Euro-NF International Workshop on
Traffic and Congestion Control
for the Future Internet
Volos, Greece, April 1st, 2011

A game-theoretic framework for ISPs' interactions in the context of Economic Traffic Management

Ioanna Papafili, George D. Stamoulis
Athens University of
Economics and Business

Sergios Soursos
Intracom Telecom S.A.

Outline

- Our context
- Economic Traffic Management
- Game-theoretic framework
- IoP Games
- Conclusions & future steps

The Internet Today: Players and Tussles

- Internet: A broad set of players (stakeholders) act simultaneously for the provision of each service
  - ISPs, application providers, content providers, users etc.

- Players can have ***complementary*** roles
  - In terms of resources and/or operations

  and ***conflicting*** interests
  - E.g. application providers desire high quality, which is costly to ISPs

- Tussles among players, who contend
  - Even they may engage in a common goal

Overlays & Information Asymmetry

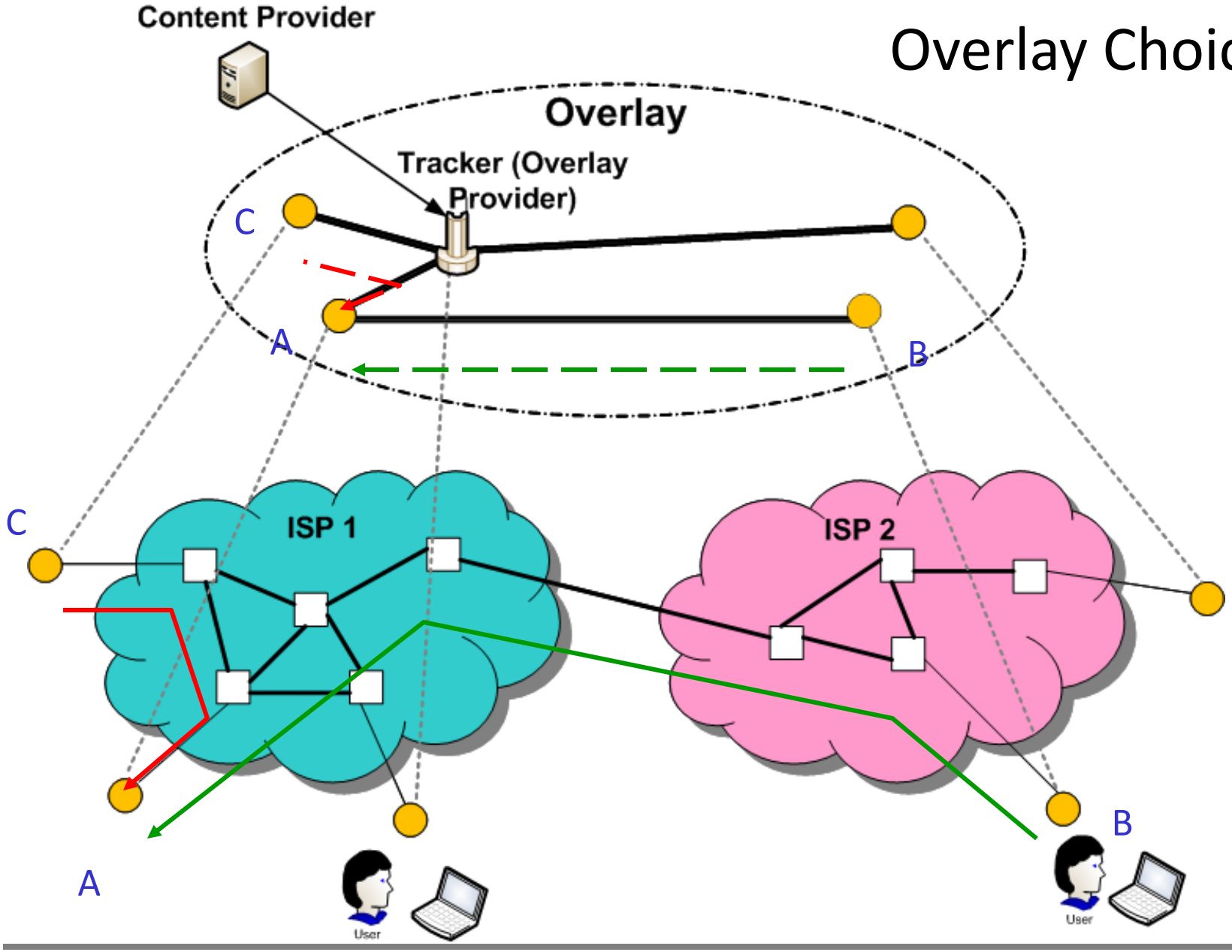
- Popular peer-to-peer (P2P) and other overlay applications; generate *significant* and *increasing* volumes of traffic

Information asymmetry

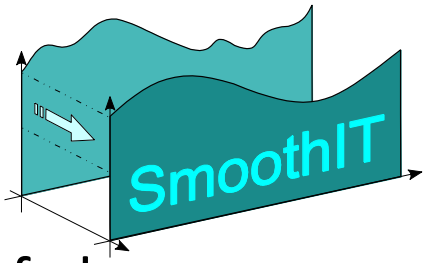
  - The underlay does *not* take into account the ovelay requirements
  - The overlays is built *independently* of the underlay network

- Conventional Traffic Engineering (TE) *not suitable* for overlay traffic, leads to traffic oscillations:
  - ***Higher costs*** for the ISP
  - ***Lower quality*** for application provider & users

Overlay Choices



The SmoothIT project
Economic Traffic Management*

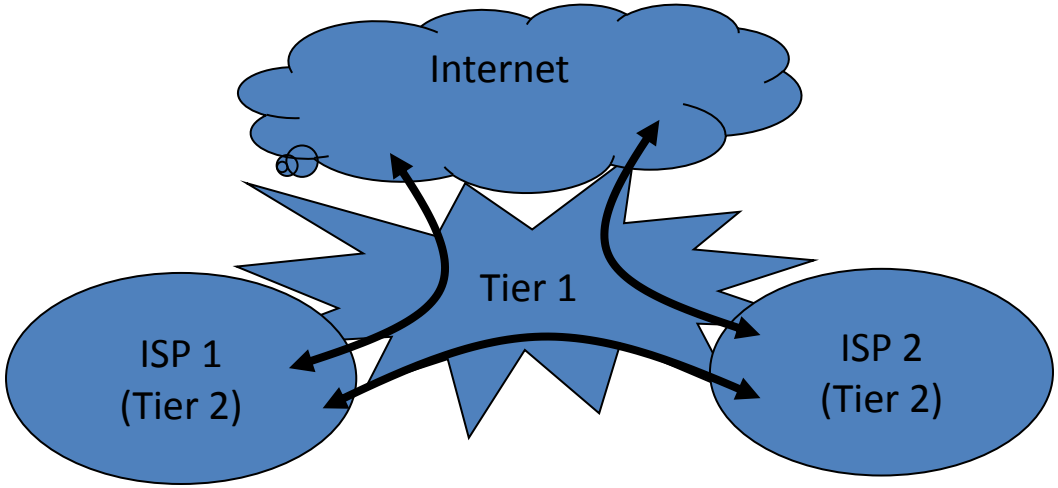


- Employs mechanisms based on the ***incentives*** of players
  - That are not contradictory to users' benefit but act ***complementary*** **to the *self-organization*** of the overlay
- Objective:
  - To ***bridge the information gap*** between overlay and underlay
  - To optimize overlay traffic mutually beneficially for all: ISP, user, application provider →"***TripleWin***"
- Under TripleWin the system operates in an *equilibrium* point
  - Traditional traffic optimization would aim at a global optimum of a single combined optimization metric
- An ETM mechanism is a means to enforce a desirable equilibrium

* The SmoothIT project: http://www.smoothit.org

Investigation of ISPs' interactions

1. ISP1 introduces an ETM mechanism
2. How should ISP2 respond?
   - Should ISP1 modify his action?



- Target: develop a unified game-theoretic framework to analyze ISP interactions and dynamic due to ETM

Game-theoretic framework

- ISPs are interacting, self-interested players
  - ISPs anticipate users' reactions
- ISP strategies involve application or not of an ETM mechanism and its possible variations
  - *Locality awareness*
  - *Insertion of caches*

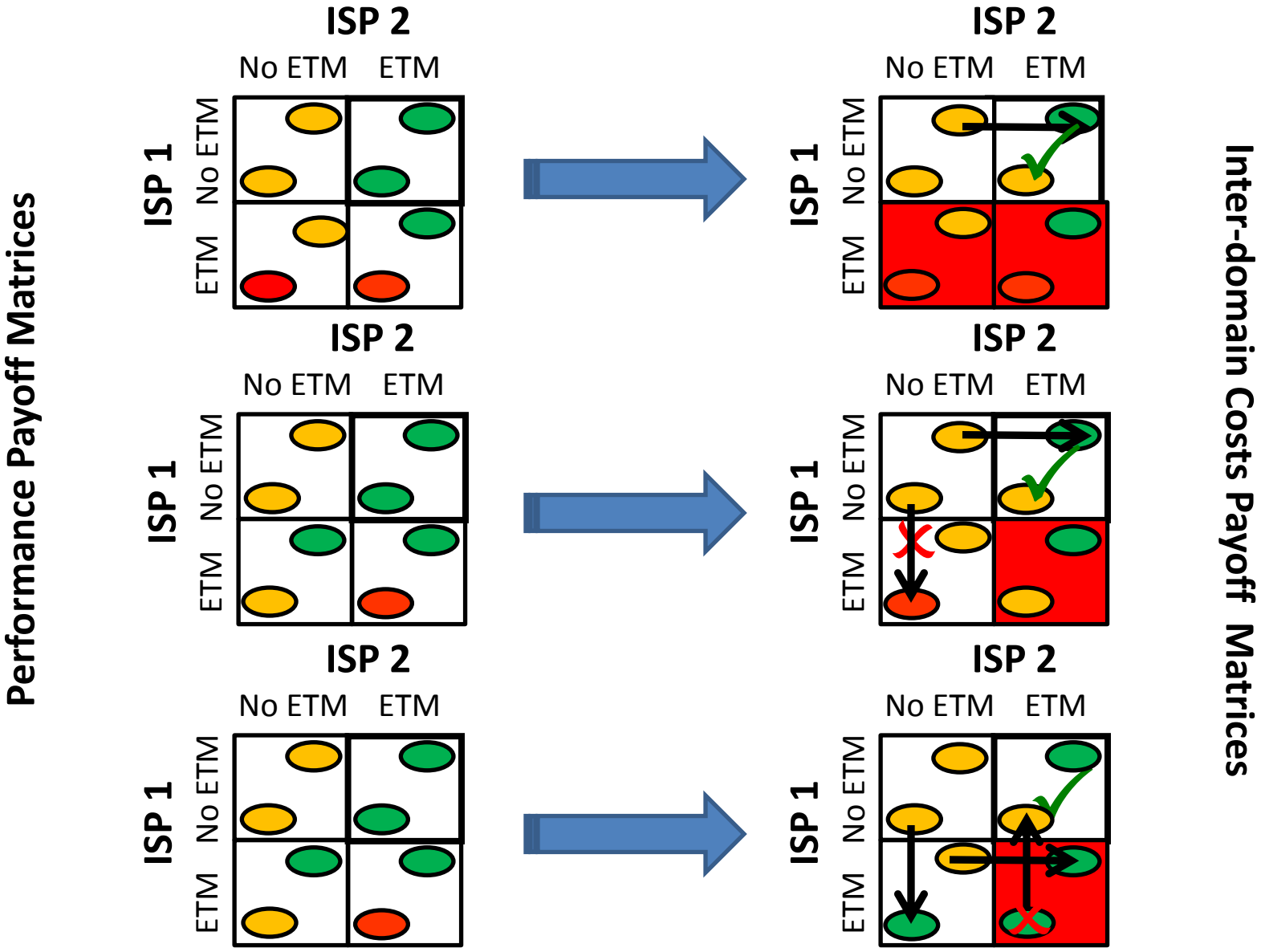
<u>Information Asymmetry</u>

- Each ISP does not know the payoff matrix of his opponent(s)
  - Each player chooses his best response strategy given the strategy played by his opponent
  - Not a Stackelberg game

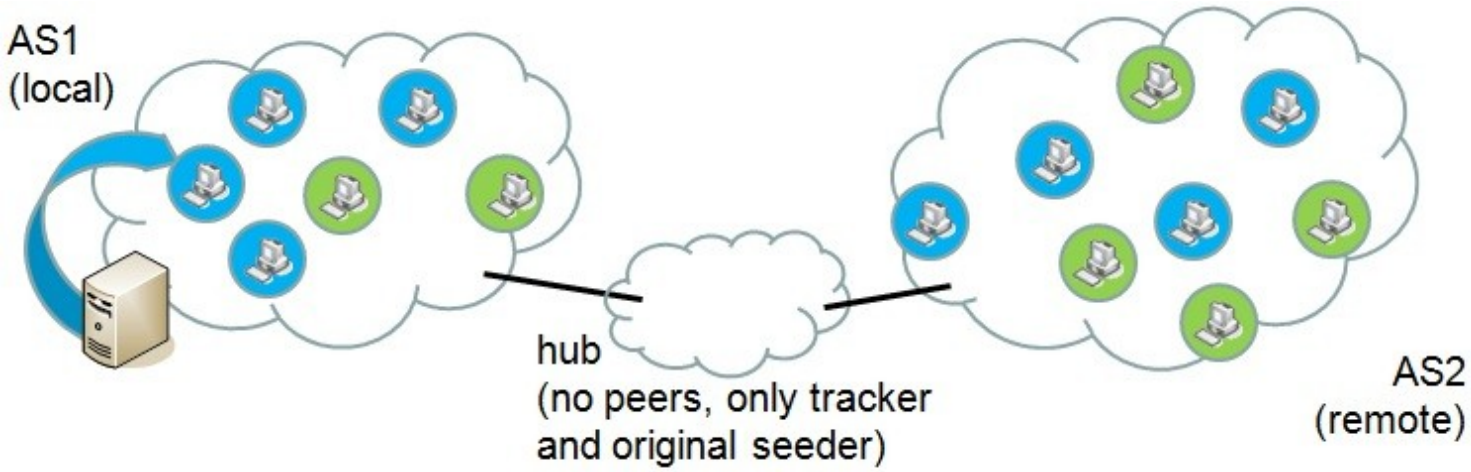
Definition of Two-level Game

- Multi-player, non-zero sum, ***two-metric***
- To decide on an action the ISP should consider *separately*:
  1. performance (1st level), and
  2. cost (2nd level)
- Metrics compared to those of the previous state
- Combination of two metrics could allow actions that imply:
  - Significant cost reduction, along with *performance deterioration*
  - Lead to loss of customers and revenue

Decisions under the two-level metric



ETM mechanism: Insertion of IoP(s)



- ISP-owned Peer:
  - Resourceful entity
  - Acts as an overlay peer
  - Controlled by the ISP
  - Transparent & non-interceptive cache
  - Exploits overlay self-organizing mechanism
- Impact:
  - Significant improvement of peers' performance
  - Reduction of incoming traffic
- Innovation:
  - Transparency, no interception required
  - Variety of policies

IoP Game

- Objective: To study ***interactions*** of 2 neighboring ISPs who can deploy IoPs with or without policy
  - Strategies = {no IoP, IoP, IoPUP}
  - IoPUP: insertion of IoP employing an Unchoking Policy;
  - UP dictates that *remote* peers are *not served* in seeding phase

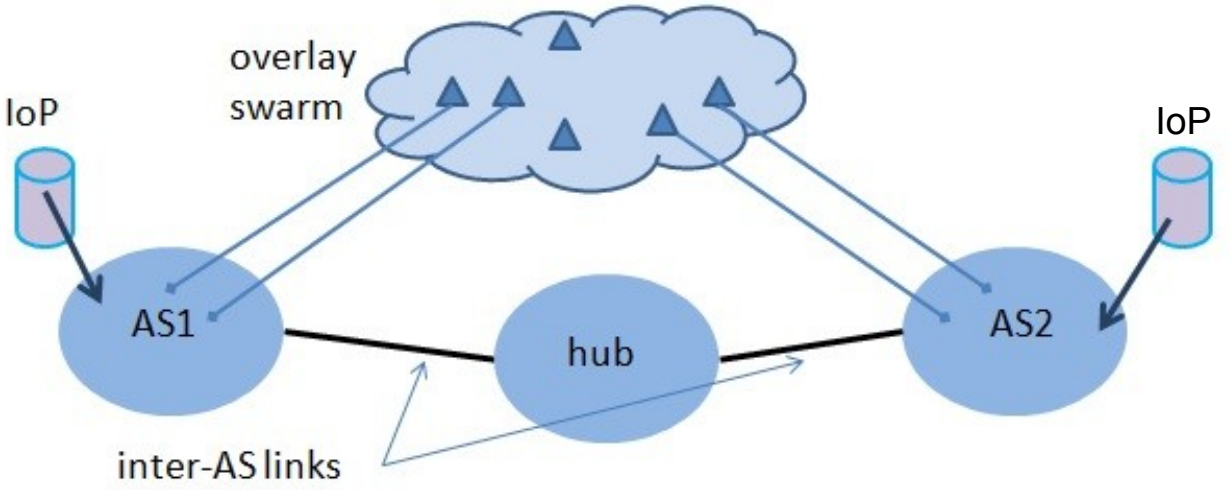
- Payoff metrics quantified using the [LD+10] model* or simulations**
  - Performance → bandwidth demand or download time
  - ISP inter-domain cost → incoming inter-AS traffic volume

* [LD+10] Lehrieder, Dan, Hossfeld, Oechsner, Singeorzan, The Impact of Caching on BitTorrent-like Peer-to-Peer Systems, IEEE P2P'10

** SmoothITSimulator v3.0, http://protopeer.epfl.ch/wiki/BitTorrent & ProtoPeer, http://protopeer.epfl.ch/index.html

Simulation Setup and Topology

- Underlay:
  - Peers: 16384/1024 kbps
  - Original seeder: 10240 kbps up & down
  - IoPs: 40960 kbps up & down
- Overlay:
  - 150 MB file
  - Mean inter-arrival time of leechers: 100 sec.
  - Mean seeding time: 600 sec.



Symmetric case: Simulation-based

- {noIoP, noIoP}, {noIoP, IoPUP}, {IoPUP, noIoP}: not feasible
- Step 1: AS2's first move leads to deterioration of AS1's cost
- Step 2: AS1's response aims at further improving cost

Level 1: Av. download times

AS1 \ AS2	no IoP	IoP	IoPUP
no IoP	4.80 4.81	1.03 1.01	1.22 2.46
IoP	1.01 1.02	0.91 0.91	0.92 0.96
IoPUP	2.43 1.22	0.96 0.92	0.98 0.98

Level 2: Inbound inter-AS traffic

AS1 \ AS2	no IoP	IoP	IoPUP
no IoP	2.14 2.07	1.43 2.66	1.04 2.11
IoP	2.58 1.52	2.06 1.92	1.43 1.49
IoPUP	2.00 1.09	2.58 1.92	1.56 1.45

Asymmetric case: Model-based

- Step 2: AS2's response deteriorates both AS1's performance (and cost)
- Step 3: AS1 tries to improve its performance compared to Step 2, not to the beginning

Level 1: Av. download times

AS1 \ AS2	no IoP	IoP	IoPUP
no IoP	1.54 0.51	1.43 0.56	1.42 0.55
IoP	1.63 0.35	1.51 0.37	1.53 0.36
IoPUP	1.64 0.34	1.50 0.39	1.52 0.38

Level 2: Inbound inter-AS traffic

AS1 \ AS2	no IoP	IoP	IoPUP
no IoP	0.40 0.38	0.38 0.41	0.39 0.42
IoP	0.36 0.26	0.32 0.28	0.34 0.27
IoPUP	0.37 0.25	0.33 0.30	0.35 0.29

Summary

- A game-theoretic framework for studying ISPs' interactions in the context of ETM
  - Users' reaction is anticipated
  - Two-level metric is used

- IoP game: results obtained by the theoretical model and simulations reveal similar dynamics for interacting ISPs

- Locality game also studied, using a new model

- Future work: formalize conditions for equilibria

Questions?

Thank you for your attention!

Thanks to all SmoothIT's project partners:

UZH, DOCOMO, TUD, AUEB, PrimeTel, AGH, ICOM, UniWue, TID

Back-up

Modeling background

- Qiu and Shrikant presented a fluid model in [QS08]
  - Study of inherent characteristics of BitTorrent
  - Steady-state analysis
  - Investigation of BitTorrent's incentive mechanism tit-for-tat

- Lehrieder *et al.* in [LD+10] extended [QS08] model to incorporate cache insertion information
  - Investigate the effects of caches on system's dynamics
  - Combination of the fluid model with a simple *inter-AS traffic model*

[QS08] Qiu, Shrikant, Modeling and Performance Analysis of BitTorrent-like Peer-to-Peer Networks, SIGCOMM'04

[LD+10] Lehrieder, Dan, Hossfeld, Oechsner, Singeorzan, The Impact of Caching on BitTorrent-like Peer-to-Peer Systems, IEEE P2P'10