On the Benefits of P2P Cache Capacity Allocation

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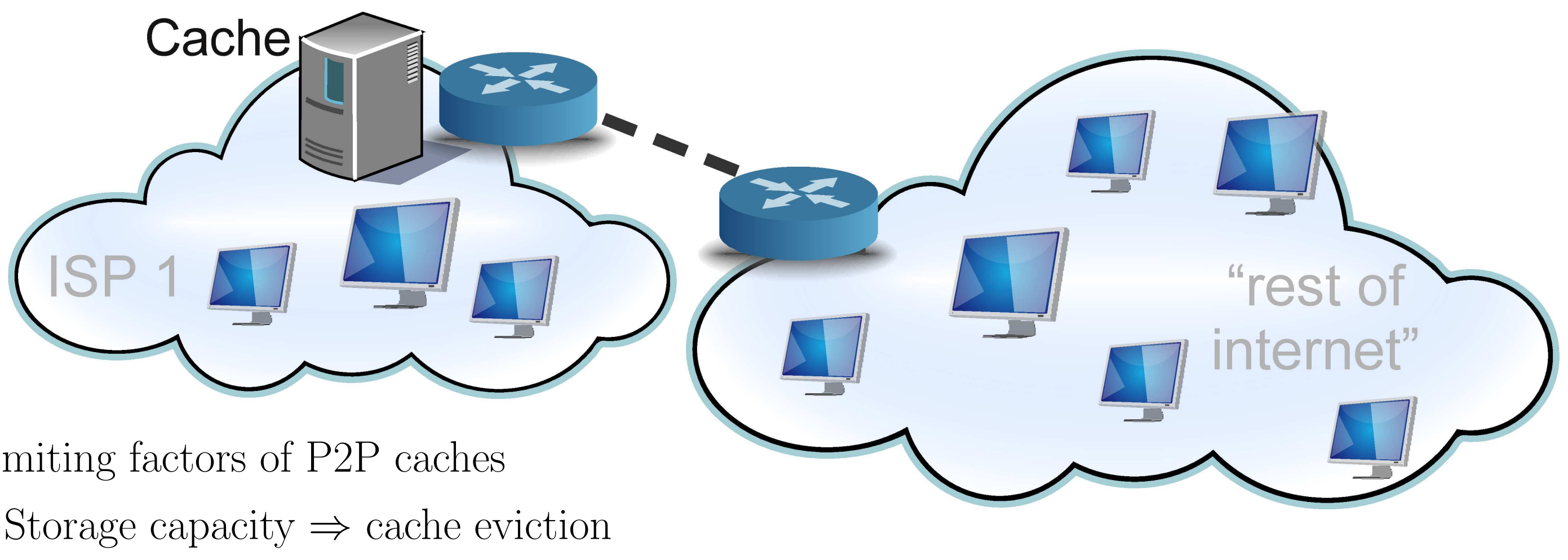
1 Decreasing Inter-ISP Traffic

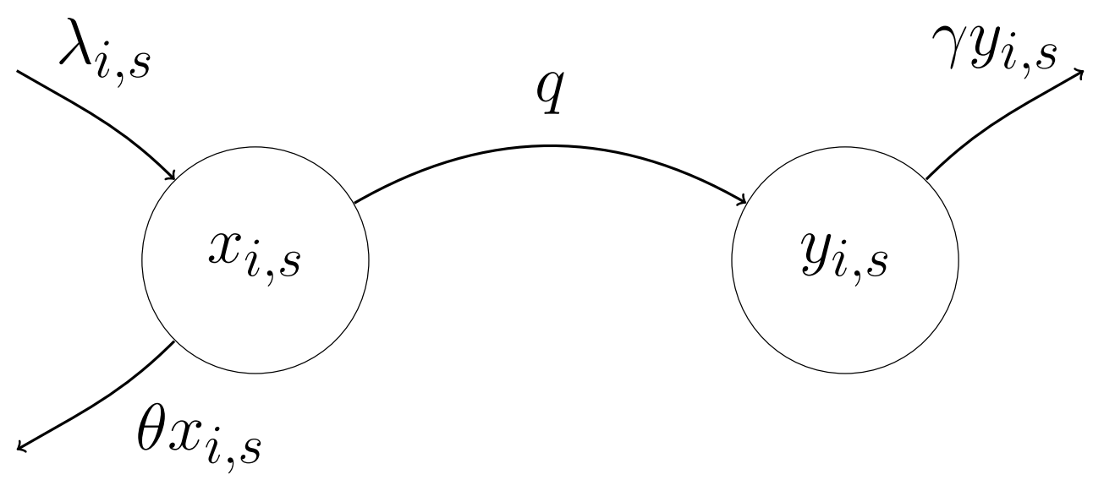
- Inter-ISP traffic is a source of cost for ISPs
- Two directions to decrease inter-ISP traffic [1]:
  1. Locality-awareness based on
     - ISP-provided information (ALTO, P4P, "Oracle")
     - Measurements or third-party provided information (ONO, BNS)
  2. P2P Caching



- Limiting factors of P2P caches
  1. Storage capacity ⇒ cache eviction
  2. Bandwidth
- Significant impact of P2P caching on both instantaneous transit traffic and system dynamic [2]
- Key question:
  - Should bandwidth be actively managed such as to minimize the inter-ISP traffic?

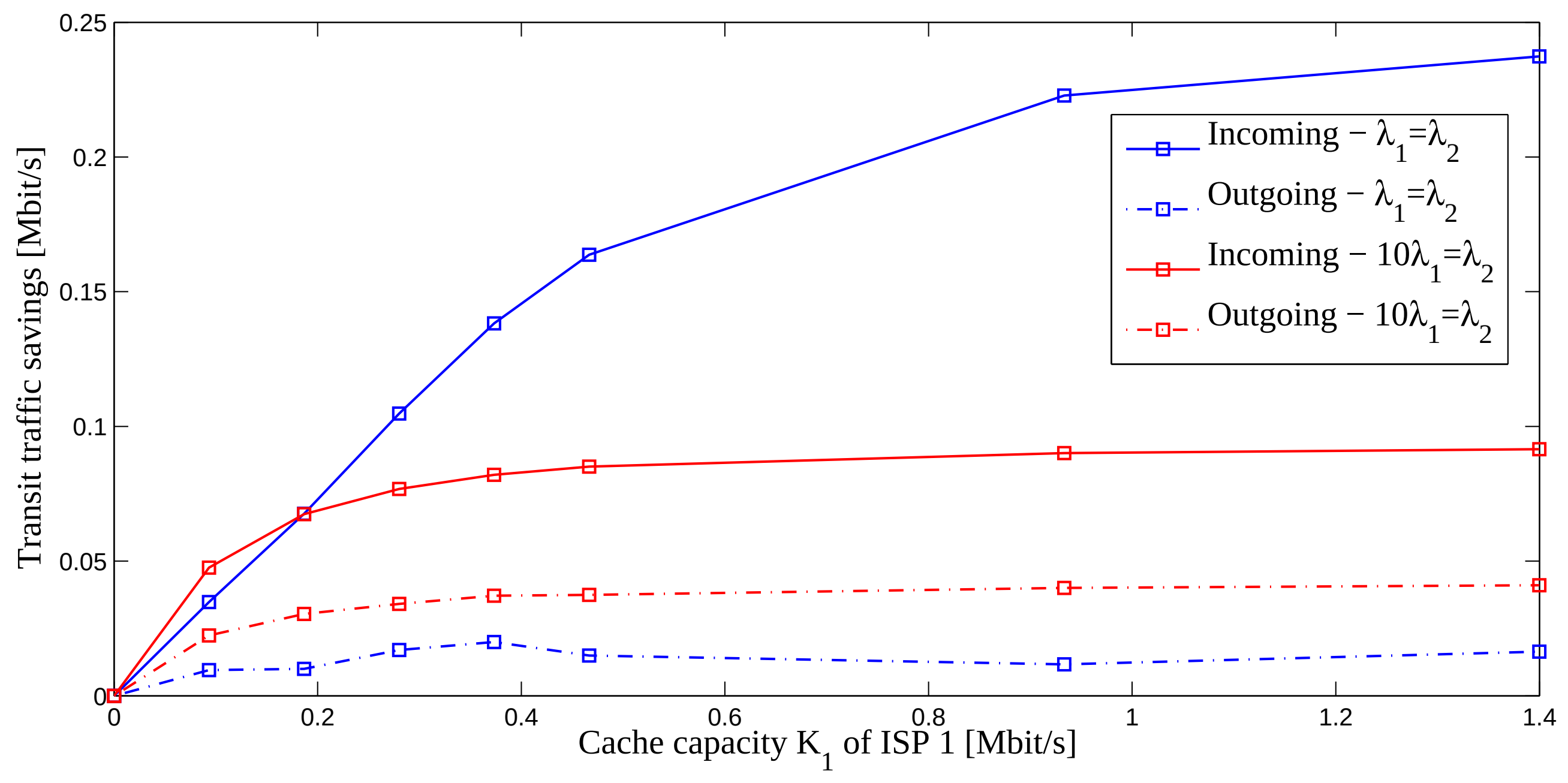
2 The Impact of P2P Caching

- $\mathcal{I} = \{1, .., I\}$ set of ISPs, $\mathcal{S} = \{1, .., S\}$ set of swarms
- $\lambda_{s,i}$ arrival rate of leecher of ISP $i \in \mathcal{I}$ to swarm $s \in \mathcal{S}$
- θ leechers' impatience, γ departing rate of seeders, μ upload capacity of peers
- $Z_{i,s}(t) = (x_{i,s}(t), x_{i,s}(t))$ state of swarm s in ISP i as the number of leechers and seeders in ISP i in swarm s at time t
- P2P cache:
  - $K_i < \infty$ upload capacity of cache in ISP i, it serves only peers in ISP i



$$q = \min(c x_{i,s}, x_{i,s}\mu(\eta x_s + y_s)/x_s + k_{i,s})$$

- $I_{i,s}(Z_s(t), k_{i,s}(t))$ incoming transit traffic rate in ISP i
- The impact of caching on the transit traffic depends on the distribution of the peers among ISPs



3 Cache Capacity Allocation Policies

A cache capacity allocation *policy* of ISP i specifies $k_i(t)$ from the set of feasible cache capacity allocations of ISP i: $\mathcal{K}_i = \{k_i | \sum_{s\in\mathcal{S}} k_{i,s} \leq K_i\}$

- *No Policy*:
  - ISP i does not actively allocate its K_i
- *Uniform Capacity Reservation*:
  - The same amount of cache capacity is reserved to every swarms: $k_{i,s} = \frac{K_i}{|\mathcal{S}|}$
- *Greedy Traffic Minimization*:
  - "short term" approximation, does not consider the impact of $k_i(t)$ on the evolution of $Z(t)$

$$k_i(t) = \arg\min_{k_i \in \mathcal{K}_i} \sum_{s\in\mathcal{S}} I_{i,s}(Z_s(t_n), k_{i,s}) \text{ for } t_n < t < t_{n+1}$$

  - every swarm with $k_{i,s} \neq 0$ should provide equal marginal traffic saving at optimality
- *Priority Based Allocation Policies*:
  - Idea: priority to swarms based on the ratio $r = \lambda_2/\lambda_1$
  - Approximated using the instantaneous ratio: $\hat{r}_{i,s} = \frac{x_{i,s}(t)}{\sum_{j\neq i} z_{j,s}(t)}$
  - *Ratio Priority*: swarms with highest ratio have highest priority
  - *Inverse Ratio Priority*: swarms with lowest ratio have highest priority

4 Performance Evaluation - Simulations

- Incoming transit traffic estimations based on two assumptions [2]:
  1. Leechers with free download capacity compete with each other for the available upload rate
  2. The distribution of the sources of content downloaded in ISP i is proportional to the amount of upload rate exposed to leechers in ISP i

$$\boxed{I_i(z_s, k_i) = D_i^r \left(\frac{\sum_{j\neq i} u_j^P}{u_i^{PL} + \sum_{j\neq i} u_j^P} \right)}$$

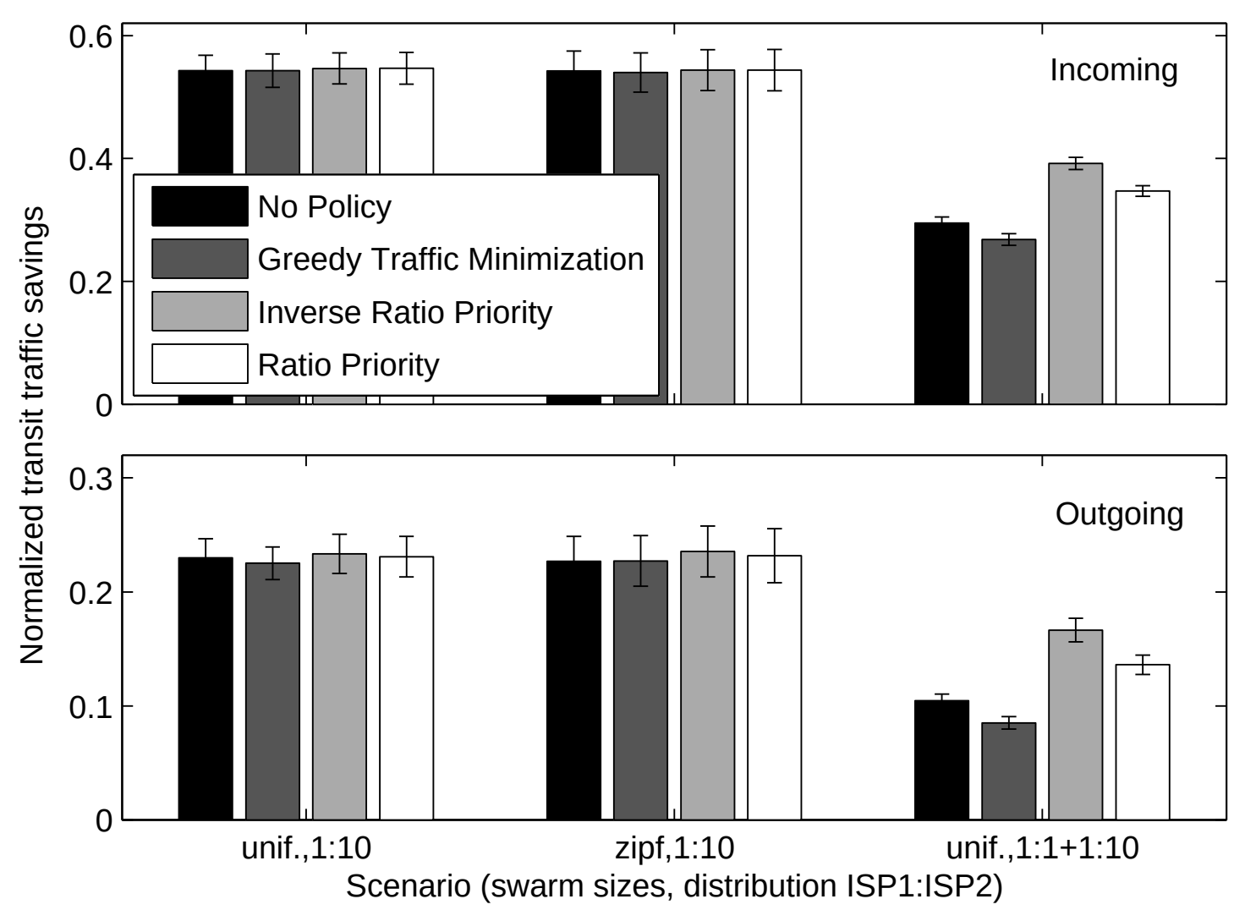
$$D_i^r = f(k_i, u_i^{PL}, (u^P)_i)$$

total receiving rate of leechers in ISP i

- $u_i^P = \mu(\eta x_i + y_i)$ publicly available upload rate in ISP i available to leechers in every ISP
- $u_i^{PL} = \max[0, \mu(\eta(x_i - 1) + y_i)]$ publicly available upload rate in ISP i available to a local leecher

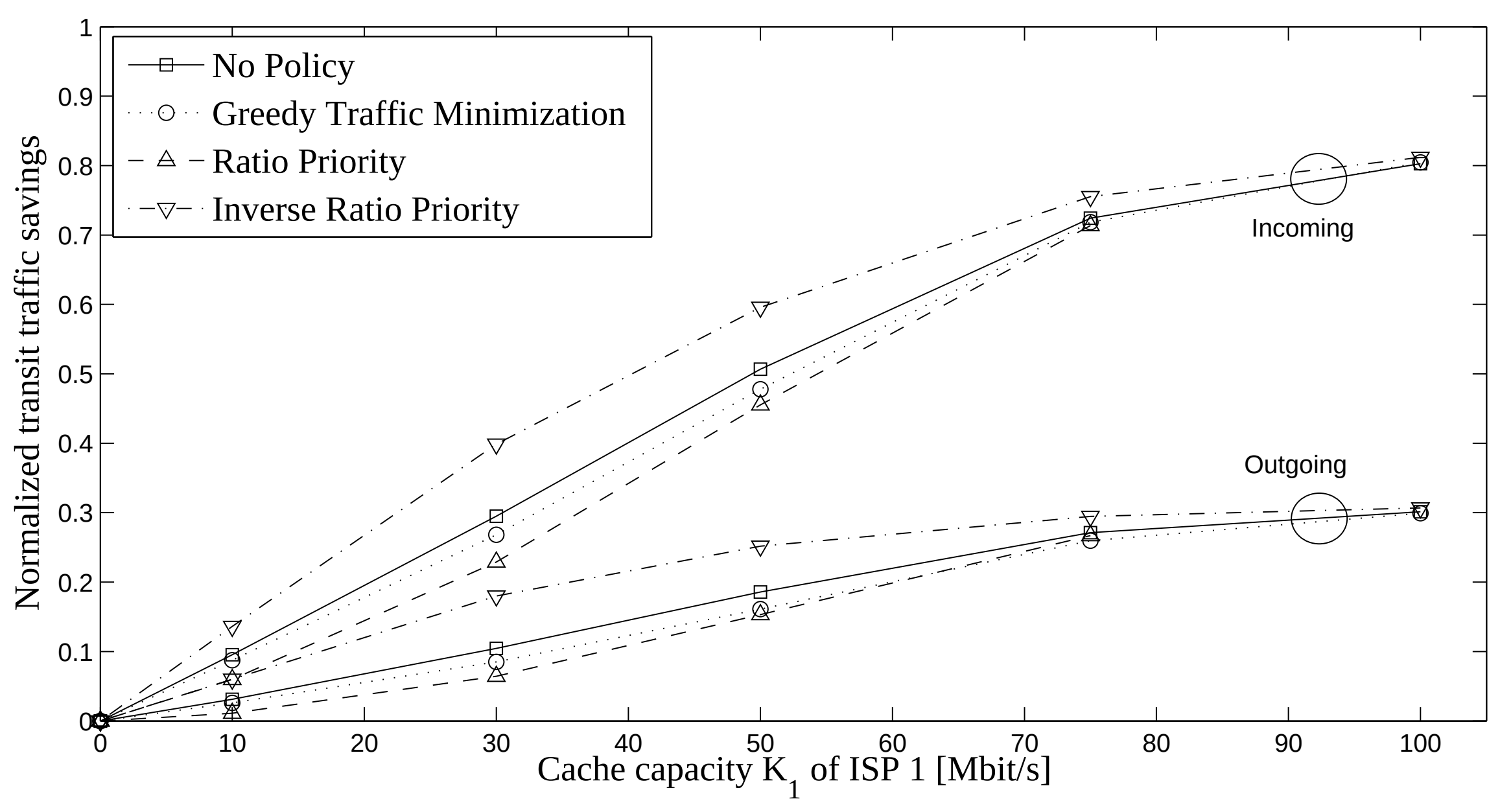
- Simulations using ProtoPeer [3]

Incoming and outgoing transit traffic savings for the scenarios described in the table:



Scenario	Identical swarms (s)	$\frac{\lambda_s}{\lambda}$	$\frac{\lambda_{2,s}}{\lambda_{1,s}}$
unif.,1:10	1,..,12	1/12	10
zipf,1:10		$\propto \frac{1}{s}$	10
unif.,1:1+1:10	1,..,10	1/12	10
	11,12	1/12	1

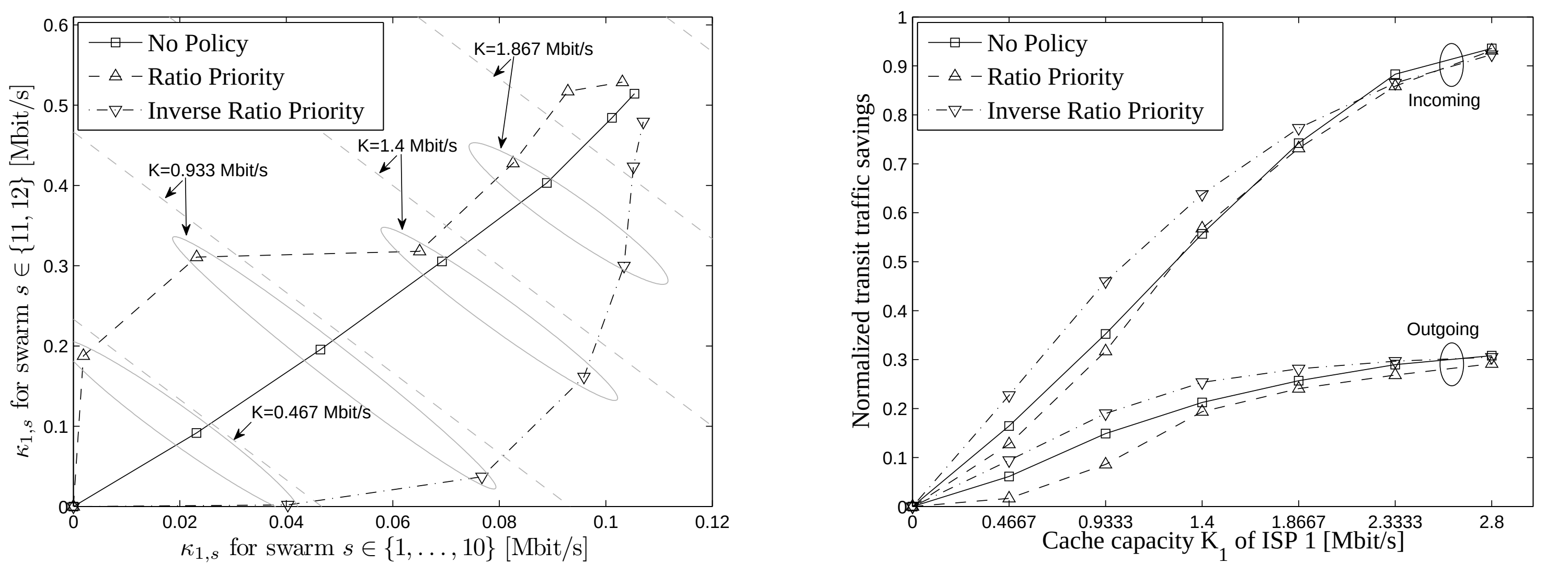
Incoming and outgoing transit traffic saving for the *unif.,1:1+1:10* scenario:



5 Experimental Validation

- Experiments on ca. 500 Planet-lab nodes using Bit-Torrent:
  - File-size 3.5 MB
  - Peers' upload capacity 23 kbit/s, download capacity 373 kbit/s
  - *unif., 1:1+1:10* scenario
  - Cache: 12 peers running on the same Linux machine
  - Cache capacity allocation policies implemented using Linux Traffic Control (tc)

Experimental results for the *unif.,1:1+1:10* scenario:



Cache capacity allocations of ISP 1

Normalized transit traffic saving of ISP i

References

[1] G. Dán, T. Hossfeld, S. Oeschner, P. Cholda, R. Stankiewitz, I. Papafili, G. D. Stamoulis, "Interaction Patterns between P2P Content Distribution Systems and ISPs", in *IEEE Communications Magazine*, vol. 49, num. 5, May 2011, pp. 222-230.

[2] F. Lehrieder, G. Dán, T. Hossfeld, S. Oechsner, V. Singeorzan, "The Impact of Caching on BitTorrent-like Peer-to-peer Systems", in *10th IEEE International Conference on Peer-to-Peer Computing 2010 - IEEE P2P 2010*, Delft, Netherlands, 2010, pp. 6978.

[3] W. Galuba, K. Aberer, Z. Despotovic, W. Kellerer "ProtoPeer: A P2P Toolkit Bridging the Gap between Simulation and Live Deployment", in *Proceedings of International Conference on Simulation Tools and Techniques*, Mar. 2009.