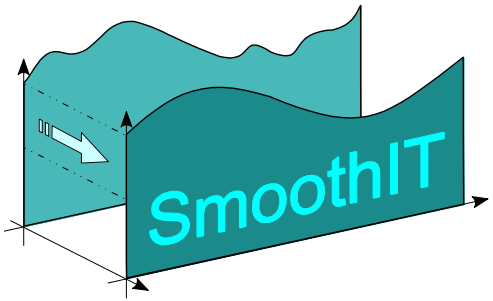
Simple Economic Management Approaches of Overlay Traffic in Heterogeneous Internet Topologies

European Seventh Framework STREP FP7-2007-ICT-216259



Improvement of Overlay Performance and Inter-Domain Traffic by Inserting ISP-owned Peers (IoPs)

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Outline

- Our context
- Insertion of ISP-owned Peer (IoP)
- Mathematical investigations
- Unchoking Policy module
- Swarm Selection module
- Summary

The context (I)

- Peer-to-peer (p2p) applications generate great amounts of Internet traffic
  - BitTorrent is the most popular p2p application

- Information asymmetry between underlay and overlay possibly leads to:

1. Increase of inter-connection costs for ISPs
   - Due to sub-optimal decisions of the overlay

2. Increase of download times for the end-users
   - Due to traffic throttling and other policies applied by the ISPs
   - Due to imperfect optimization in the overlay

The context (II)

- Optimization approaches try to solve the Information Asymmetry problem, by proposing:
  - Alternative peer selection mechanisms based on proximity information
    - By a centralized entity provided by the ISP
    - Employing peer ranking
    - Or, by using existing information supplied by CDNs
  - **Insertion of caches in the overlay**,

- Evaluation of such optimization approaches is a field of ongoing research

The FP7-ICT Project *SmoothIT*

***S**imple Economic **M**anagement Approaches **o**f **O**verlay **T**raffic in **H**eterogeneous **I**nternet **T**opologies*

- Main objective:

  To optimize overlay traffic mutually beneficially for all ISP, user, application provider → *win-win-win* situation
  - Both file-sharing and Video-on-Demand are covered

- Approach: Economic Traffic Management (ETM)
  - Employs mechanisms that:
    - Are based on the incentives of players
    - Bridge the information gap between overlay and underlay

Insertion of ISP-owned Peer*

* I. Papafili, S. Soursos, G. D. Stamoulis, Improvement of BitTorrent Performance and Inter-Domain Traffic by Inserting ISP-owned Peers, 6th International Workshop on Internet Charging and QoS Technologies (ICQT'09), Aachen, Germany, May 2009

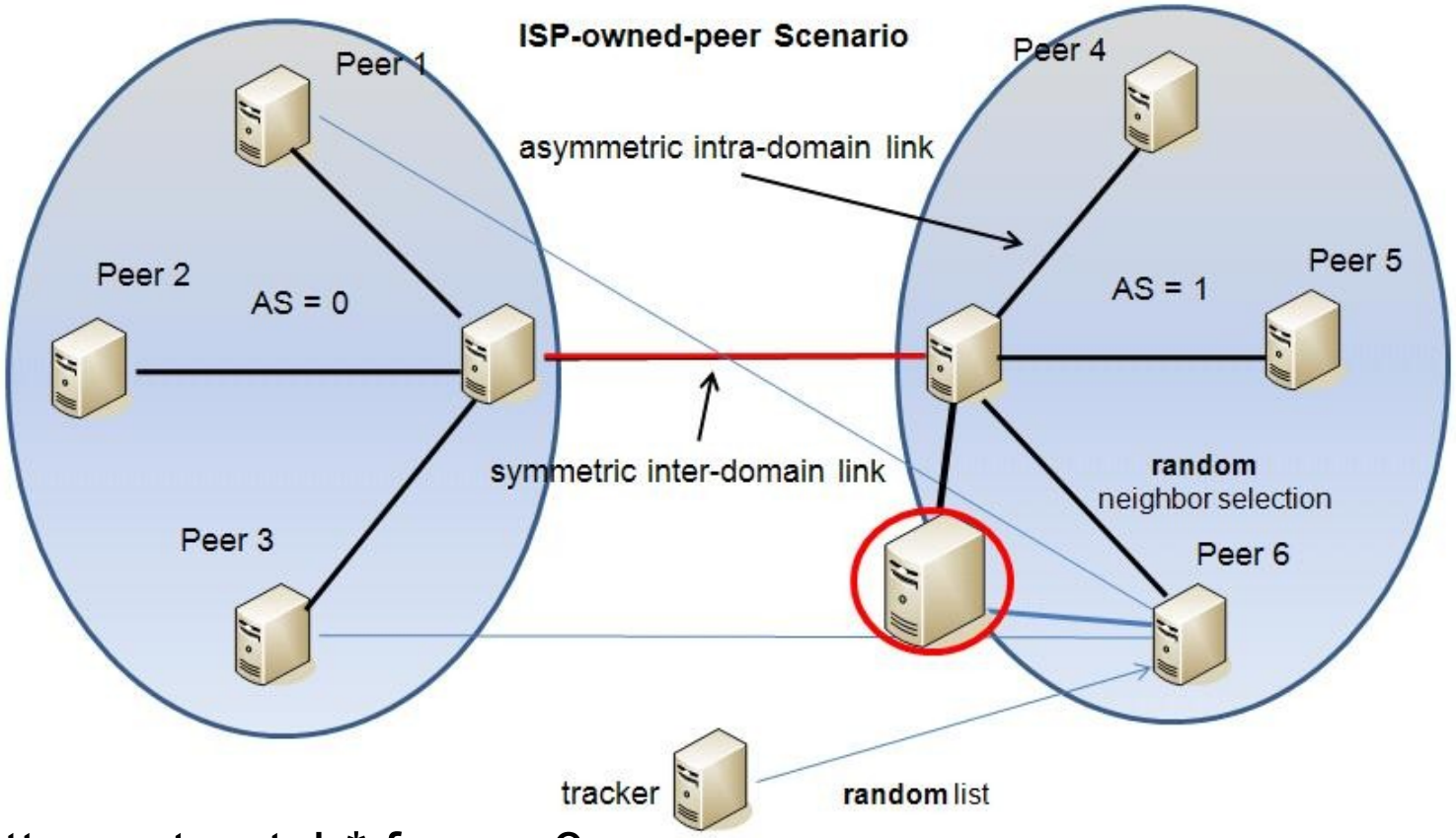
ISP-owned Peer (IoP)

- Resourceful ***entity*** that acts as an overlay peer:
  - Belongs to and is controlled by the ISP
  - Participates actively in the overlay
  - Exploits self-organizing mechanism of “tit-for-tat” (t4t)
  - Not an interceptive cache
  - Not a gateway peer
  - *Transparent*

- IoP: *no* content initially → acquires the content gradually

- ISP-owned Seed (IoS): possesses the *entire* content file from the beginning
  - IoS is expected to achieve better performance than IoP

Simulation topology



- bittorrent.patch* for *ns-2*

* Eger K., Simulation of BitTorrent Peer-to-Peer (P2P) Networks in ns-2: https://sites.google.com/site/koljaeger/bittorrent-simulation-in-ns-2

Simulation scenarios

1. Original BitTorrent
2. BitTorrent and locality awareness
   (biased neighbor selection by Bindal et al.)
3. Insertion of IoP in original BitTorrent
4. Insertion of IoP in BitTorrent with locality awareness

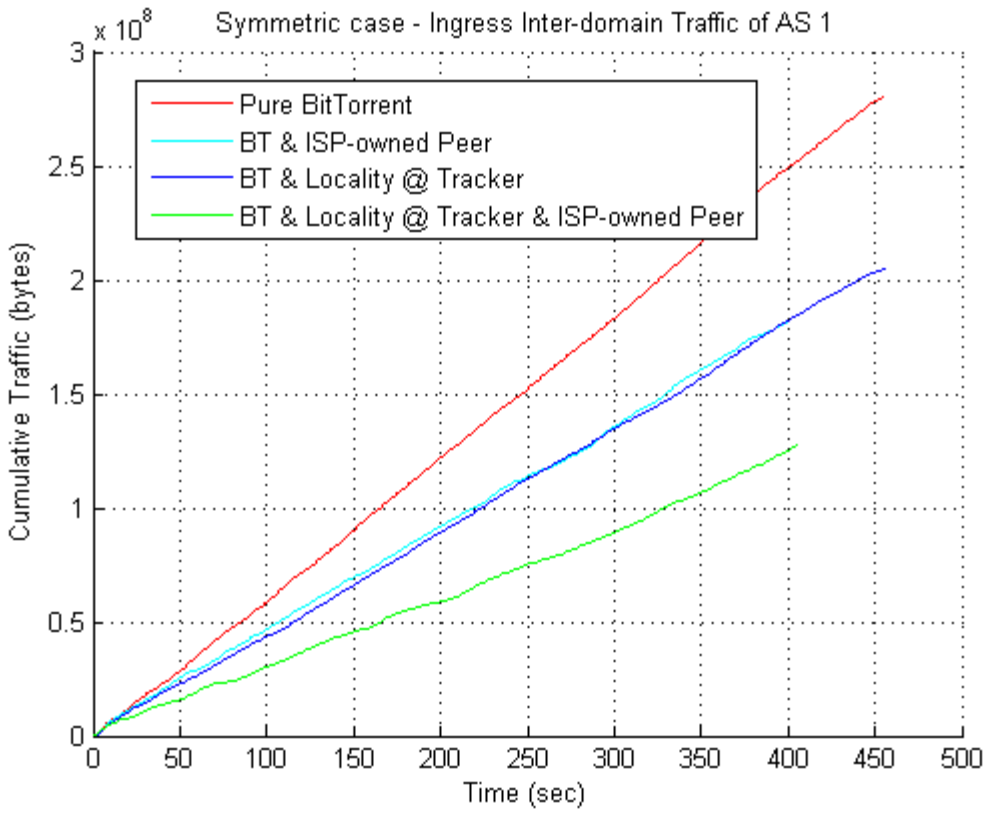
- Symmetric or Asymmetric
  - Symmetric: same number of peers in 2 ASes, e.g. 2 Tier-3 ISPs
  - Asymmetric: one AS larger than the other, e.g. Tier-2 and Tier-3
- All-together or Split
  - All-together: Joining time of all peers ~U(0,10)
  - Split: Joining time of 5 peers in each AS ~U(150,300), joining time of the rest of the peers and the ISP-owned peer ~U(0,10)

Simulation parameters

Description	Value
Number of peers	50
Number of seeds	1
Number of ASes	2
Number of peers per AS	(25,25), (35,15)
Upload capacity of regular peers	512K
Download capacity of regular peers	4096K
File size	20M
Number of peers requested from tracker (Size of tracker's list)	25
Number of local peers replied by tracker	20
Number of connections	20
Choking interval	10
Number of unchoked connections permitted per peer	4, **10 (in case of IoP)**
Number of ISP-owned peers	1
Upload/download capacity of ISP-owned peers	**40960K**

Inbound inter-domain traffic for AS 1

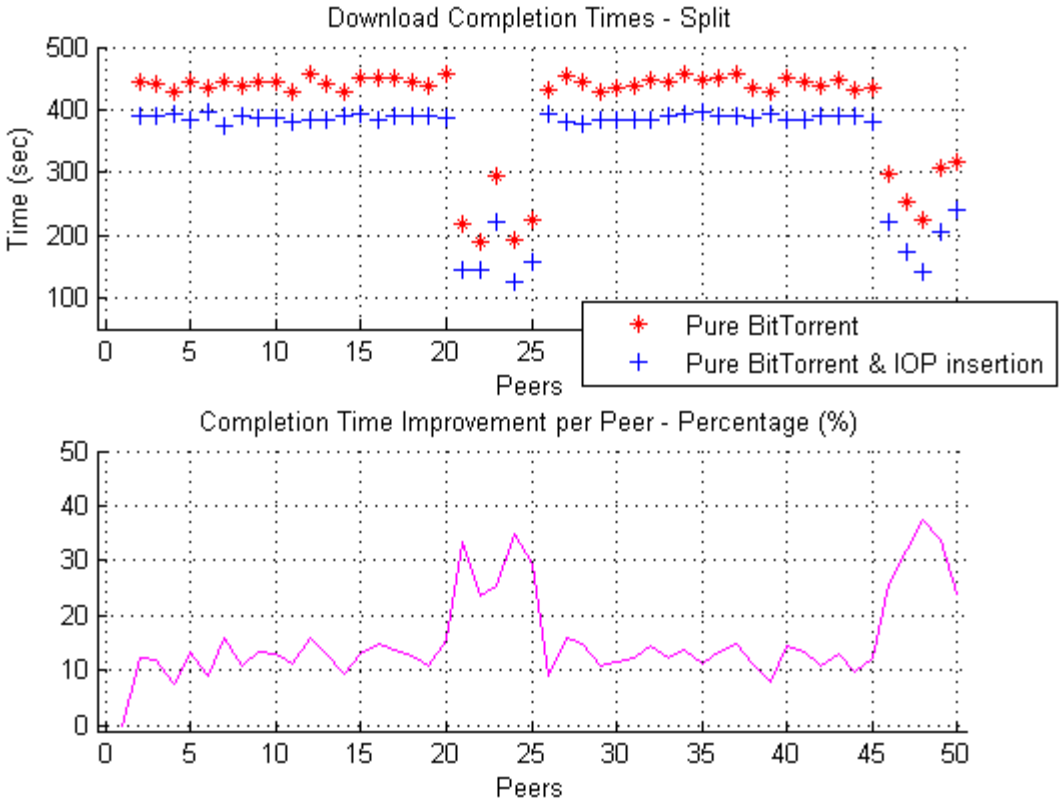
- Symmetric, All-together



- Up to 35% traffic reduction when IoP is inserted (either in BT or in BT&LA)
- Up to 50% traffic reduction when IoP insertion is combined with LA vs. original BT

End-Users' download times

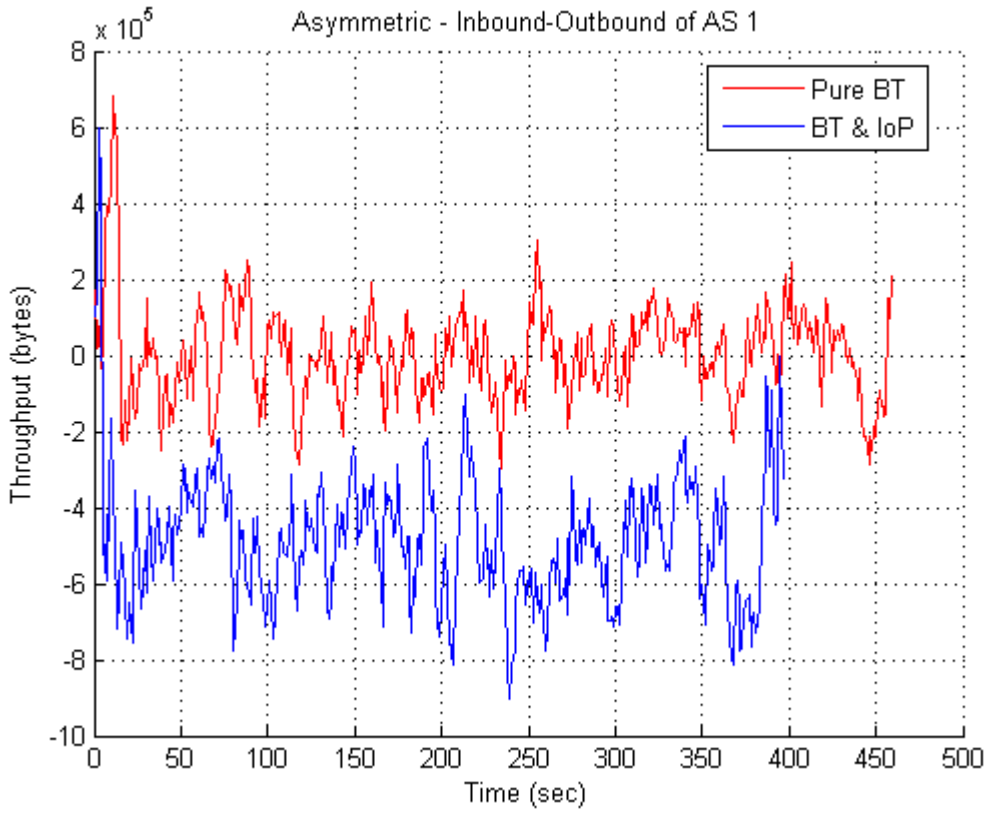
- Symmetric, Split



- Significant improvement especially for peers that enter the swarm later, when IoP has already turned into a seed

Instantaneous difference between inbound-outbound traffic of AS 1

- Symmetric, All-together



- Consider an interconnection charging scheme that takes into account the ***difference*** of inbound-outbound

Evaluation of IoP by means of mathematical modeling*

* I. Papafili, G. D. Stamoulis, A Markov Model for the Evaluation of Cache Insertion on Peer-to-Peer Performance, EuroNF NGI conference, Paris, June 2010

Motivation of a mathematical model for dimensioning purposes

- Analysis / verification of p2p performance characteristics
  - Even for the native overlay protocol
- Perform transient analysis of swarm evolution
  - Particularly relevant for IoP/IoS
  - Dimensioning
- Evaluation of optimization approaches that involve system's capacity modification
  - and parameter selection

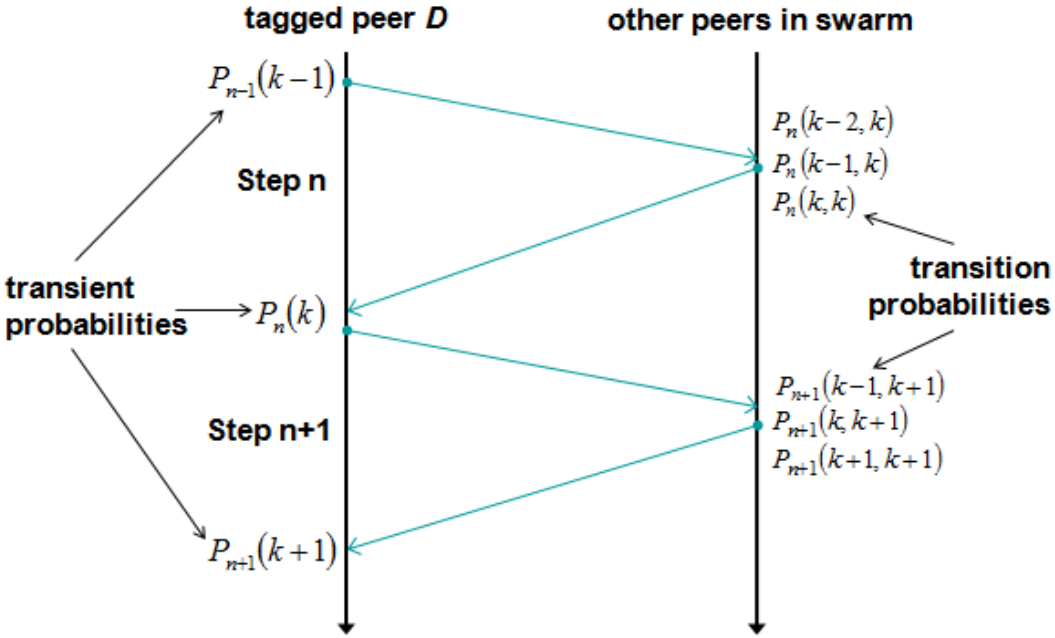
Assumptions and simplifications on the BitTorrent protocol …

… for the purposes of the Markov model

- ***Random*** chunk selection instead of ‘rarest first replication’
- ***Random*** peer selection instead of ‘tit-for-tat’
- Up to ***two*** chunks downloaded by a peer at each step
- ***Unique*** original seeder in the swarm

- *Key idea*: Due to *symmetry,* transient distribution of tagged peer *D* characterizes all other peers too

Markov chain evolution



End state of Markov Chain:

$$n^*: P_{n^*}(K) > 0.95$$

- State of a tagged peer D at step n: number of chunks obtained → Complete content file: *K* chunks
- Transient distribution: $P(n) = [P_n(0), P_n(1), \ldots, P_n(K)]$
- $P_{n+1}(k-2,k-2) + P_{n+1}(k-2,k-1) + P_{n+1}(k-2,k) = 1$

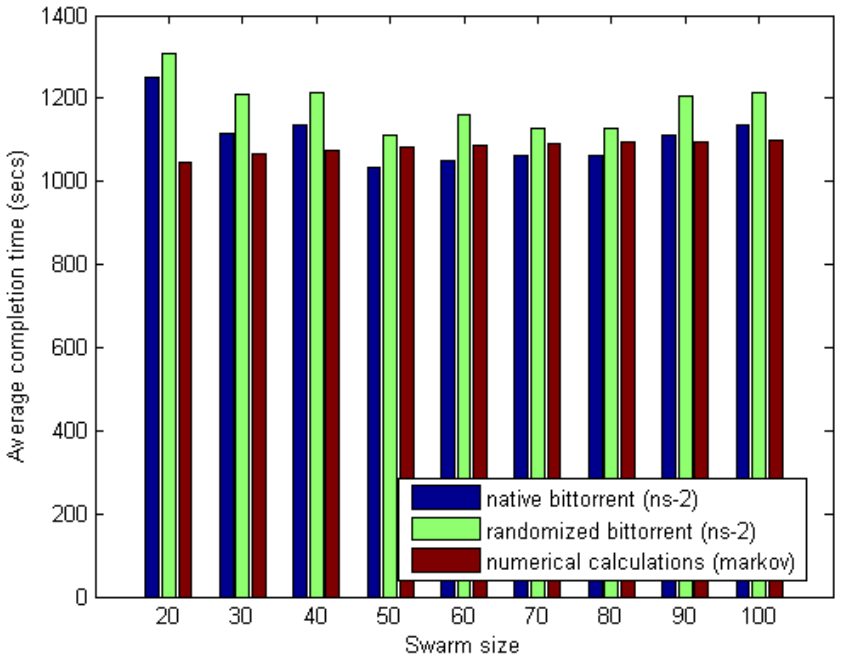
$$P_{n+1}(k) = P_n(k-2)P_{n+1}(k-2,k) + P_n(k-1)P_{n+1}(k-1,k) + P_n(k)P_{n+1}(k,k)$$

Model verification

Comparison of simulation results vs. results derived by the Markov model

- Markov model calculations in Matlab
  - Discrete time: *Transformation* to continuous time:

    Each choking interval corresponds to 10 secs.



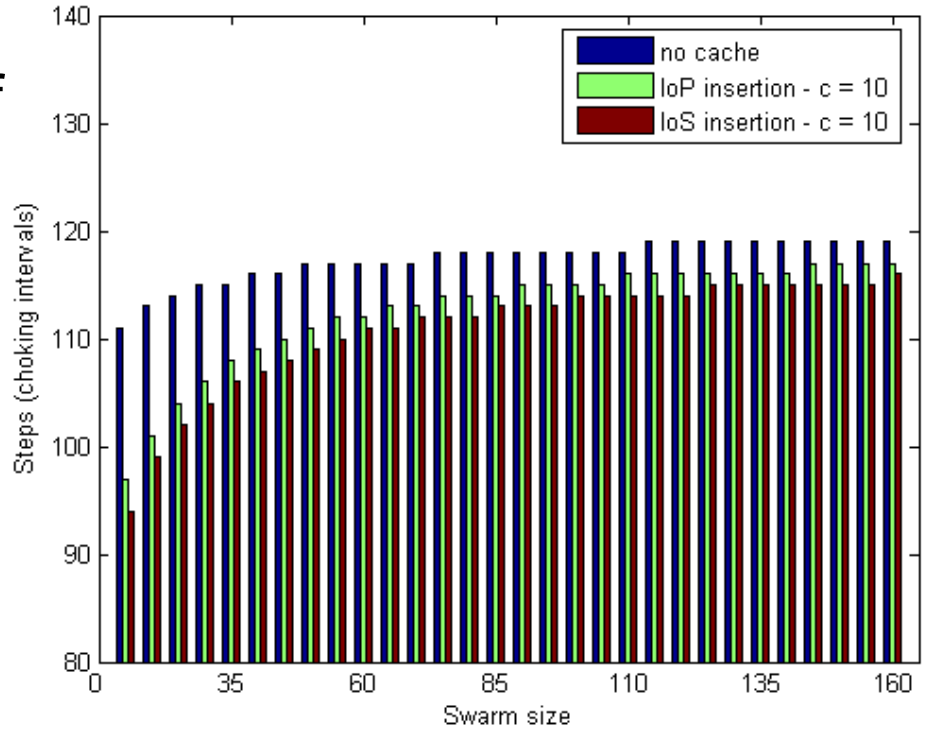
- Parameters
  - Peers' upload capacity: *cl* = *2*
  - Original seeder's upload capacity: *cs* = *2*

- Relative difference between the simulated native and the Markov model lies under 5% (except for the case of swarm with *N* = *20*)

Evaluation of the insertion of IoP (I)

No IoP/IoS vs. IoP vs. IoS

- 95-th percentile of completion time: *G = 0.95*
- IoP/IoS's capacity: *cp = 10*
- Swarm size: *N = {10, 15, 20, …, 160}*
- Insertion of IoP achieves significant improvement of performance;
  - slightly better performance by IoS



Unchoking Policy module – Evaluation*

* S. Soursos, I. Papafili, F. Lehrieder, M.A.C. Rodriguez, S. Spirou, G.D. Stamoulis, IoP Insertion: Specification and Evaluation (under preparation)

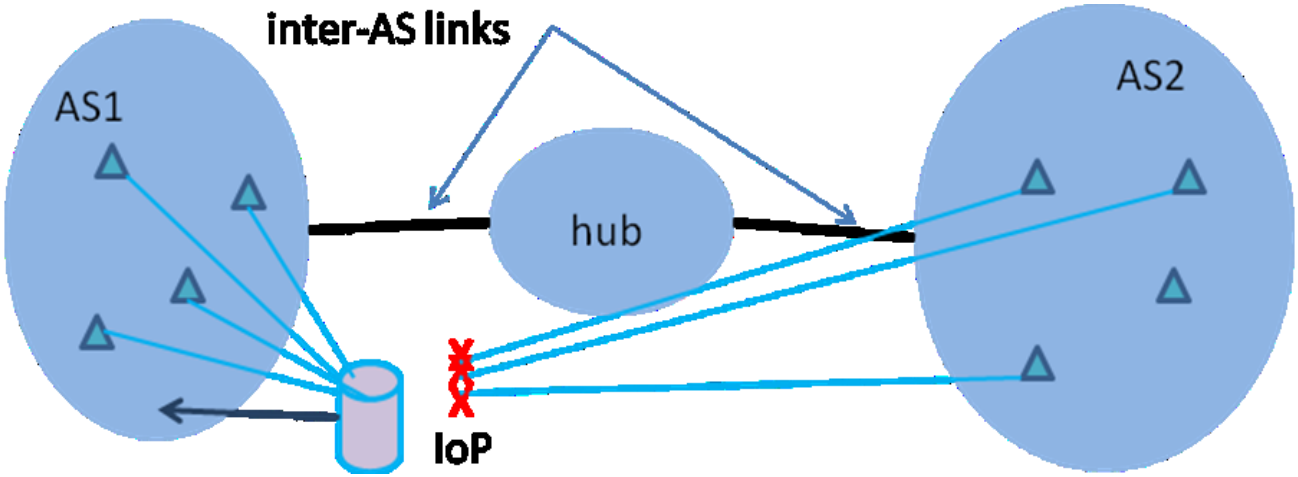
Simulation design

- Issue: *Increase of outgoing inter-AS traffic*

- Unchoking Policy
  - Restrictive policy
  - Enforced by the ISP on the IoP
  - Does not allow remote peers (of different ASes) to be served by the IoP

- Objective:
  - To evaluate the impact of the Unchoking Policy enforcement
  - Significant effect in the outgoing inter-domain traffic

Simulation topology



- Simple 2-AS topology: AS1 & AS2
  - Hub-AS has no peers!
  - Only the original seeder and the tracker are located in hub-AS
- IoP **always** inserted in AS1
- IoP may or may not employ the Unchoking Policy

Simulation setup (i)

- Simulation duration: 6.5 hours (1.5 warm-up)
  - Steady-state
- Metrics of interest:
  - Inter-AS traffic of AS1 (incoming and outgoing)
  - Peers' performance (in terms of download time)

Underlay

- Homogeneous scenario
- Peers' bandwidth: 16384/10240 kbps
- Original seeder's bandwidth: 10240 kbps up
- IoP's bandwidth: 40960 kbps up&down

Simulation setup (ii)

Overlay

- File size: 150 MB
- Exponential arrival times
  - Mean inter-arrival time of leechers: 10.0s
- Exponential seeding times
  - Mean seeding time of seeders: 600.0s

- SmoothIT-Simulator* for ProtoPeer** platform

* SmoothITSimulator v3.0, http://protopeer.epfl.ch/wiki/BitTorrent

** ProtoPeer, http://protopeer.epfl.ch/index.html

Evaluation scenarios

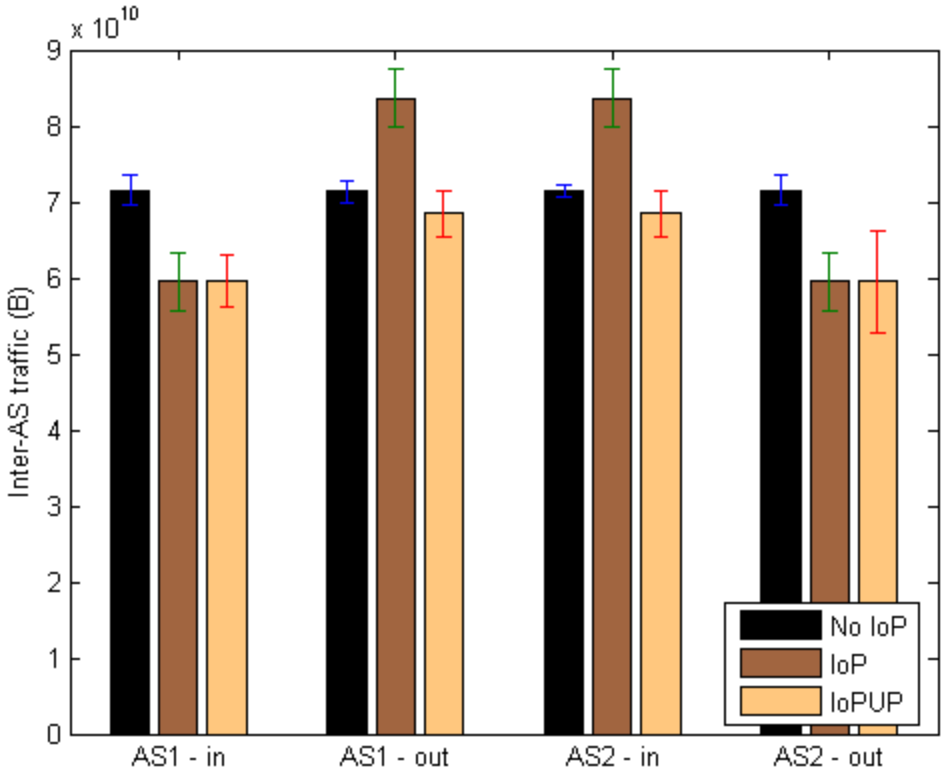
1. No IoP insertion

2. IoP insertion in AS1 without any policy
   - The IoP serves indiscriminately all possibly requesting peers

3. IoP insertion in AS1 employing the Unchoking Policy
   - The IoP serves only peers located within AS1
   - Requests of remote peers are rejected

Impact on inter-domain traffic

- Average values over 10 simulation runs
- 95-percentile confidence intervals



No policy

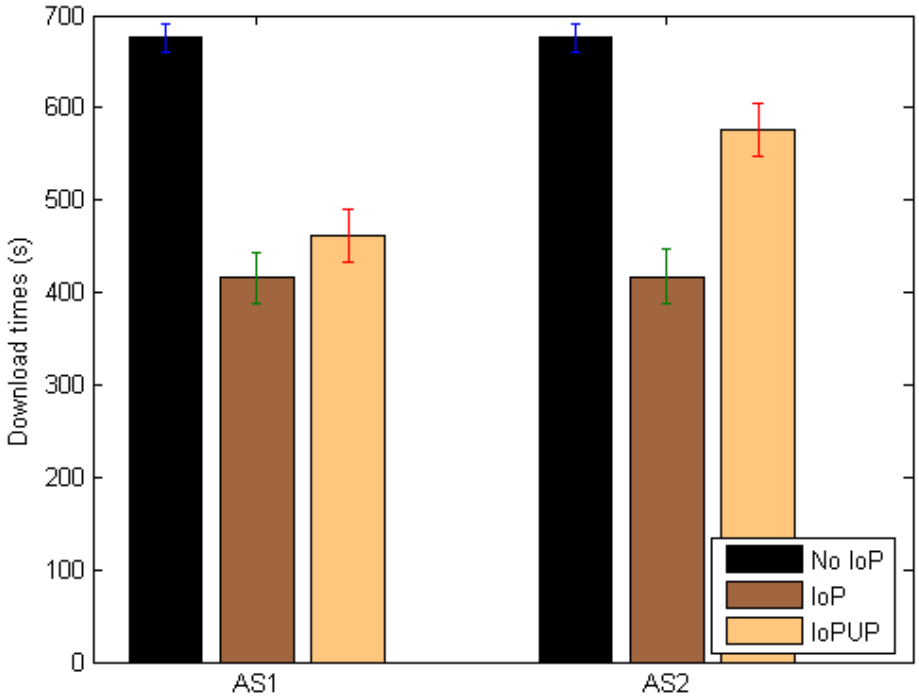
- About 20% reduction of incoming inter-AS traffic; equivalent increase of outgoing though!

With Unchoking Policy

- Incoming traffic almost remains unchanged; however, outgoing traffic is significantly reduced!

Impact on users' performance

- Average values over 10 simulation runs
- 95-percentile confidence intervals



No policy

- About 40% improvement of peers' download times

With Unchoking Policy

- Slight deterioration compared to No_policy

Swarm Selection module – Evaluation*

* I. Papafili, G. D. Stamoulis, F. Lehrieder, B. Kleine, S. Oechsner, Cache Capacity Allocation to Overlay Swarms, 5th International Workshop on Self-Organizing Systems (IWSOS'11), 23-24 February 2011, Karlsruhe, Germany

Simulation design

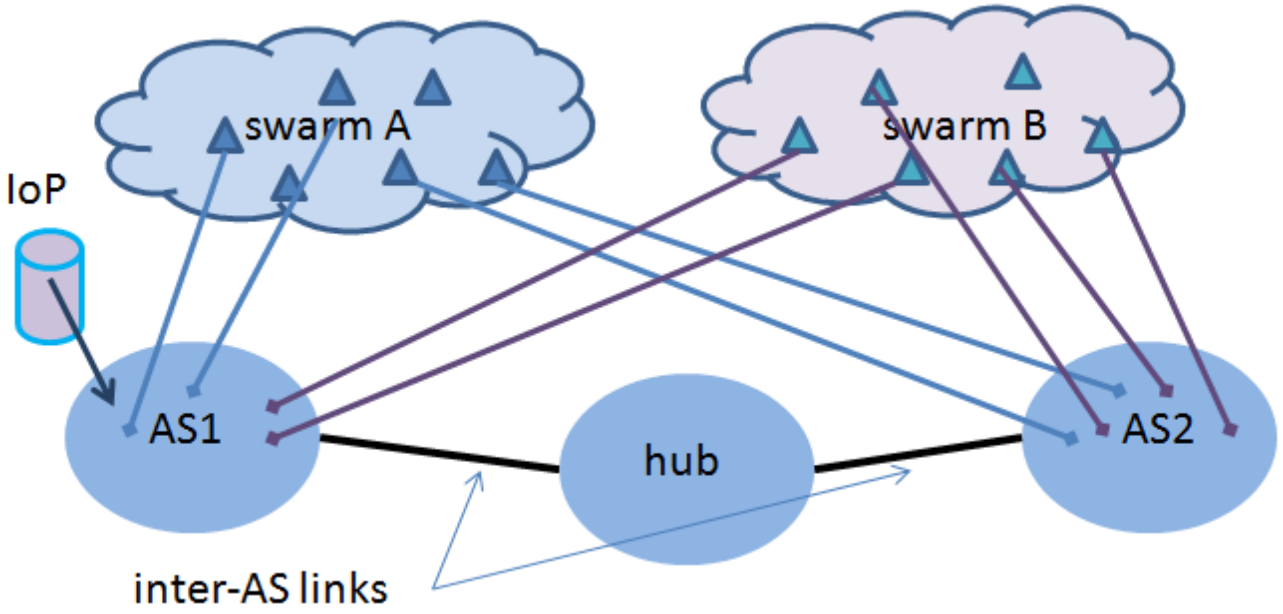
- Issue: The IoP *cannot* join all available swarms

- Perform selection of swarms
  - Try to achieve larger impact for all

Objective

- To evaluate the impact of swarm selection on the effect of the IoP in simple and more complex scenarios
- To investigate the impact of the three a priori known overlay factors:
  - File size, mean inter-arrival time, and mean seeding time

Simulation topology



- Simple 2-AS topology: AS1 & AS2
  - Hub has no peers!
- IoP **always** inserted in AS1

Simulation setup (i)

- Simulation duration: 3.5 hours (1.5 warm-up)
- Metrics of interest:
  - Inter-AS traffic of AS1 (incoming and outgoing)
  - Peers' performance (in terms of download time)

Underlay

- Homogeneous scenario
- Peers' bandwidth: 16384/10240 kbps
- Original seeder's bandwidth: 10240 kbps up
- IoP's bandwidth: 51200 kbps up&down

Simulation setup (ii)

Overlay

- Two different swarms: A & B
  - Peers of AS1 either participate only in swarm A, or only in swarm B, or in both
  - Same applies for peers of AS2
  - Participants of both swarms are **not** subject to changes!

- SmoothIT-Simulator* for ProtoPeer** platform

* SmoothITSimulator v3.0, http://protopeer.epfl.ch/wiki/BitTorrent

** ProtoPeer, http://protopeer.epfl.ch/index.html

Evaluation scenarios

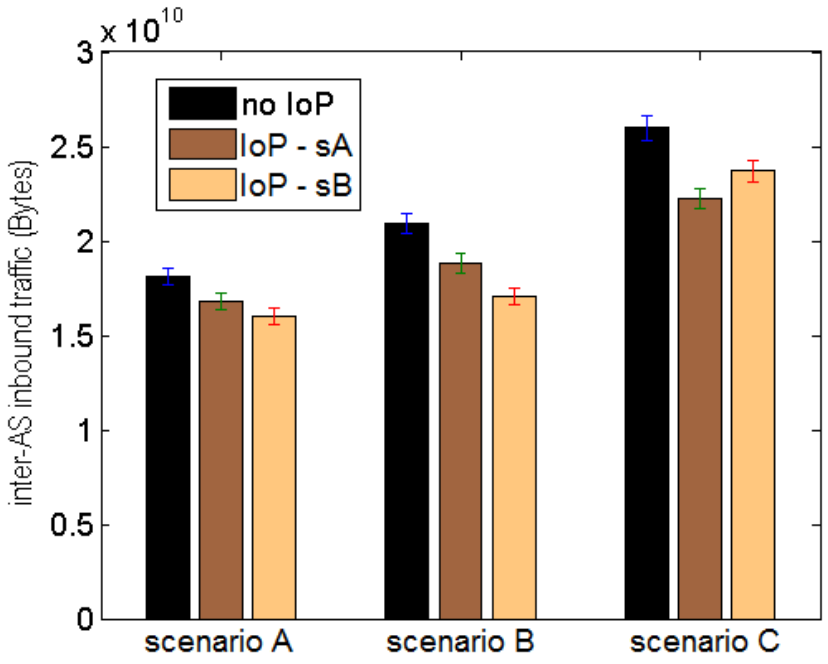
Scenario	*A*	*B*	*C*	*D*	*E*	*F*
Modified parameters	File Size: 50 MB	meanIAT: 300.0 s	meanST: 200.0 s	File Size: 50 MB, meanIAT: 300.0 s	File Size: 50 MB, meanST: 200.0 s	meanIAT: 300.0 s, meanST: 200.0 s

Default values

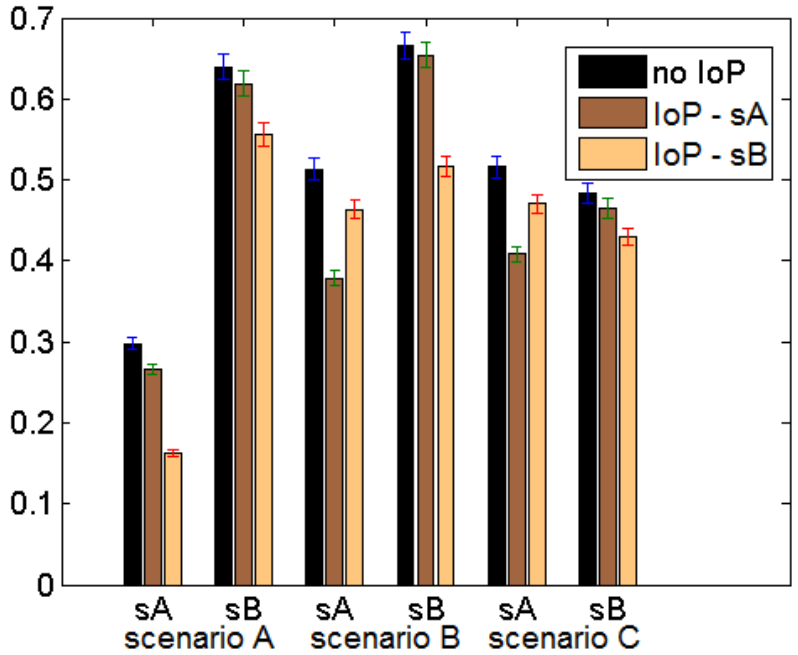
- File size: 150 MB
- Mean inter-arrival time: 100.0 s
- Mean seeding time: 600.0 s

Scenarios A, B, C

Incoming inter-AS traffic for AS1



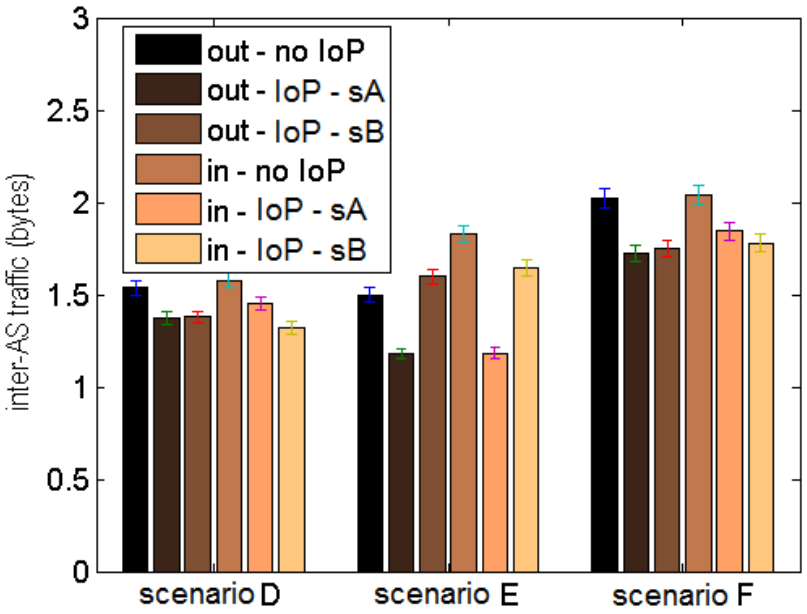
Download times for peers of AS1



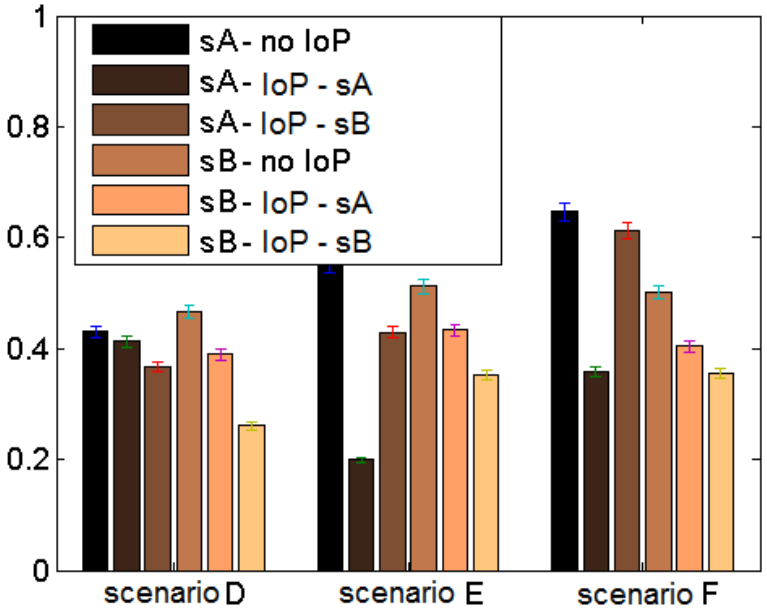
- IoP's impact is more significant when it joins the swarm with higher capacity needs!

Scenarios D, E, F

Incoming inter-AS traffic for AS1



Download times for peers of AS1



- Inter-AS traffic and users' performance more affected by the mean seeding time of seeders

Summary and conclusions

Incentive Compatibility

- IoP achieves simultaneously:
  - Significant inbound inter-domain traffic reduction of the AS that deploys the IoP and therefore:
  - Reduction of charges for inter-domain traffic under different charging schemes based on ingoing and/or outgoing traffic – *win*
  - Improvement of end-users' completion times – *win*
    - Investigation by means of simulations and theoretical modeling

Evaluation of the two modules

- Unchoking Policy
  - Implies important outgoing traffic reduction
  - Valuable under charging schemes that take into account also the outgoing traffic

- Swarm Selection
  - The three overlay factors investigated proved to be closely connected with the efficiency of the Swarm Selection
  - Impact of the IoP is more significant when it joins swarms with:
    - Large content file
    - Low mean inter-arrival time of leechers and
    - Low mean seeding time of seeders
  - Definition of a swarm selection rule based on these three factors is needed!

Work in progress

- Definition of a game-theoretic framework
  - Study of ISPs' dynamics when they are deploying or not IoPs, with or without caches

- Extension of this work for other types of traffic!

Questions?

Thank you for your attention!