Performance and Locality Tradeoff in BitTorrent-like P2P File-Sharing Systems

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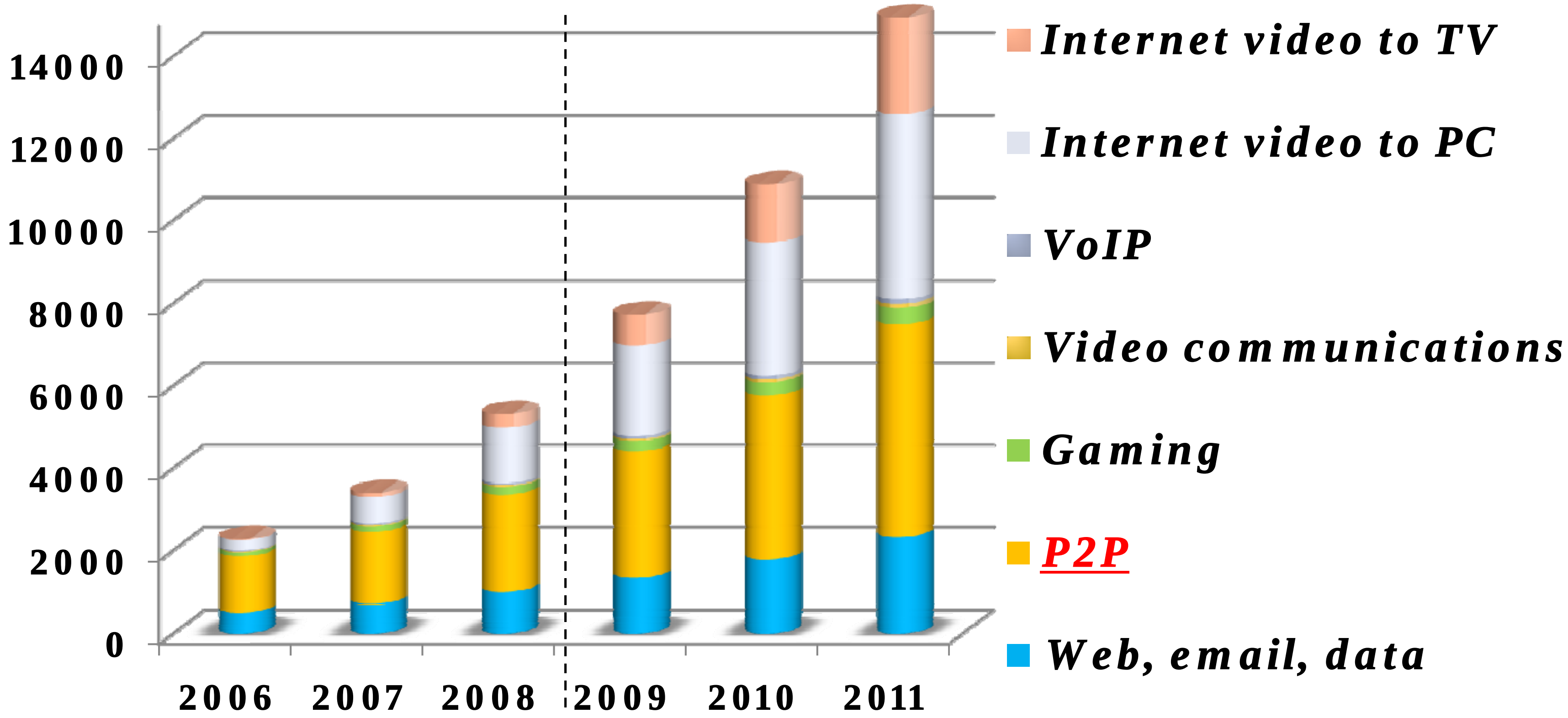
P2P Traffic Problem

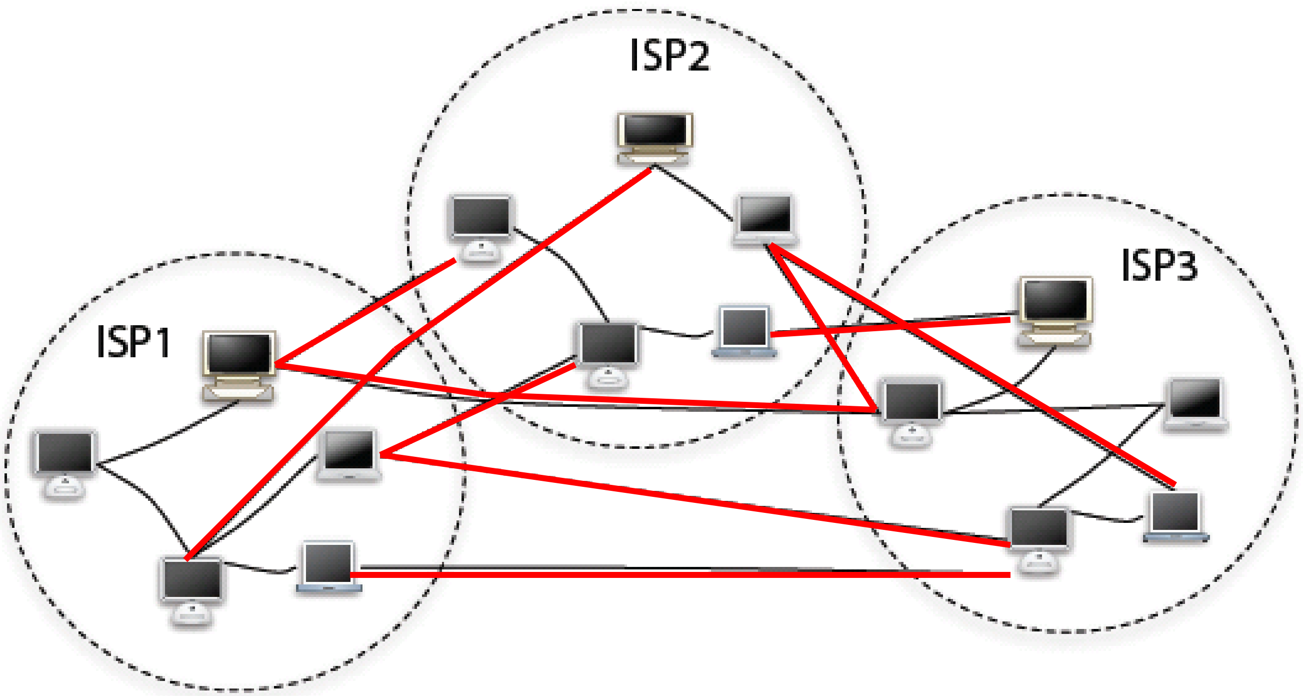
- Global Consumer Internet Traffic (PB per Month)



Data from: Cisco Visual Networking Index – Forecast and Methodology, 2008–2013

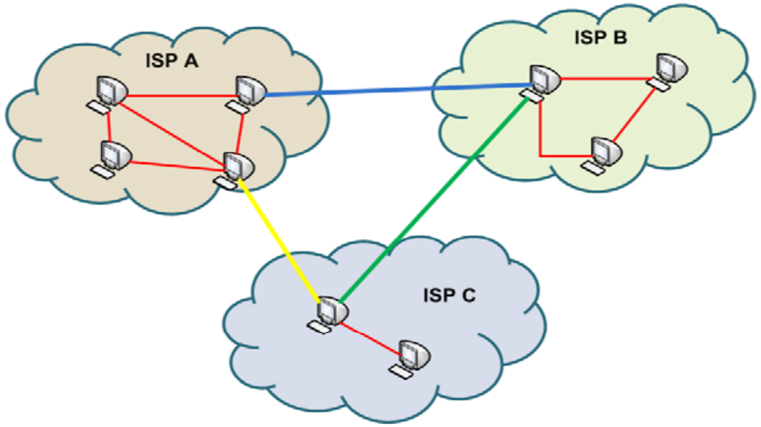
P2P Traffic Problem

- Large Volumes of Cross-ISP Traffic Has Been Incurred!

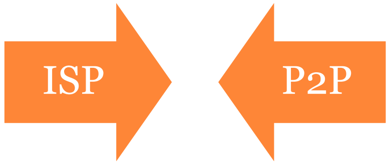


ISP vs. P2P

- Passive Strategy:
  - Packet filtering and blocking
- Positive Approaches: Localization
  - ISP deploy caches/proxies
  - P2P adopts localized peer selection
  - ISP collaborates with P2P



- One question remains:
  - To what extend should P2P traffic be localized, such that the benefits of both P2P users and ISPs are respected?

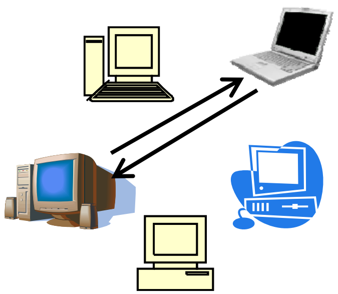


Our Contributions

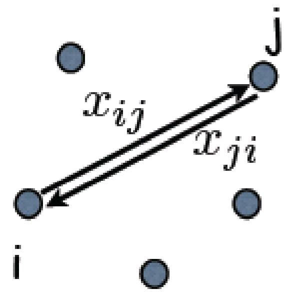
- Characterize **tradeoff** between Performance and Locality
  - Starting from a generic maximum-weight b-matching model
    => model BitTorrent-like peer selection
  - Introducing multiple objectives for both goals of download rate maximization and inter-ISP traffic minimization
    => model the tradeoff
    => derive Pareto-optimal peer selection solution
- Design fully **distributed algorithm** to achieve any desired Pareto-optimal peer selection

Modeling BitTorrent-like peer selection

- A maximum-weight b-matching model



Network	Graph
a BitTorrent-like P2P network	a directed graph $G = (V,E)$
tit-for-tat	match of two nodes $x_{ij} = x_{ji} = 1$
unchock at most **b** peers	At most **b** matches per node



* Note: a simplified model ignoring seeding and opportunistic unchoking

Modeling BitTorrent-like Peer Selection

- Maximum-weight b-matching Model
  - Optimal peer selection at peer i:

$$\max \sum_{j \in N_i} q_{ji}(x_{ji})$$

Subject to:

$$\sum_{j \in N_i} x_{ji} \le b,$$

$$x_{ji} = x_{ij}, \forall j \in N_i,$$

$$x_{ji} \in \{0, 1\}, \forall j \in N_i.$$

q_{ji} : generic preference function $[0,1] \rightarrow [0, +\infty)$

N_i : neighborhood of peer i

x_{ji} : peer i downloads from peer j, or not

b : maximum number of download connections

Modeling BitTorrent-like Peer Selection

- Maximum-weight b-matching Model
  - Global optimal peer selection:

$$\max \sum_{i\in V}\sum_{j\in N_i} q_{ji}(x_{ji})$$

Subject to:

$$\sum_{j\in N_i} x_{ji} \le b, \forall i \in V,$$

$$x_{ji} = x_{ij}, \forall i \in V, j \in N_i,$$

$$x_{ji} \in \{0,1\}, \forall i \in V, j \in N_i.$$

Take $q_{ji}(1)+q_{ij}(1)$ as weight W_e on edge e

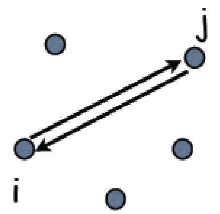
==>

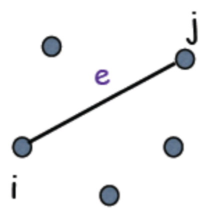
$$\max \sum_{e\in E} w_e x_e$$

Subject to:

$$\sum_{e \text{ adj. to } i} x_e \le b, \quad \forall i \in V,$$

$$x_e \in \{0,1\}.$$





Characterizing Performance and Locality Tradeoff

- Introducing multiple objectives

At Peer i:

$$\begin{cases} \max \sum_{j \in N_i} r_{ji} x_{ji} \\ \min \sum_{j \in N_i} c_{ji} x_{ji} \end{cases}$$

subject to:

$$\sum_{j \in N_i} x_{ji} \le b,$$
$$x_{ji} = x_{ij}, \forall j \in N_i,$$
$$x_{ji} \in \{0, 1\}, \forall j \in N_i.$$

Global:

$$\begin{cases} \max \sum_{i \in V} \sum_{j \in N_i} r_{ji} x_{ji} \\ \min \sum_{i \in V} \sum_{j \in N_i} c_{ji} x_{ji} \end{cases}$$

Subject to:

$$\sum_{j \in N_i} x_{ji} \le b, \forall i \in V,$$
$$x_{ji} = x_{ij}, \forall i \in V, j \in N_i,$$
$$x_{ji} \in \{0, 1\}, \forall i \in V, j \in N_i.$$

r_{ji}: downloading rate from j to i, downloading performance
c_{ji}: network cost from j to i, neighbor locality

Characterizing Performance and Locality Tradeoff

- Definition of Solution at Pareto optimal
  - feasible x* is Pareto optimal if no other solution performs better for both objects, i.e., no x such that

$$\sum_{i \in V} \sum_{j \in N_i} r_{ji} x_{ji} > \sum_{i \in V} \sum_{j \in N_i} r_{ji} x^*_{ji} \quad \text{and} \quad \sum_{i \in V} \sum_{j \in N_i} c_{ji} x_{ji} < \sum_{i \in V} \sum_{j \in N_i} c_{ji} x^*_{ji}$$

- How to achieve Pareto optimal?
  - Centralized: Calculation
  - Distributed: Our algorithm

Distributed Multi-objective Peer Selection

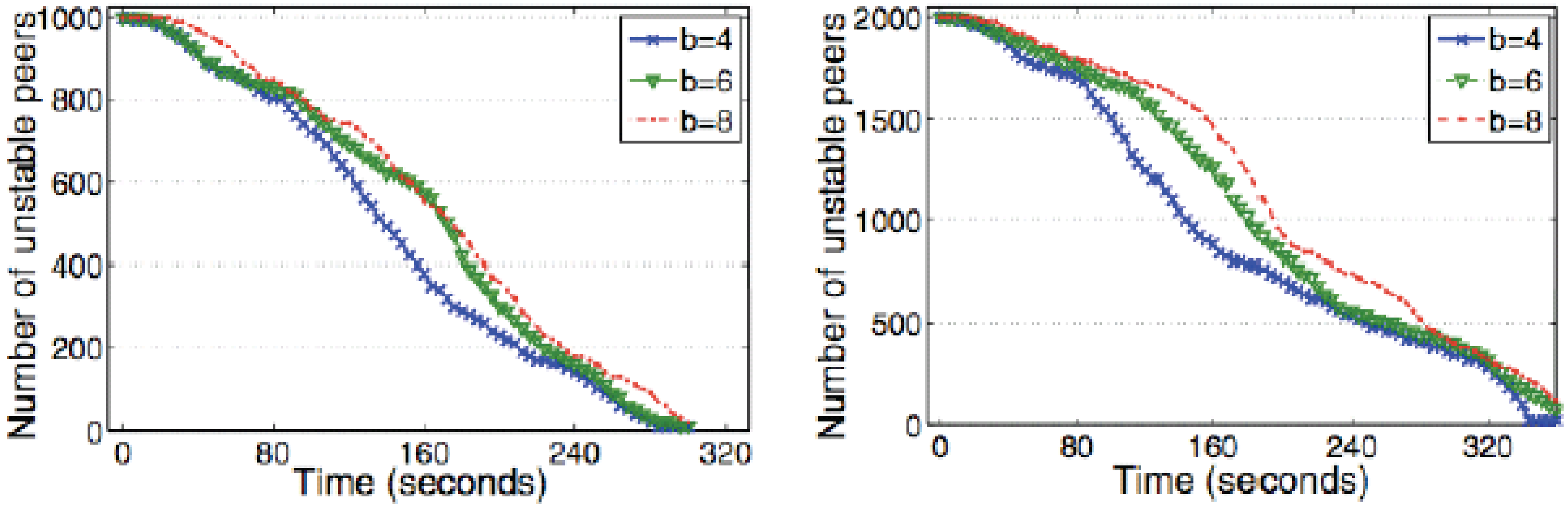
- Algorithm sketch
  - each peer ranks all known neighbors according to preference
  - sends requests to download to b peers in the order of preference
  - downloads from matched peers and dynamically adjusts to better matching choices
- Example:

Trace-driven Evaluations

- A P2P swarm with up to 2000 peers, in 10 ISPs
- Download a file of 128 MB
- Upload capacity: heavy-tailed Pareto distribution
  [256 Kbps, 10 Mbps]
- Traffic-relay cost matrix among the ISPs from the traces

Trace-driven Evaluations

- A Convergence of distributed peer selection (matching) algorithm



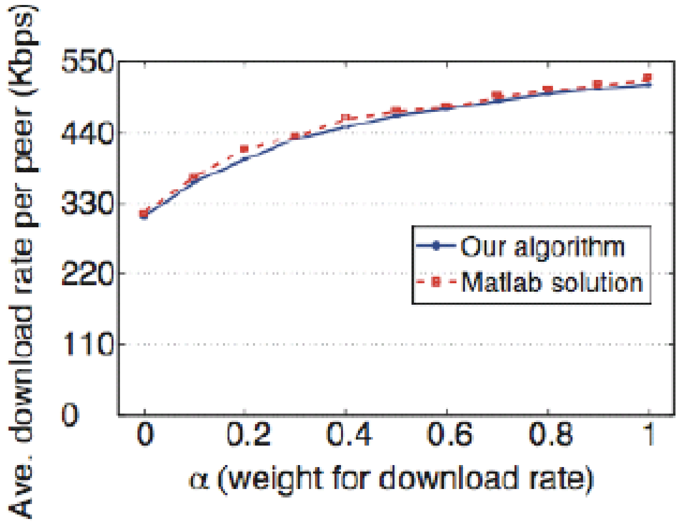
(a) 1000-peer swarm (b) 2000-peer swarm

- According to the settings, it takes about 40-50 minutes to download the entire file for a peer
  - The convergence time is tolerable

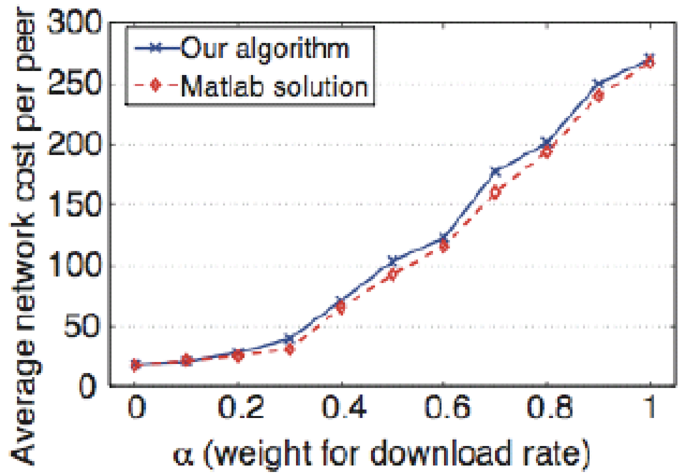
Trace-driven Evaluations

- Optimality of resulting peer selection (matching) :

  2000 peers, b=6



(a) Download rate



(b) Network cost

- Compared to the centralized algorithm on global optimal, the distributed algorithm approximately achieves optimal

Thank You!

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