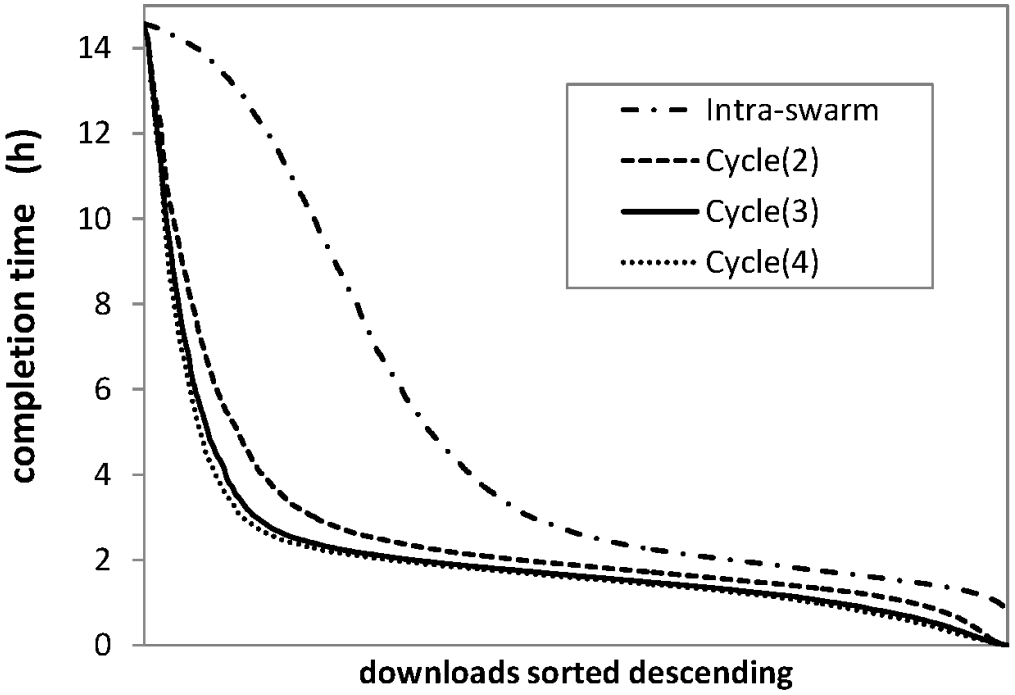
Evaluation: System Throughput



Take home messages:

1. **Cycle(2) already nice improvement (12%) over intra-swarm!**
2. **Cycle(3) yields 24% increase of peak rate.**
3. **Higher cycles lenghts do not give you so much! (Good news as cycles are more complicated to compute, maintain, synchronize!)**

Evaluation: Download Completion Times



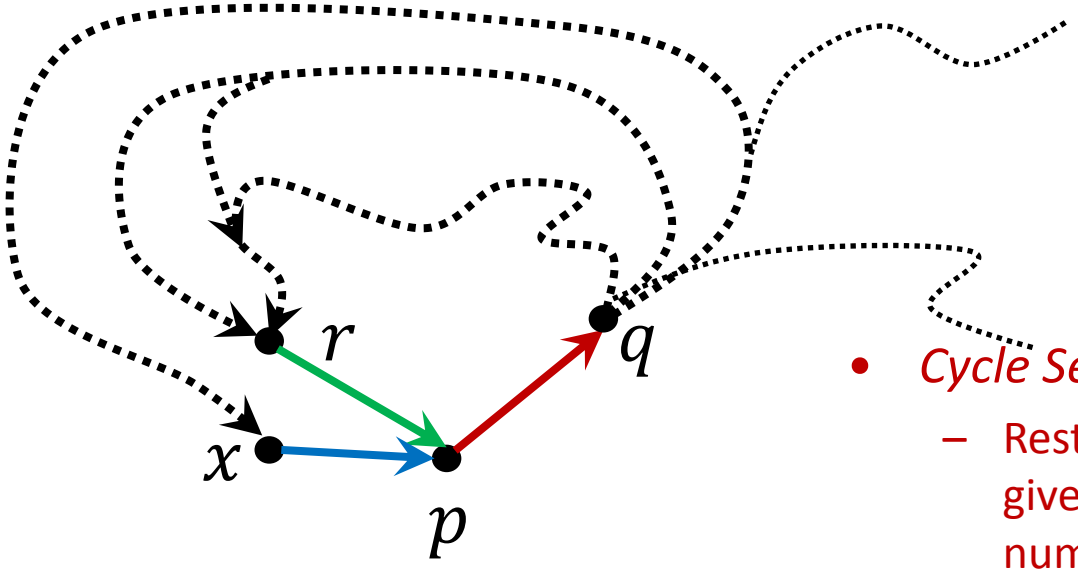
Take home messages :

1. **Intra-swarm has completion time of 5h on average!**
2. **Cycle(2) down to 2.5h on average (49% on average, 85% of all downloads finish faster)**
3. **Cycle(3) improvement of 58% on average (2h 8min), 97% of all simulated downloads faster**
4. **Higher improvements for download time than for peak rate! But some redundant requests: twice as many duplicates as for 2-cycle!**

Reduce Redundancy

- Trade-off liquidity vs. redundancy
  - Problem: if too many interest cycles over a given neighbor, neighbor cannot provide so many different new blocks!
  - Problem: peers ask random missing block, but re-request a pending block when neighbor has no non-requested blocks anymore

=> threat of re-requesting a block many times: redundant downloads (or unfair)

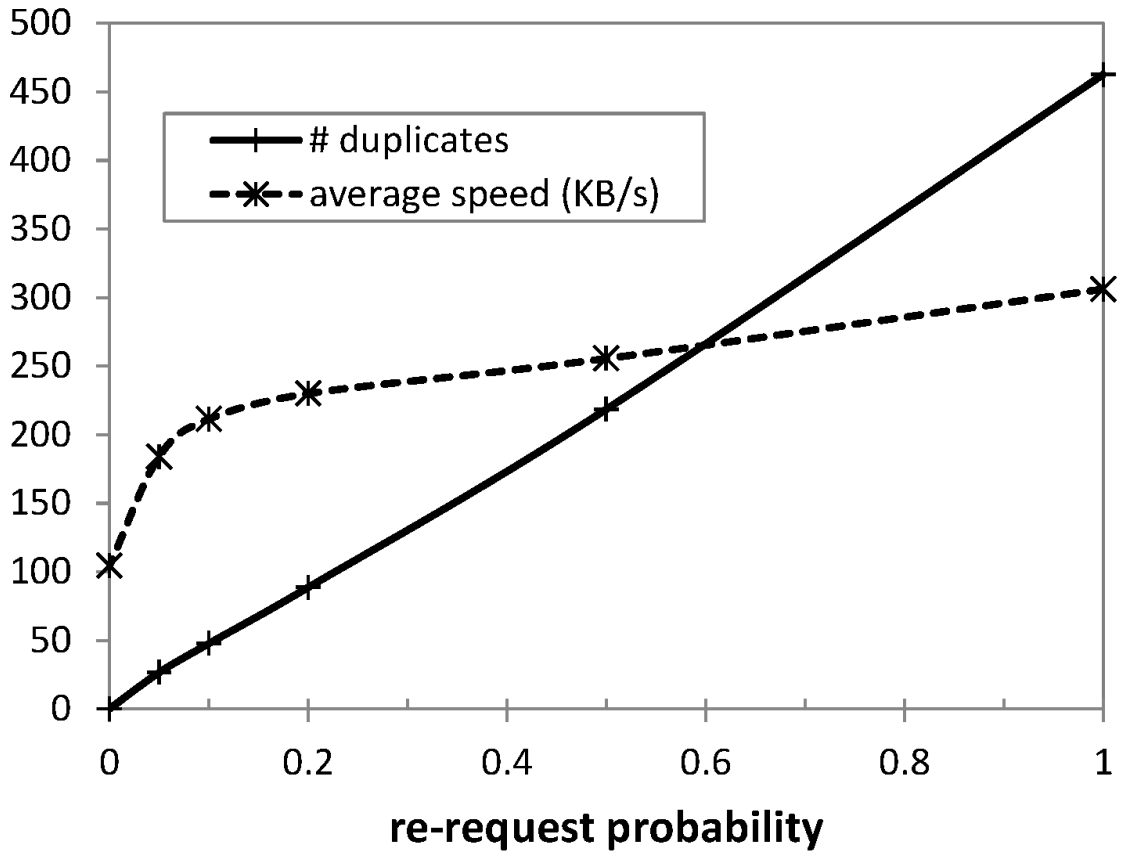


- *Cycle Selection*
  - Restrict number of cycles over a given neighbor depending on number of blocks it has!
- *Probabilistic Re-Request*
  - Re-request with prob ρ

Probabilistic Re-Request

Good news: duplicates increase linearly with re-request probability, while for average download speed it does not help so much

⇒ **Tradeoff!**



A good choice? :

- $\rho = .5$ for `Intra-swarm` and `Cycle`(2)
- $\rho = .1$ for `Cycle`(3) and `Cycle`(4)

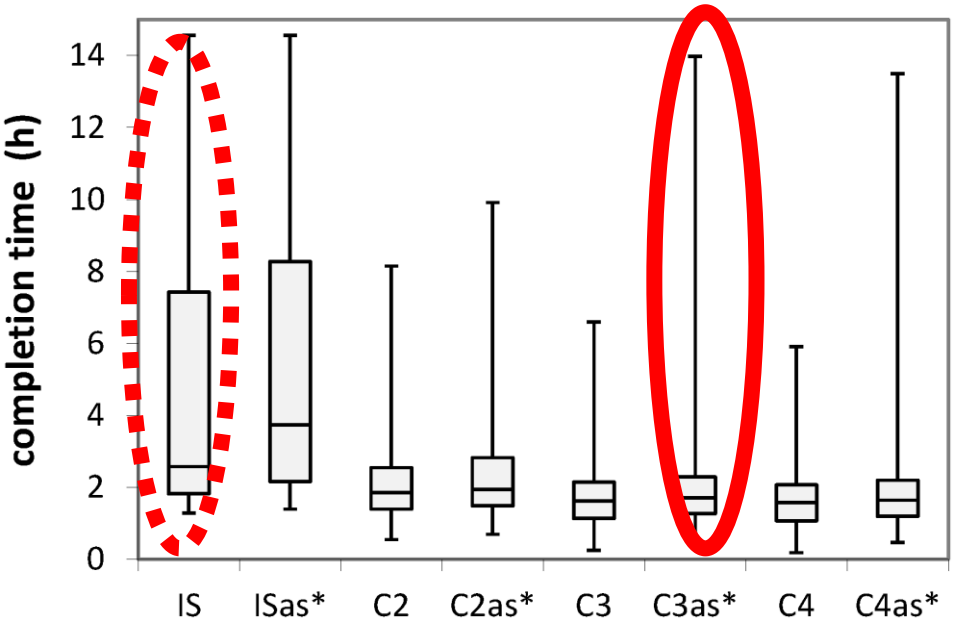
➔ average redundancy < 5%

Final Evaluation

Further extensions:

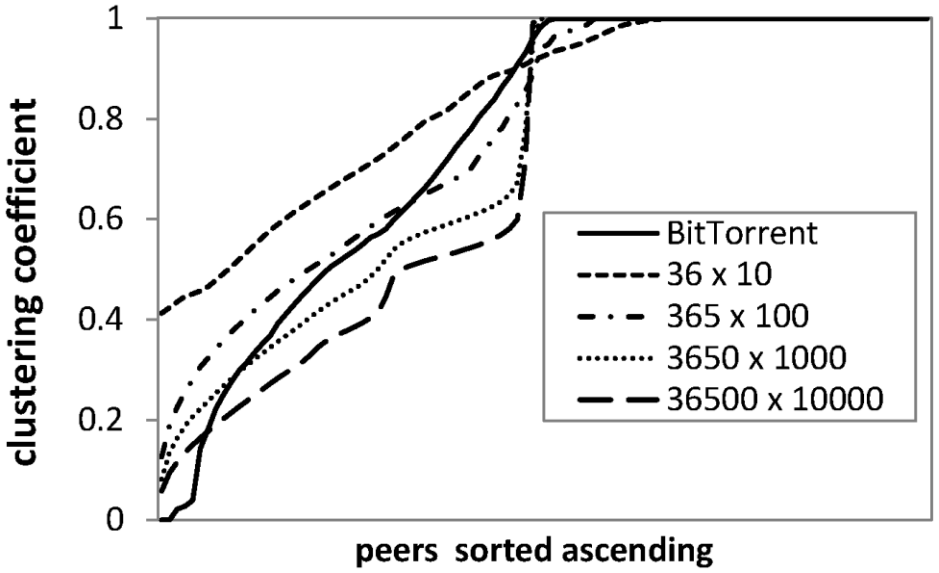
- Active set concept: peer only trades with 10 most active peers per swarm (optimistic unchoking to find new ones)
- Intra-swarm (IS) vs IS with active set (as) and redundancy-avoidance mechanism in place (*)

Example: compared to IS, even with as and * C3 yields reduction of download completion time of 44% (average) with 2.6% duplicates (average).



Also in the Paper..

- Modeling preferences to fit clustering coefficients
  - Preferential attachment:
    popular swarm more popular
    (but what about clustering?)
  - Co-Occurrence:
    peers together in many swarms
    more likely also in other swarms



$$Pr[p \text{ enters } S] \approx \frac{(|N_p \cap S| + 1)^{\alpha} + (|S| + 1)^{\beta}}{\sum_{X \in \mathcal{S}} (|N_p \cap X| + 1)^{\alpha} + (|X| + 1)^{\beta}}$$

- Distributed implementation CYCT4T
  - Approximates k-neighborhood to prune search space

Conclusion

- P2P, a Renaisance Age for barter?
- Inter-swarm trading can boost download speeds and durations (first study!)
- Especially short cycles useful, no big difference between Cycle(4) and higher!
  - This is good news as short cycles are less complex!
- Open questions, e.g., on selfish behavior
  - Cross-swarm trading: peerrs remain online longer, keep data as seeders?
  - Peers prefer shorter cycles (e.g., more robust)?
  - Collusion: fake many cycles? (Balance per peer in addition to per cycle)
- Privacy? Do not need to know which swarms a peer in,

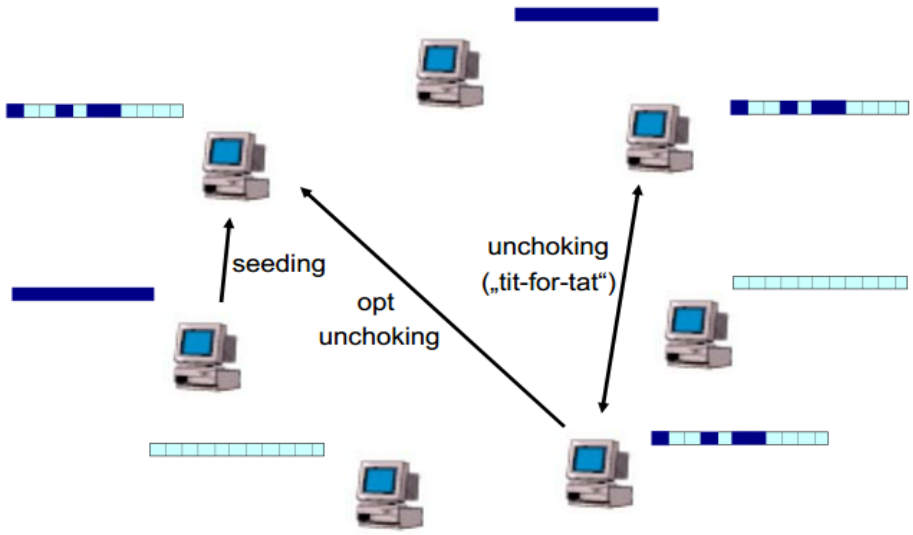
  only interest graph: okay?


Thank You!
Questions & Comments?
www.net.t-labs.tu-berlin.de/~stefan

Simplified BitTorrent in a Nutshell

- Peers interested in same file are organized in swarm
  - Peers in swarm trade blocks of shared file
  - «Tit-for-tat» (actually active set trading) with some peers, seeding others, optimistic unchoking to find new active set candidates, ...

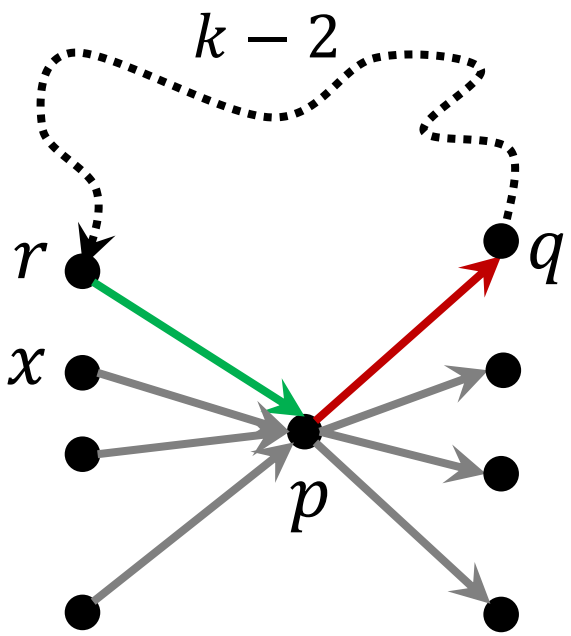
- Tracker organizes swarm
  - Get new set of random peers when needed



Cyclic Trading Protocol CYCT4T

inTable

source	via	dist
q	r	$k-1$
r	r	1
x	x	1
…		



outTable

id
q
…

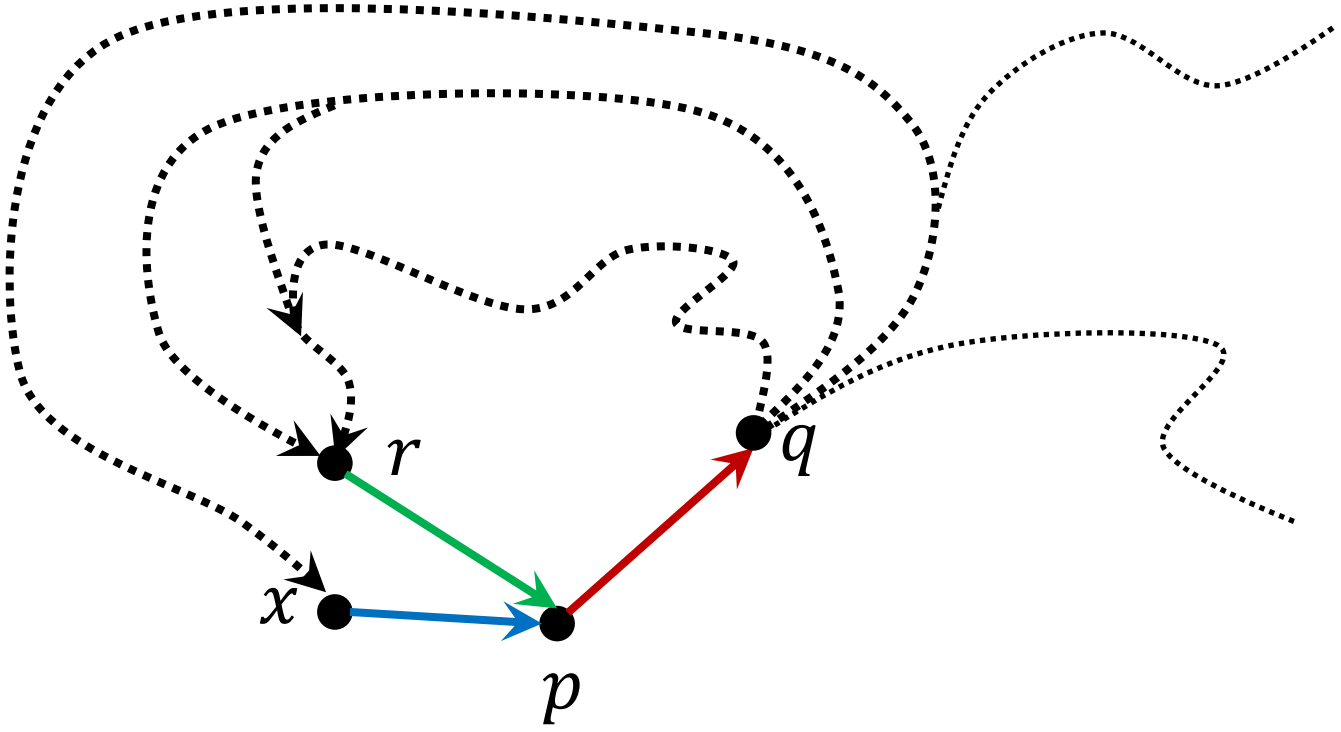
Update:

```
SELECT DISTINCT source, dist
FROM inTable
WHERE distance < k - 1
AND via ≠ q;
```

Out-neighbors on cycles from r:

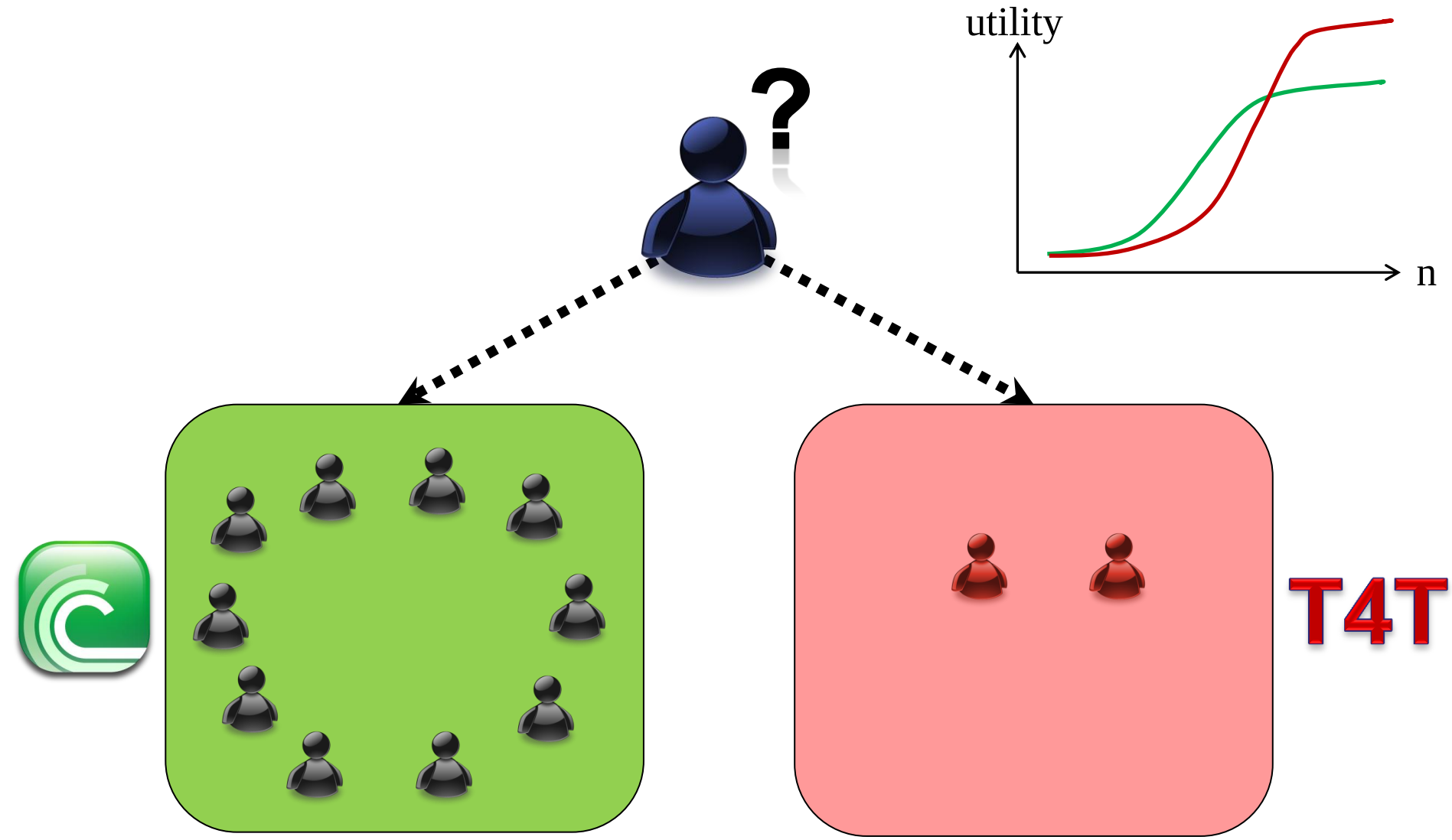
```
SELECT id
FROM outTable INNER JOIN inTable
ON outTable.id = inTable.source
WHERE via = r;
```

Cyclic Trading Protocol CYCT4T

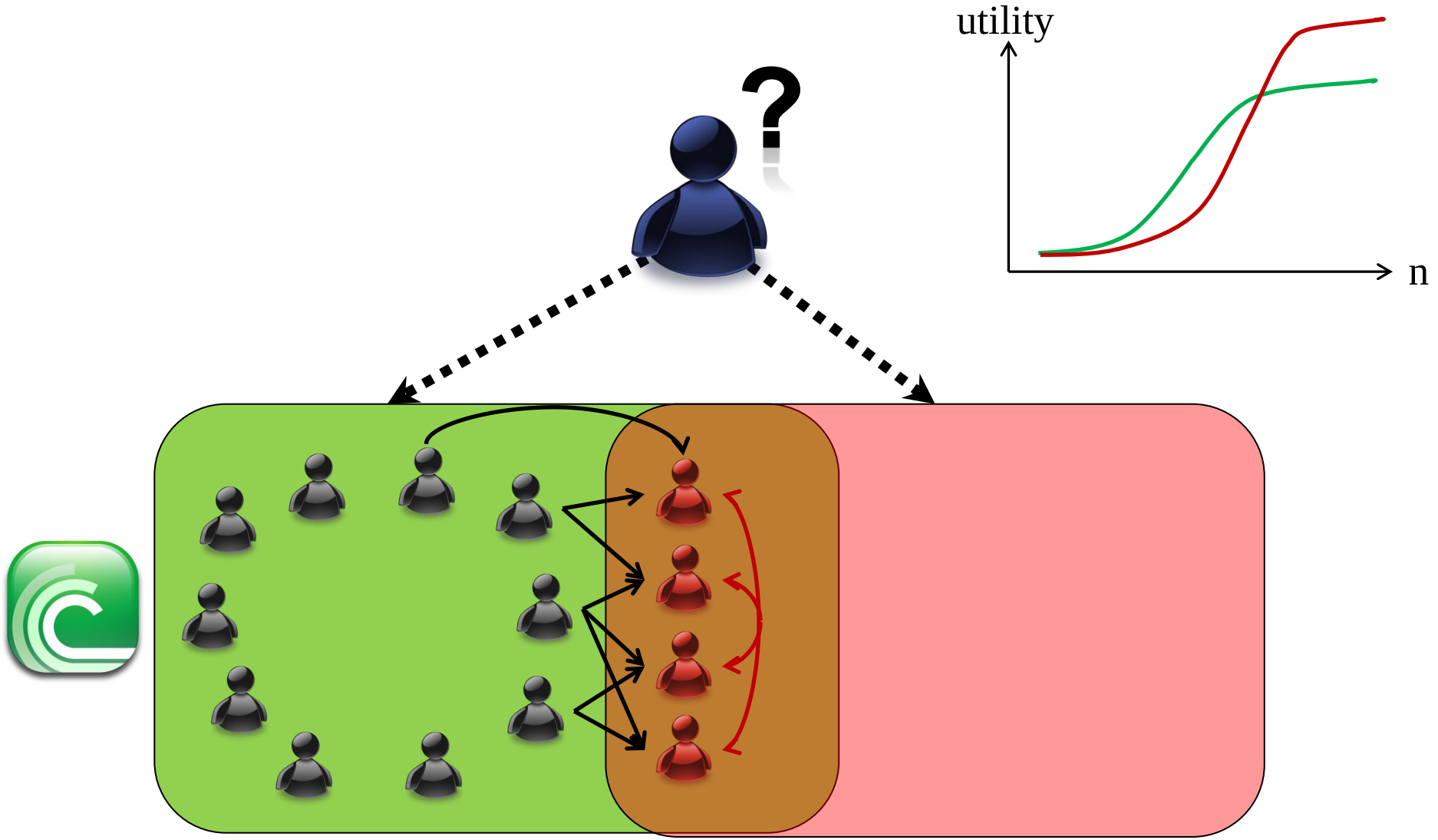


$$CID = h_p(p||q) \oplus (q||\_) \oplus \ldots \oplus h_r(r||p)$$

Established Equilibrium



BitThief: Smooth Transition



BitThief: Smooth Transition