CIPT: Using Tuangou to Reduce IP Transit Costs

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1. Internet Protocol (IP) transit costs
2. Cooperative IP Transit (CIPT)
3. Data-driven evaluation
   1. Data collection
   2. CIPT gains
4. Beyond gains sharing
5. Open problems and conclusion
Introduction: IP (Internet Protocol) transit

IP transit
An Internet Service Provider (ISP), the costumer, pays another ISP, the provider, for having its bidirectional traffic reaching the global Internet.
IP transit billing

• Traffic metering
  • peak (traffic) = 95th percentile of short term traffic rates
  • SUM = peak (upstream) + peak (downstream)
  • MAX = Max [peak(upstream), peak(downstream)]

• Subadditive pricing

<table>
<thead>
<tr>
<th>Committed Data Rate (Mbps)</th>
<th>Price per Mbps per month</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>$25</td>
</tr>
<tr>
<td>50</td>
<td>$15</td>
</tr>
<tr>
<td>100</td>
<td>$10</td>
</tr>
<tr>
<td>1000</td>
<td>$5</td>
</tr>
<tr>
<td>10000</td>
<td>$4</td>
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</table>

Voxel pricing
Source= [https://www.voxel.net/ip-services](https://www.voxel.net/ip-services)
(as accessed on June 2011)
Motivation

Per-Mbps transit price decline vs. interdomain traffic growth

ISPs seek to reduce transit costs

Source: https://www.telegeography
Existing approaches to cost reduction

- Altering transit traffic
  - Settlement-free peering: reciprocal exchanges of own customer traffic between two ISPs
  - Other techniques: paid peering, multicast, peer-to-peer localization, Content Distribution Networks (CDNs)...

Diagram:
- ISP 1
- ISP 2a
- ISP 2b
- ISP 2c
- Users
Existing approaches to cost reduction

- Altering transit traffic
  - Settlement-free peering: reciprocal exchanges of own customer traffic between two ISPs
  - Other techniques: paid peering, multicast, peer-to-peer localization, Content Distribution Networks (CDNs)…
CIPT (Cooperative IP Transit)

- Novel cost-reduction concept
  - Does not alter traffic
  - Reduces per-Mbps price
- Coalitional arrangement among multiple ISPs
  - Is modeled as a cooperative game
  - Uses Shapley value to distribute gains
- Data-driven analysis
  - Collects data from IXPs’ (Internet eXchange Points) websites
  - Estimates transit traffic
  - Evaluates aggregate and individual gains
Cooperative IP Transit (CIPT) concept

- **Tuangou**
  coalitional arrangement for bulk buying of IP transit

- **CIPT gains**
  Per-Mbps price reduction thanks to subadditive billing
Cooperative IP Transit (CIPT) concept

- **Tuangou**
  coalitional arrangement for bulk buying of IP transit

- **CIPT gains**
  Per-Mbps price reduction thanks to subadditive billing
Shapley value for CIPT gains’ sharing

• Expected marginal contribution of a player to overall CIPT gains

• Properties
  • Existing and unique for any cooperative game
  • Fair, efficient, symmetric, additive and null-player
  • Individually rational

• Calculation
  • Hard to calculate exactly
  • Estimated accurately by our Monte-Carlo method
Shapley value definition

- **Shapley value**\((i)\)

ISP \(i\)'s expected marginal contribution if the players join the coalition one at a time, in a uniformly random order

\[
\phi_i(c) = \frac{1}{N!} \sum_{\pi \in S_N} (c(S(\pi, i)) - c(S(\pi, i) \setminus i))
\]

\(i\)'s marginal contribution

\(N = \text{number of players}\)
\(c(S) = \text{cost of coalition } S\)
\(S(\pi, i) = \text{set of players arrived in the system not later than } i\)
\(\pi = \text{permutations of the set of players } N\)
Shapley value estimation

• Monte Carlo method*

  • We estimate the Shapley value as the average cost contribution over set \( \pi_k \) of \( K \) randomly sampled arrival orders.

  \[
  \hat{\phi}_i(c) = \frac{1}{K} \sum_{\pi \in \Pi_K} (c(S(\pi, i)) - c(S(\pi, i) \setminus i))
  \]

• Estimation accuracy

  • \( K \) is the knob controlling the accuracy
  
  • We use \( K = 1000 \) to keep the error under 1%


Data-driven evaluation

1. Crawling the Internet to **collect traffic images** from IXP’s websites

<table>
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<tr>
<th>IXP</th>
<th>acronim</th>
<th># of members</th>
<th>peak (Gbps)</th>
<th>average (Gbps)</th>
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<tr>
<td>Neutral IX (Prague)</td>
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Data-driven evaluation

1. Crawling the Internet to **collect traffic images** from IXP’s websites

![Internet diagram with IXP websites]

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Data-driven evaluation

1. Crawling the Internet to **collect traffic images** from IXP’s websites

   ![Collection of mrtg images]

   Optical Character Recognition (OCR)

2. Transform images into **numeric data on peering traffic**

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From peering to transit traffic

- Transit traffic is rarely available

- Our hypothesis is that transit traffic and peering traffic are similar

- We validate the similarity with public data from two ISPs (HEATNET and SANET)
Cosine-similarity \approx \frac{\sum_{i=1}^{T} X_i Y_i}{\sqrt{\sum_{i=1}^{T} X_i^2} \sqrt{\sum_{i=1}^{T} Y_i^2}}.

- If \( \text{sim}(X; Y) = 1 \), then \( X = \alpha \cdot Y \)
- Otherwise \( \text{sim}(X; Y) < 1 \)

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<th>ISP</th>
<th>\text{sim}(T_{up}, P_{up})</th>
<th>\text{sim}(T_{down}, P_{down})</th>
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<tr>
<td>HEANET</td>
<td>0.988</td>
<td>0.965</td>
</tr>
<tr>
<td>SANET</td>
<td>0.996</td>
<td>0.991</td>
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Peering-transit traffic similarity

- Peering and transit follow very similar patterns
- $\alpha = 1.5$
- We scale peering traffic by $\alpha$ within the range $[0.5;4]$
Aggregate CIPT gains

- Absolute aggregate CIPT gains grow with IXP size (in terms of billed traffic)

- Relative aggregate CIPT gains decrease with IXP size
Absolute aggregate CIPT gains grow with IXP size (in terms of billed traffic)

Relative aggregate CIPT gains decrease with IXP size
Per-partner CIPT gains

- Absolute individual CIPT gains grow with ISP size
- Relative individual CIPT gains decrease with ISP size

There are large gains for all CIPT members
CIPT gains and coalition size

- Fraction of CIPT gains in SIX (52 ISPs)
Fraction of CIPT gains in SIX (52 ISPs)

Small coalitions provide most of total attainable gains
Beyond gains sharing

- Organizational embodiment
- Physical infrastructure
- Inter-domain routing
- Performance
- Traffic confidentiality
- Transit providers and strategic issues
Strategic issues

- Costs saved by CIPT coalitions are not necessarily the revenues lost by a transit provider
  - CIPT as a new customer
Strategic issues

- Costs saved by CIPT coalitions are not necessarily the revenues lost by a transit provider
  - CIPT as a new customer
  - bypass the middle-man
Costs saved by CIPT coalitions are not necessarily the revenues lost by a transit provider

- CIPT as a new customer
- bypass the middle-man
Open problems

- **#1**: How do changes in CIPT affect its dynamic?
- **#2**: Can we quantify the factors that influence the CIPT coalition formation process?
- **#3**: Can we derive more suitable metrics that would approximate the Shapley value closely, while being explicit and simple to calculate?
- **#4**: What would be the effect of CIPT on the Internet AS-level topology?
Conclusions

- We propose a novel mechanism for IP transit cost reduction: Cooperative IP Transit (CIPT)
- CIPT reduces costs significantly through bulk buying of IP transit
- We model CIPT as a cooperative game and use Shapley value as a mechanism for cost sharing
- The evaluation of CIPT with real data shows
  - Significant aggregate and individual gains
  - Large gains even with small coalitions