

Efficiency and cooperation in the routing of flows

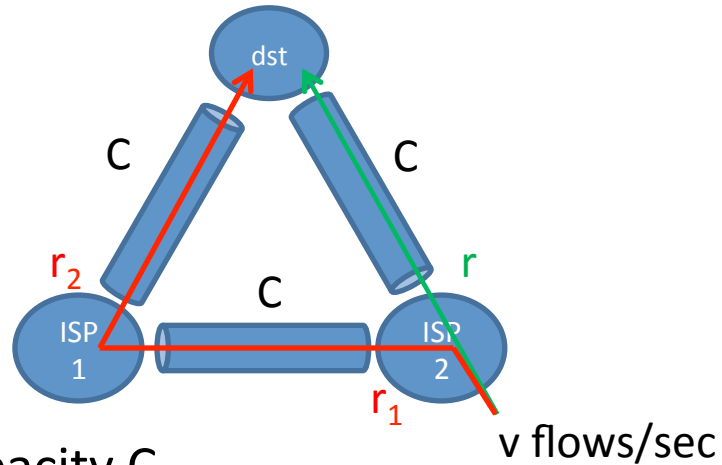
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Motivation

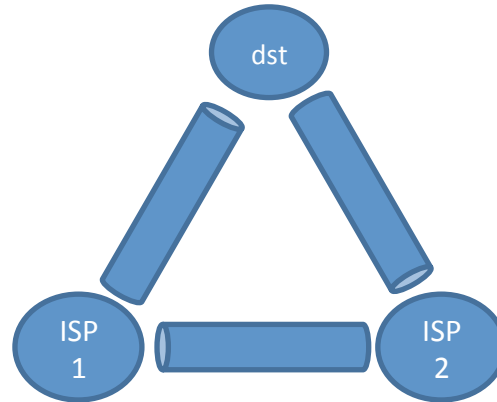
- To provide e2e services, ISPs need to cooperate
- Interesting “**tussle**” (conflict): **keeping local control** vs **maximizing global benefit**
- What is the effect on profits for different degrees of cooperation?
 - Minimum cooperation and restrictions (loose federation)
 - Maximum cooperation (maximum 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
- $r = r_1 + r_2$

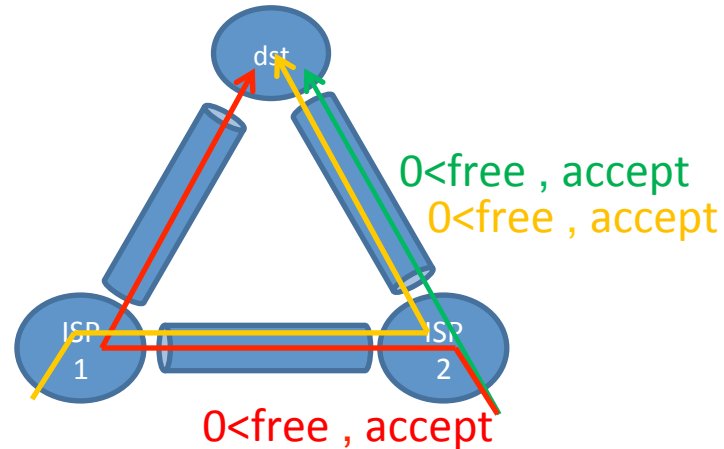
Routing Game



- **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*

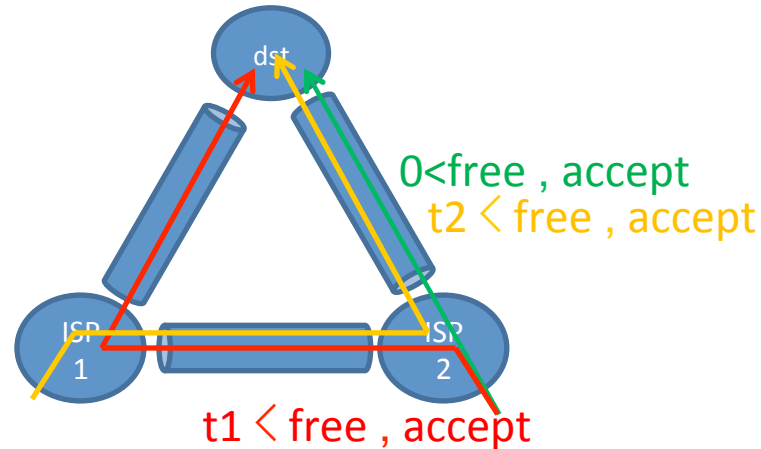
Nash strategy: maximizes ISP_i 's reward rate over all strategies given that competing ISPs follow that same strategy

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* 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

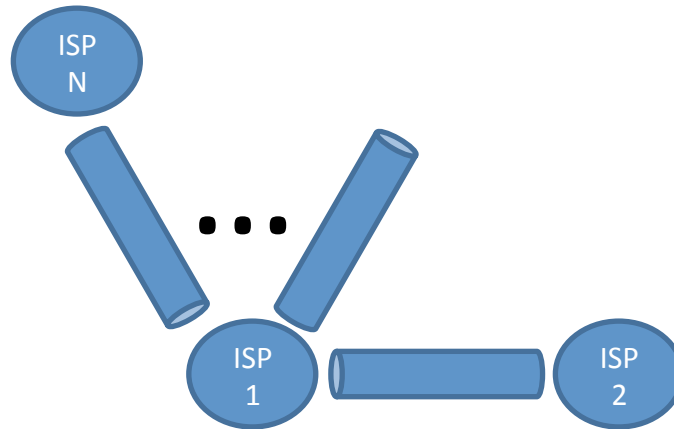


- **Trunk reservation** with parameters t_1, t_2
 - If direct path fails, try the alternative only if at least t_1 units of bandwidth is available
 - Accept transit flows only if at least t_2 units are available
- Direct route **bias enforces high reward states** system-wide
- Trunk reservation is a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

Questions

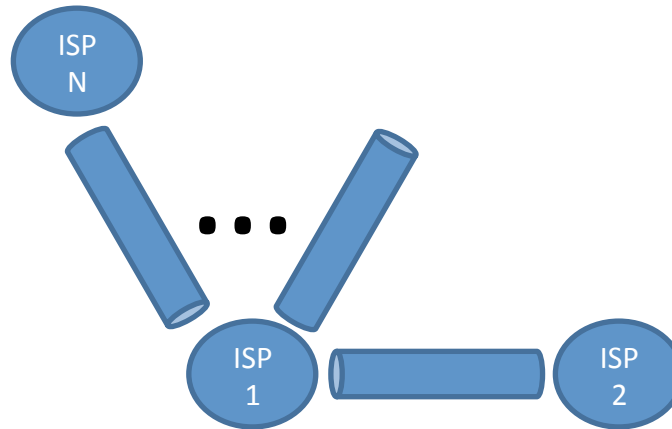
- Determine Nash strategies
 - Myopic strategy seems a natural candidate
- Do Nash strategies exhibit low system-wide rewards?
 - **Trunk reservation known to be optimal for good choice of parameters**
 - Price of anarchy
 - Incentives to follow trunk reservation
- Next slides: focus on large symmetric networks

Large symmetric networks



- *Fully connected, symmetrically loaded* network of N ISPs
- Strategy set = $\{s_0, s_1, \dots, s_K\}$
- 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 $N \rightarrow \infty$ 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 lose 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