Peer-Assisted Content Distribution with Prices

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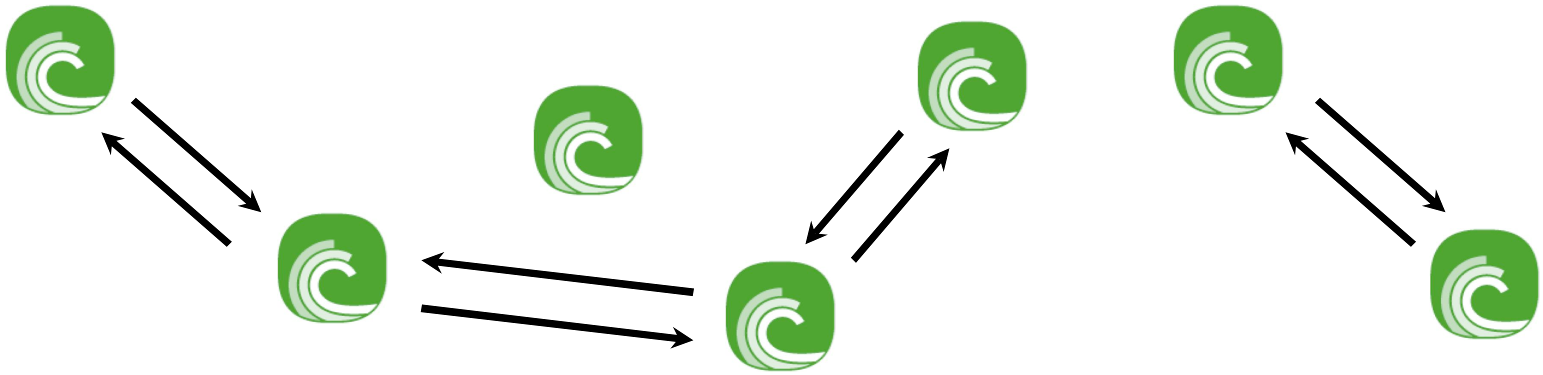
Peer-to-peer technology today

- Comprises 35-90% of “all” Internet traffic

- Not just a technology for (illicit) filesharing

Content exchange mechanisms

- Most prevalent exchange systems are *bilateral*: downloading possible in return for uploading to the same peer.



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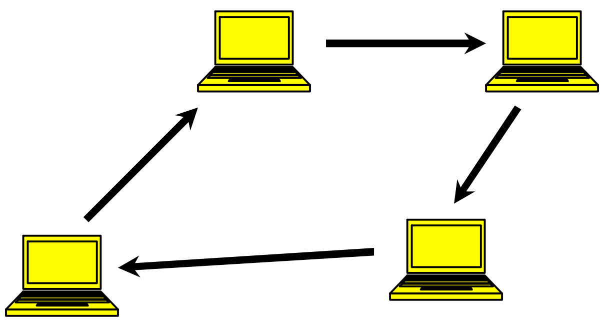

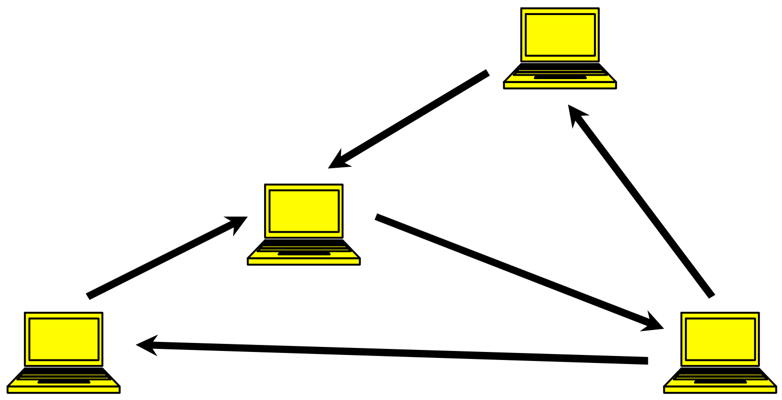

Content exchange mechanisms

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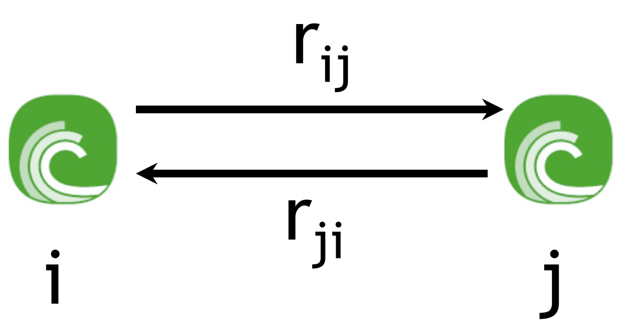
- Questions:

  What are the benefits of multilateral exchange?

  Is multilateral exchange feasible?

Bilateral content exchange

- Peers exchange content on a *pairwise* basis
- Let r_{ij} = rate of upload from i to j
- *Exchange ratio*: $\gamma_{ij} = r_{ij} / r_{ji}$



BitTorrent and BitTyrant

- Canonical example: BitTorrent
- Peer j splits upload rate B_j equally among k_j peers with highest rates to j (the "active set")
- For a peer i in the active set: $\gamma_{ij} = B_j / (k_j \, r_{ij})$

- Note:
  This is decreasing in r_{ij}, so there is an incentive for i to make r_{ij} as small as possible while remaining in the active set) **BitTyrant**

Bilateral and Multilateral Exchange

- Model bilateral exchange via *exchange ratios*
- Multilateral exchange is enabled via *prices*: peers trade a virtual currency, where downloading from peer j costs p_j per unit rate
- Compare the two types of exchange through the resulting equilibria

Bilateral vs Multilateral Exchange

Bilateral Equilibria (BE):

- May not exist
- May be not be *Pareto efficient*
- May not be *robust to collusive deviations*

Multilateral Equilibria (ME) exist, are Pareto efficient, and are robust to collusive deviations (under mild conditions)

Bilateral vs Multilateral Exchange

Given information on popularity of files, and the number of files (N) and peers (K) in the system, compare *E[# of peers that do not exchange]*

Example: Preferences follow uniform distribution

If $N > K > \sqrt{N}$, then in large systems:

- Almost all peers exchange in ME
- A significant fraction of peers does not exchange in BE

Feasibility of Multilateral Exchange

- Choosing the right pricing scheme
- Network structure
- System design
- Simulation results

How should you price?

- ~~One price per file (PF)?~~
- One price per peer (PP)?
- One price per peer per file (PPF)?

If a PF ME exists, then PP ME exists.

But not vice versa: PF pricing can't account for locality of demand in the network.

How should you price?

- ~~One price per file (PF)?~~
- One price per peer (PP)?

  ≈

- One price per peer per file (PPF)?

The set of PPF ME is the same as the set of PP ME

How should you price?

- ~~One price per file (PF)?~~

- One price per peer (PP)?

  ≈

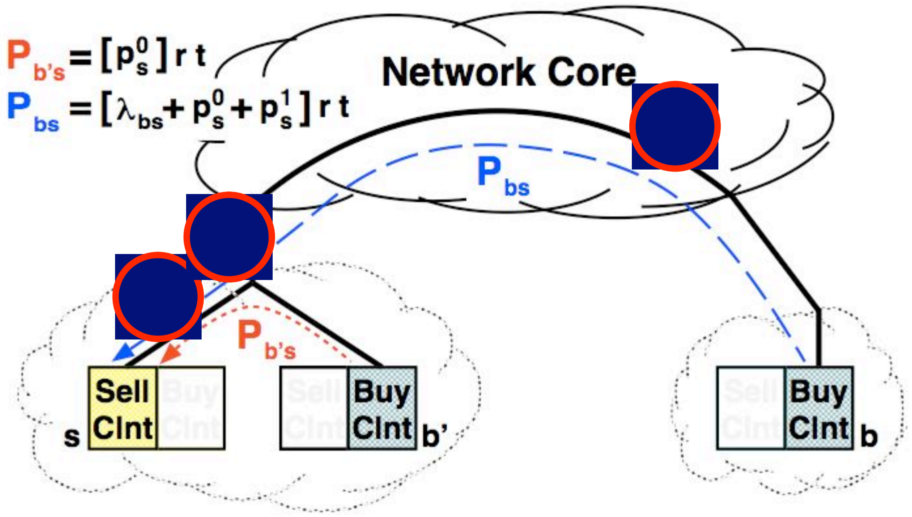
- One price per peer per file (PPF)?

- Practical advantages of PP:
  - State requirement less, service discipline easier
  - Simple (fully decentralized) price update

Prices and network structure

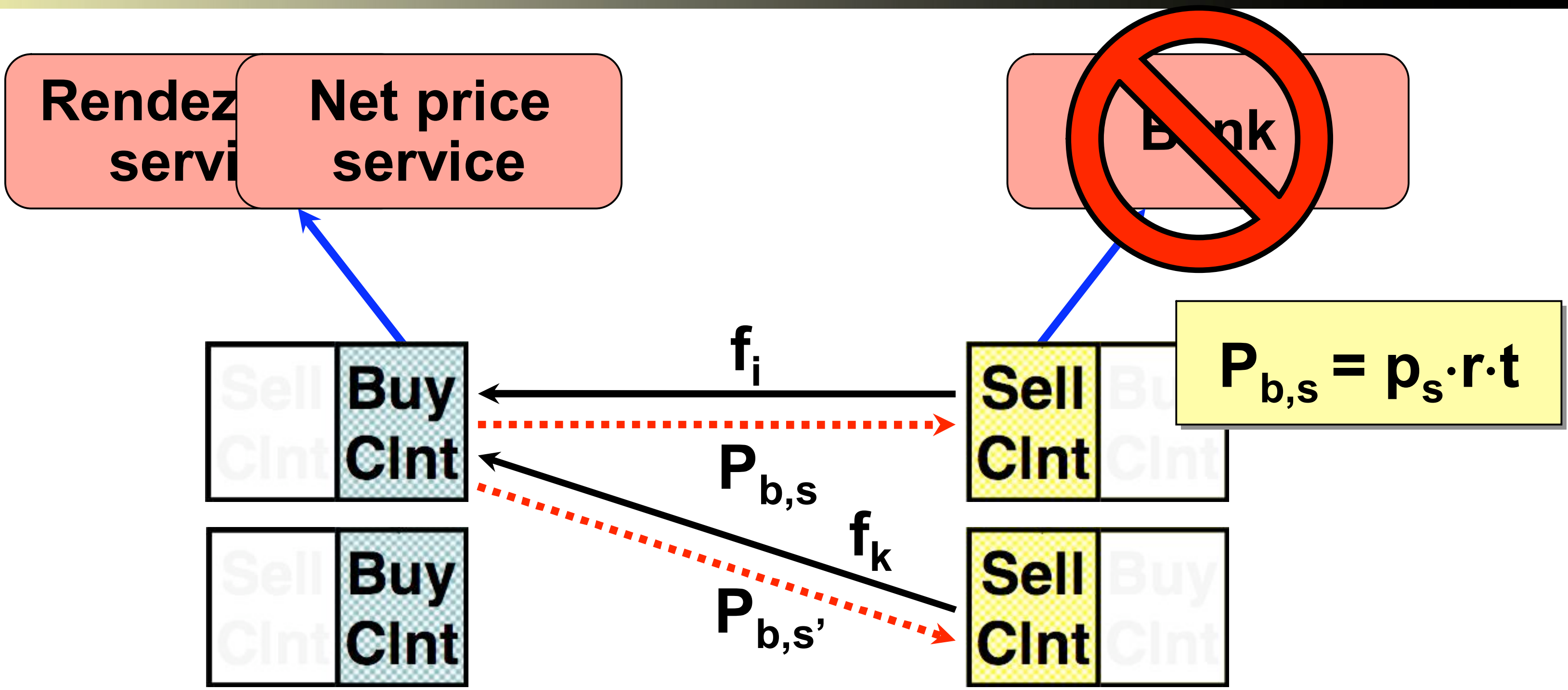
- So far we haven't explicitly dealt with network resource constraints.
- Ideal solution:
  One price per resource constraint)
  one price per network link
- This is not feasible yet
  (without ECN-like functionality)

Hierarchical network model



- Price different edge bottlenecks
- Price long-haul network carriage: λ_{bs}
- Network cost collection rebated to users

*P*rice-*A*ssisted *C*ontent *E*xchange

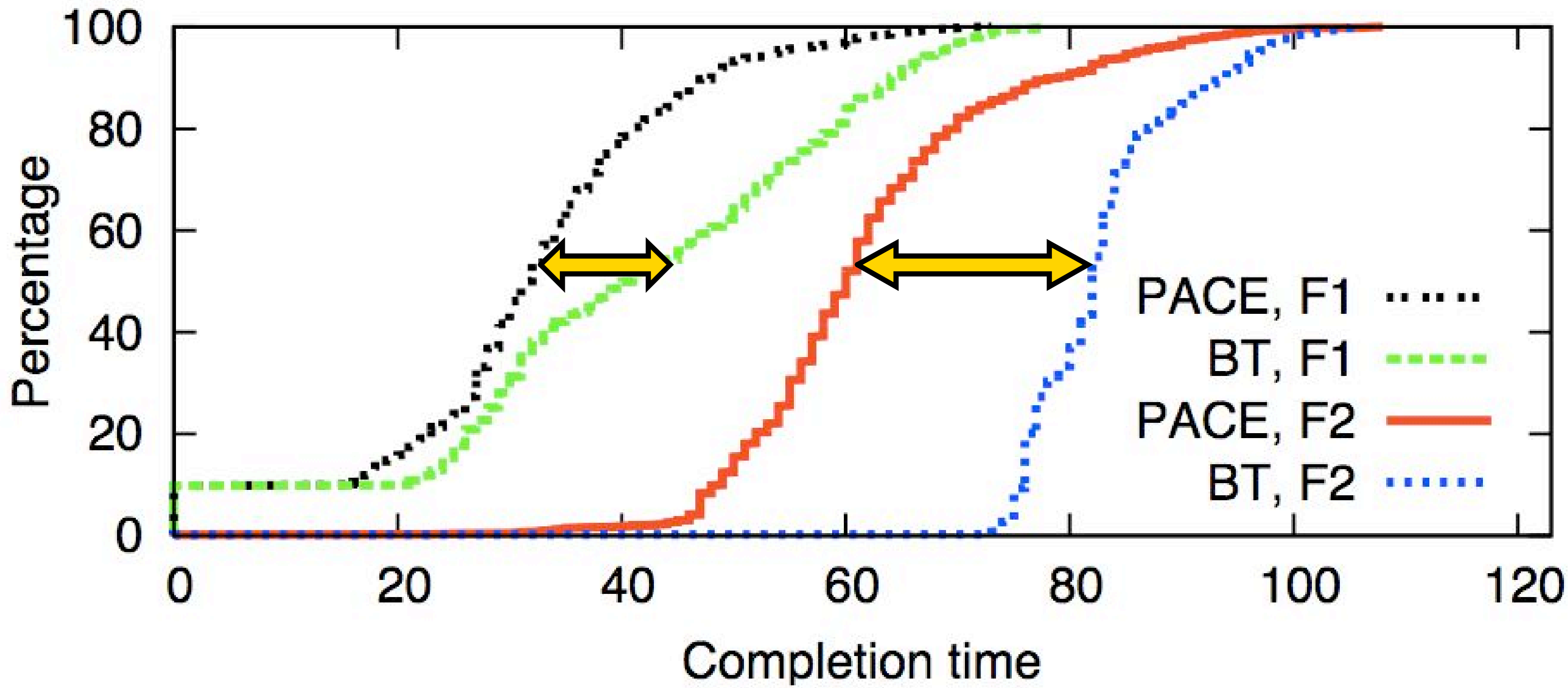


- Agents act as sellers and buyers for users
- Rendezvous service enables peer discovery
- Network price service supports network-friendly pricing
- In distrustful settings, also need a currency mechanism

Simulations

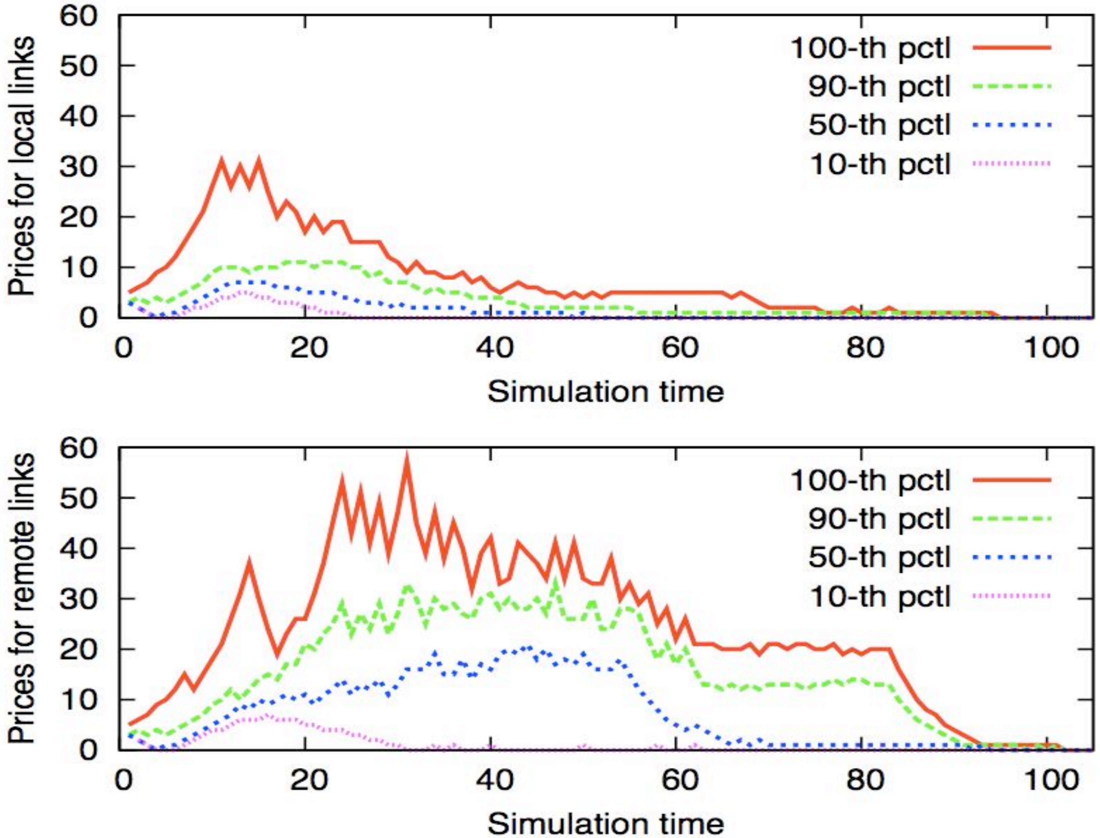
- PACE
  - Hierarchical topology (BRITE), varying link capacity
  - Network costs rebated equally to all users
  - 1000 initial currency, didn't matter much
- BitTorrent
  - Optimistic unchoking (2), active set sizing (max(4, $\sqrt{B}$))
  - Rate-based tit-for-tat with equal-split bandwidth

PACE vs. BT: Completion time



Two files: F1 starts at 10% of nodes;
F2 at a single node

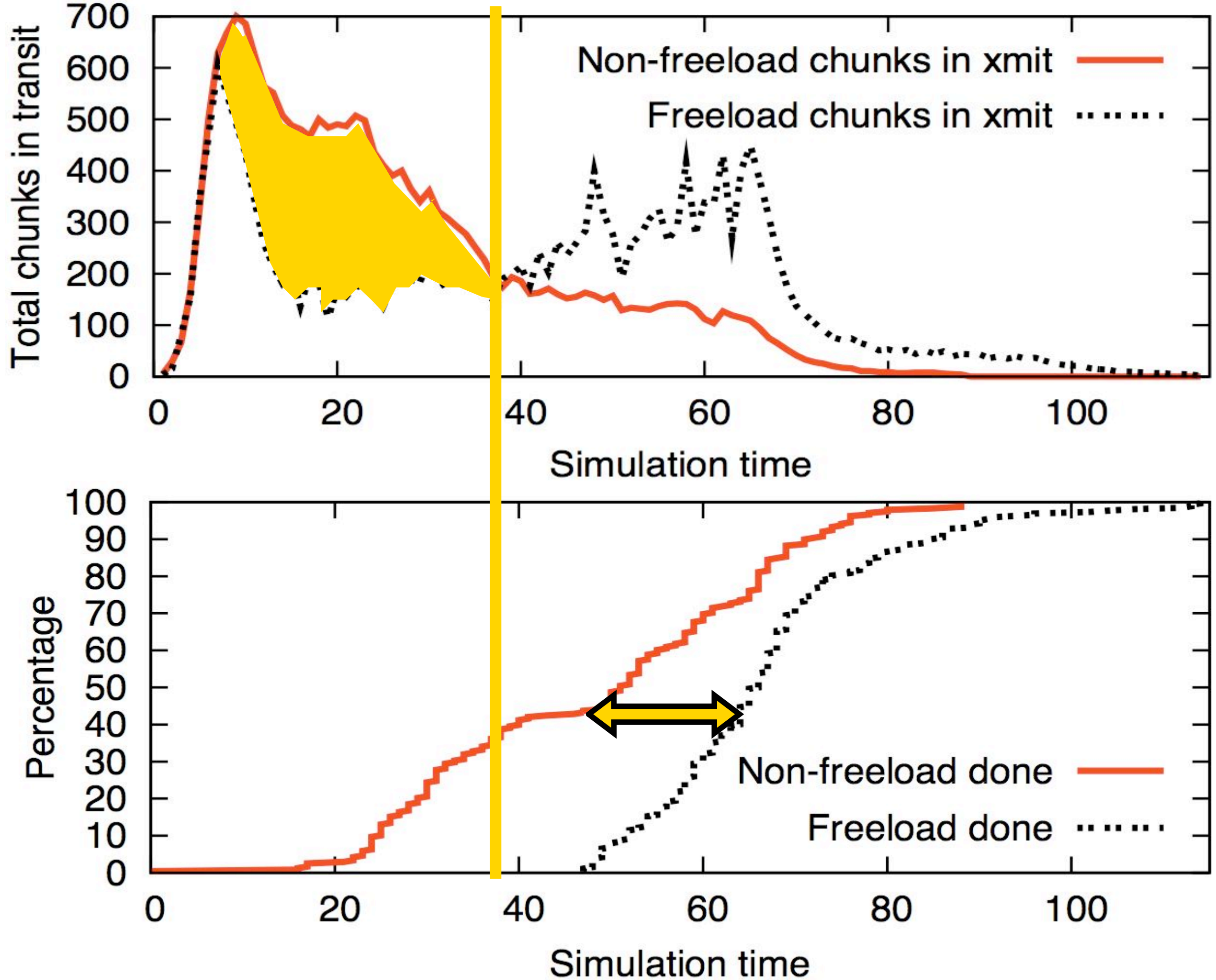
Network-friendly transfers



PACE: 130% more remote transfers than optimal

BitTorrent: 700% more remote transfers than optimal

Participation and performance



Common criticisms

- *"Prices and markets are too complex"*
  - Users completely unaware of prices / market
  - Prices can be coarse-grained (per peer)
    - Still capture desirability of different files
    - Still capture network constraints for ISP friendliness
- *"Currency requires a bank, which won't work"*
  - Secure and fair? Sellers / buyers can't cheat
  - Centralization? Most/all P2P systems have it already
  - Scalability? Techniques to reduce load and/or federate
  - Money supply? Unnecessary if currency short-lived
  - Sybils and bootstrapping? No worse and likely better

Conclusion

- Multilateral exchange: efficiency and robustness
- Bilateral exchange: simplicity
- Our work studies the feasibility of multilateral exchange in peer-assisted distribution

Incentives

- Buyers:
  - prefer local sellers to remote sellers
  - prefer “cheap” wide-area connections
- Sellers:
  - are incented to upload their most valuable content whenever possible
  - will not have an incentive to manipulate the price in a large system (i.e., with *sufficient competition*)
  - create competitors at an exponential rate when the file is uploaded to others

Implication for system dynamics

- Price-assisted multilateral content exchange
  - *Peer discovery*: Tracker sorts by explicit price
  - *Price discovery:* Locally set by supply/demand
  - Per-peer prices especially powerful
    - Can store prices at central tracker
    - Single demand/supply to track
    - Simple service discipline at sender
- Implicit prices in BitTorrent learned slowly *in situ*
  - Source of slow peer discovery
  - Source of freeloading (optimistic unchoking)

Hide complexity from users

- Users express:
  (1) Files to download and upload
  (2) “Saving rate” for the future
- Buy/sell clients shield user from price dynamics
- *Sell client price update*:
  Simple MIMD per supply/demand event
- *Buy client algorithm*:
  Split budget over desired files, greedily allocate per-file budget to cheapest peers