Efficiency and cooperation in the routing of flows

Costas Courcoubetis
AUEB

ETICS Workshop, June 1\textsuperscript{st}, 2011
Motivation

• To provide e2e services, ISPs need to cooperate
• Interesting “tussle” (conflict): keeping local control vs maximizing global benefit
• What is the effect on profits for different degrees of cooperation?
  – Minimum cooperation and restrictions (loose federation)
  – Maximum cooperation (maximum regulation, facilitator)
• Simple model:
  – Simple hub topology, destinations reached with paths of lengths 1 and 2
  – Revenue generated by flows (video calls), shared among ISPs in the flow path in a pre-specified way
  – ISP strategy: originating ISP decides on call routing
Three links each of capacity C

Flow arrival rate from ISP\(_i\) to dst = \(v\)

Each consumes 1 unit of bandwidth and lasts for 1 time unit on the average

Reward to originating ISP:
- Directly routed = \(r\)
- Alternatively routed = \(r_1 < r\)

Transit ISP gets a \(r_2 < r_1\) reward per alternatively routed flow
- \(r = r_1 + r_2\)
• **Actions** on arrival of a new flow:
  – Route on direct or alternative path
  – Accept or reject (applies to transit flows as well)

• **Strategy** = action to be taken on a flow arrival *based on perfect state info*

**Nash strategy**: maximizes ISP$_i$’s reward rate over all strategies given that competing ISPs follow that same strategy
Example strategies, I

• **Myopic** strategy (maximize instantaneous reward rate):
  – If direct path fails, try the alternative
  – Always accept transit flows if bandwidth is available

• **Bistable** behavior:
  – One with many direct flows (*high* reward states)
  – One with many transit flows (*low* reward states)
    • Limited reward rate because of transit link constraint.
Example strategies, II

- **Trunk reservation** with parameters $t_1, t_2$
  - If direct path fails, try the alternative only if at least $t_1$ units of bandwidth is available
  - Accept transit flows only if at least $t_2$ units are available
- Direct route **bias** enforces high reward states system-wide
- Trunk reservation is a **regulated decision** for the global benefit
- Not a Nash equilibrium
Questions

• Determine Nash strategies
  – Myopic strategy seems a natural candidate

• Do Nash strategies exhibit low system-wide rewards?
  – Trunk reservation known to be optimal for good choice of parameters
  – Price of anarchy
  – Incentives to follow trunk reservation

• Next slides: focus on large symmetric networks
Large symmetric networks

- **Fully connected, symmetrically loaded** network of N ISPs
- Strategy set = \{s_0, s_1, ..., s_K\}
- \(s_i\) = try up to \(i\) (randomly chosen) two-hop alternative routes

- Nash equilibrium = \(s_K\): “try as many alternatives as possible”
- Regulated operation: use trunk reservation
Large symmetric networks

- Say ISP\textsubscript{2}-ISP\textsubscript{N} follow \( s_K \), as ISP\textsubscript{1} except on link ISP\textsubscript{1}-ISP\textsubscript{2}

- As \( N \to \infty \) blocking probability = \( B \) on every link and blocking is independent

ISP\textsubscript{1} adopts \( s_K \) on ISP\textsubscript{1}-ISP\textsubscript{2}
Some more questions

• The sub-optimality of the myopic (non-cooperative) policies is intrinsic, or is due to poorly chosen revenue sharing policies?
• Can we do better by ISPs using dynamic charges?
  – The price charged to transit traffic increases as free capacity decreases
  – This deters originating ISPs to use alternative paths when capacity is scarce
  – Is it equivalent with trunk reservation and static revenue sharing?
• Allow ISPs to pick prices in a competitive market
  – A greedy ISP that charges more protects his direct link and makes more income from transit traffic, but may unnecessarily loose income because of competition
  – How good is the market equilibrium?
Conclusions

• A formal approach to the ETICS question about the benefits of cooperation between ISPs
• Our “loose” cooperation model assumes that ASQ paths have been constructed but ISPs are free to choose how to route flows in a greedy way
• Our “tight” cooperation model assumes that a trusted 3d party operates the system for the global benefit
• We raise issues related to the performance of the two extreme case, and to the effects of revenue sharing structures
• We like to capitalize on existing research on loss networks
• Large hub networks may be tractable for analysis of certain cases
• Simulations will be valuable