Efficiency and cooperation in the routing of flows

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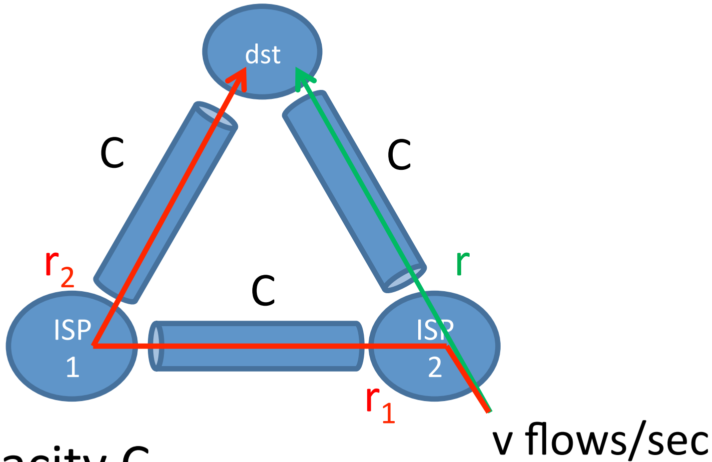
Motivation

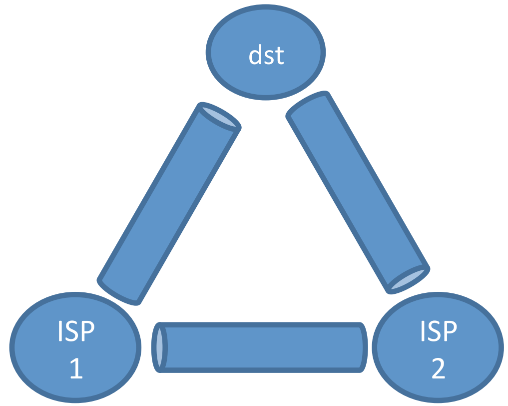
- To provide e2e services, ISPs need to cooperate
- Interesting “**tussle**” (conflict): keeping local control vs maximizing global benefit
- What is the effect on profits for different degrees of cooperation?
  - Minimum cooperation and restrictions (loose federation)
  - Maximum cooperation (maximum 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**

Simple model



- 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
- $r = r_1 + r_2$

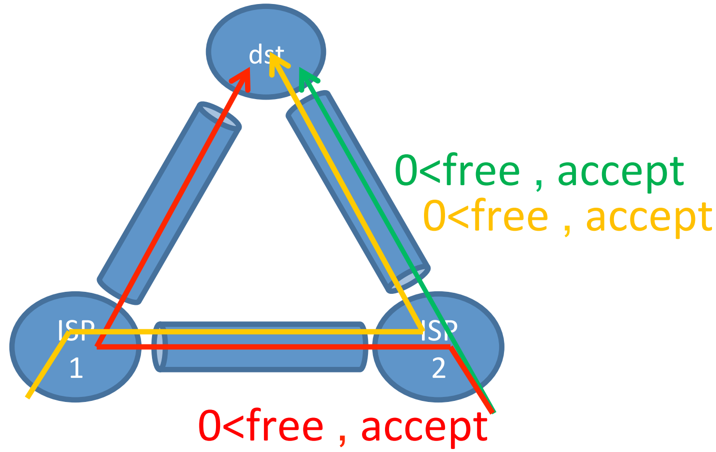
Routing Game



- **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*

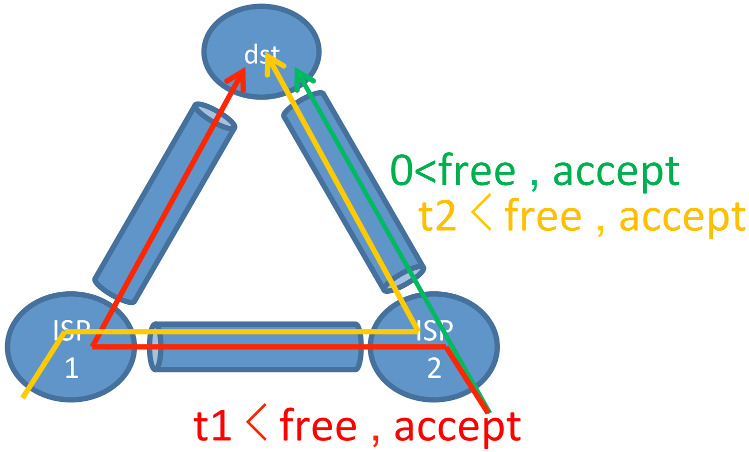
Nash strategy: maximizes ISP_i's reward rate over all strategies given that competing ISPs follow that same strategy

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* bevavior:
  - 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

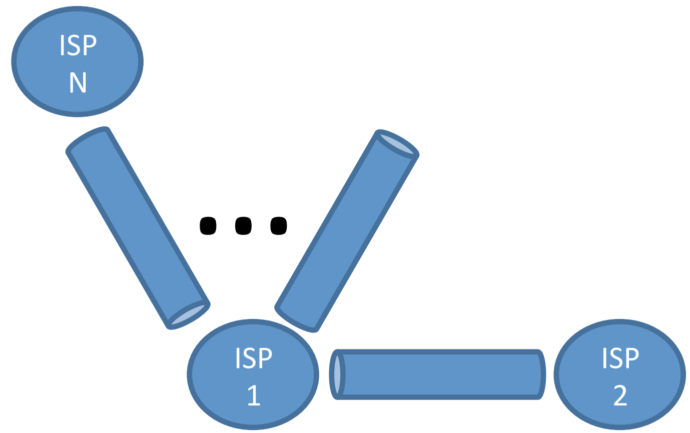


- **Trunk reservation** with parameters t_1 ,t_2
  - If direct path fails, try the alternative only if at least t_1 units of bandwidth is available
  - Accept transit flows only if at least t_2 units are available
- Direct route **bias** enforces high reward states system-wide
- Trunk reservation is 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

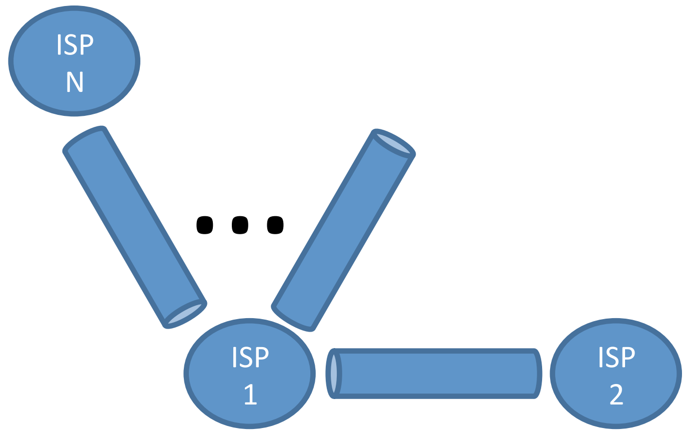
Large symmetric networks



- *Fully connected, symmetrically loaded* network of N ISPs
- Strategy set = $\{s_0, s_1, \ldots, s_K\}$
- 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_2-ISP_N follow s_K, as ISP_1 except on link ISP_1-ISP_2

- As N->∞ blocking probability = B on *every* link and blocking is independent

ISP_1 adopts s_K on ISP_1-ISP_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