An Inter-domain Overlay Network Based on ISP Alliance

Background and objective

- Tiered Internet structure
  - Tier 1: Backbone ISPs
  - Tier 2: Regional ISPs
  - Tier 3: Access ISPs

- Sub-optimality of current inter-domain routing protocol -- BGP
  - Technical: Path of the least hop count is not equal to path with best performance
  - Economic: Route choice space is limited by BGP policies, e.g. path with valley is not allowed

- Our work
  - An inter-domain overlay network based on ISP alliance
  - More efficient routing and economic structure within the overlay network
  - A simple algorithm for ISPs to search the optimal transit prices

Inter-domain overlay network

- Overlay network based on ISP alliance
  - ISP alliance: comprised of adjacent ISPs
  - Inter-domain overlay network: constructed by overlay nodes operated by ISPs within the ISP alliance

- Basic routing and economic structure within ISP alliance

<table>
<thead>
<tr>
<th>ISP alliance</th>
<th>Internet</th>
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</thead>
<tbody>
<tr>
<td>Routing structure</td>
<td>Source routing Multi-path routing</td>
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<tr>
<td>Business relations</td>
<td>Every ISP in the alliance provides transit service</td>
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<td>Charging</td>
<td>Traffic users pay every ISP along the routes that their traffic traverse.</td>
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Interaction of traffic user ISPs and transit ISPs

- ISPs dual roles
  - Traffic user
  - Transit provider
- Interaction of the two roles
  1. Transit ISPs decide prices
  2. Traffic user ISPs make routing decision
  3. Transit ISPs obtain revenue

Pricing scheme

- Non-cooperative pricing game: Each ISP decides price for each route individually
  - Inefficient in traffic routing
  - Unfair for ISPs’ revenue sharing
- A small-scaled cooperative game based on route bundle
  - Route bundle: a bundle of routes with the same source, destination and entrance ISP
  - Price is decided for route bundle rather than route
  - Price can be decided by entrance ISP simply
- A simple pricing algorithm to search the optimal prices
  1. Initialize price $p$ as $p_0$
  2. Loop step 3 ~ step 5 until optimal price being found
  3. Increase $p_i$ as one unit. If revenue increases, go to 4, else go to 5
  4. Keep increasing $p$, until revenue decreases
  5. Keep decreasing $p$, until revenue decreases

ISP’s routing decision and optimal transit price

- ISP’s routing decision with single path
  - $d_i(p_i)$ is ISP’s traffic demand on path $i$, given the route price $p_i$
  - $d_i(p_i)$ is decreasing and differentiable
  - $g_i'(p_i) = -d_i'(p_i)/d_i'(p_i)$ is decreasing

- ISP’s routing decision with multiple paths $<R_1, ..., R_n>$ in ascending order with performance as well as price
  - Traffic demand through $R_i$: $d_i(p_i) - d_{i+1}(p_i)$
  - Revenue obtained from $R_i$: $p_i(d_i(p_i) - d_{i+1}(p_i))$
  - Optimal transit price $p_i = \arg\max p_i(d_i(p_i) - d_{i+1}(p_i))$ has a unique solution

Experiment for verifying the pricing algorithm

- The theoretical optimal price $p^*$:
  - $p^{*1-3-6} = 7.00$
  - $p^{*1-2-6} = 4.00$
  - $p^{*1-5-6} = 2.00$

The prices of route bundles can converge into optimal values with which the revenues obtained from those route bundles can reach the theoretical maximum