A Solution Approach for AS Relationships-aware Overlay Routing

<draft-asai-cross-domain-overlay-00>

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The Internet

- Autonomous systems (ASes)
  - e.g., ISPs, companies, and universities
- Inter-AS economics
  - transit charge
Motivation

• Reduction in transit traffic/charge

  Why?
  
  • Most of ISPs providing their network to P2P nodes are residential ones.
    – i.e., not tier-1, but customers
  
  • Transit traffic costs more compared to peering or intra-domain traffic.
Approach

- Be aware of commercial relationships between ASes
  - in overlay networks

  Similar to ALTO
  - but
    - focusing mainly on cross-domain traffic
    - with hiding ISP’s confidential information as much as possible (i.e., minimum ISP cooperation)
Detail with valley-free path model

<table>
<thead>
<tr>
<th>Destination Edge</th>
<th>p2c</th>
<th>p2p</th>
<th>c2p</th>
</tr>
</thead>
<tbody>
<tr>
<td>p2c</td>
<td>+,+</td>
<td>+,0</td>
<td>+,-</td>
</tr>
<tr>
<td>p2p</td>
<td>0,+</td>
<td>0,0</td>
<td>0,-</td>
</tr>
<tr>
<td>c2p</td>
<td>-,+</td>
<td>-,0</td>
<td>-,-</td>
</tr>
</tbody>
</table>

Note: edge ASes accommodate CDN peers.

Higher preference path:
- p2c: provider to customer
- c2p: customer to provider
- p2p: peer to peer

The worst path: both ASes pay transit charge.
Requirements (1/2):
AS relationships

• Information on AS relationships
  □ Inference methods (N.B., assuming ISPs do not want to reveal AS relationships)
    • Path analysis [Gao2001, etc]
    • Adjacency analysis [Asai2010]
      – A method for provisioning this information to peers
        » Inferred then provisioned from server(s)
          • written in the draft
Requirements (2/2): Delivery cost for a certain path

- Delivery cost computation
  - End-to-end path (AS path)
    - A method for provisioning this information to peers
      - traceroute by peers
      - Provisioned by servers in ASes
        » written in the draft
  - Function
    - i.e., \( f(P) = \) (transit charge on residential ASes)
      - \( f \): function, \( P \): AS path

AS relationships inference

- Heuristics: Common approach
  - **Degree** (i.e., # of neighbors)
    - High degree $\Rightarrow$ large
      - tends to be provider
    - Low degree $\Rightarrow$ small
      - tends to be customer

**Diff. in degree**
- **p2c**: provider to customer
- **c2p**: customer to provider
- **p2p**: peer to peer

AS relationships inference (cont’d): Improving degree-based approach

Take into account the size of $n$-hop neighbor ASes

$\Rightarrow$ “Magnitude”

ASes neighboring larger ASes are also large.


Example of cost function (e.g., in CDN)

- Metrics for peer selection
  - (1) Inter-AS transit cost
    - Estimated AS relationships
      - for reducing transit traffic and charge for ASes accommodating peers
  - (2) Network cost
    - AS hop count (or distance)
      - for AS-level localization (well-known way)
  - (3) Quality
    - #simultaneous uploads
      - for avoiding deteriorating content delivery throughput (very naïve parameter…)

Simulation result:
High-cost transit traffic reduction

Fig. Breakdown of inter-domain traffic on ASes accommodating CDN peers
Simulation result:
Transit charge reduction

N.B., provider ASes charges customer ASes for transit traffic based on the exchanged traffic volume.

Fig. Charged transit traffic volume with the 95th percentile charging policy

Conclusion

- **Approach for reducing transit traffic**
  - **Pros.**
    - Not require ISPs’ information (available by end-to-end)
  - **Cons.**
    - Efficiency depends on inference methods.
- **TODO**
  - Field experiment to evaluate the system
  - Discussion on deployment possibility and next step
    - Can ISPs provide AS paths?
      - Yes → How to deploy
      - No → traceroute-based approach or other alternatives?
Thank you for your attention
Questions or Comments?

BACKUP SLIDES: SIMULATION SETUP
Improved AS relationships inference

(1) Define a weighted AS adjacency matrix

\[ nA := \begin{pmatrix} \ a_{vi,vj} \end{pmatrix} \]

(i) \( n = 0 \)

\[ n_{a_{vi,vj}} = \begin{cases} 1 & \text{if AS } v_i \text{ and AS } v_j \text{ are adjacent} \\ 0 & \text{otherwise} \end{cases} \]

(ii) \( n \geq 1, n \in \mathbb{Z} \)

\[ n_{a_{vi,vj}} = \begin{cases} (n-1)\rho_{v_j} & \text{if AS } v_i \text{ and AS } v_j \text{ are adjacent} \\ 0 & \text{otherwise} \end{cases} \]

(2) Convert the weighted AS adjacency matrix to a traffic transition matrix

\[ nT := \left( \frac{n_{a_{vi,vj}}}{\sum_{v_k} n_{a_{vi,vk}}} \right) \]

(3) Calculate the left eigenvector of the traffic transition matrix corresponding to the maximum eigenvalue

\[ n\rho = [n\rho_{v_1}, \ldots, n\rho_{v_m}]^t : \text{the left eigenvector} \]

(\( \|n\rho\| = 1 \))

Peer selection preference

Peer Selection Preference

\[ p(P) := \alpha c_i(P) + \beta c_t(P) + \gamma q(P) \]

\( \alpha, \beta, \gamma: \) parameters

(1) Internal CDN cost; i.e., AS relationships

\[ c_i(P) := \begin{cases} 
\epsilon \Delta \rho_{N,D,D} + (1 - \epsilon) \Delta \rho_{N,S,S} + 2\max \rho & (S \neq D) \\
0 & (S = D) 
\end{cases} \]

\( \epsilon: \) weighting factor, \( \epsilon = 0.5 \)

(2) Total network cost

\[ c_t(P) := H_{S,D} \]

(3) Quality

\[ q(P) := b_s^2 \]

\( P: \) path from peer \( s \) in AS \( S \) to peer \( d \) in AS \( D \)

\( N_S: \) neighbor (next hop) AS of AS \( S \)

\( N_D: \) neighbor (previous hop) AS of AS \( D \)

\( H_{S,D}: \) AS hop count from AS \( S \) to AS \( D \)

\( b_s: \) the number of simultaneous uploads on peer \( s \)

Simulation setup

- Evaluation model
  - Request pattern
    - based on measured peer distribution in *BitTorrent*
  - Internet topology
    - CAIDA AS Relationships Dataset (10/08/2009)
- Algorithms
  - random: select one uniformly at random
  - AS-hops: minimize AS hop count
  - proposed algorithm ($\alpha = 1, \varepsilon = 0.5$): minimize preference
    - ($\beta, \gamma$) = {(0, 0), (0, 0.5), (50, 0), (50, 0.5)}
preprocess (measurement / annotation)

retrieve a peer list from BitTorrent tracker every minute

aggregate one-minute peer lists into a five-minute peer list

extract unique IP address list from peer lists

annotate IP addresses with an AS number and a country name

CAIDA dataset (2009/8/10)

create AS-level topology; calculate full-route from an AS relationships dataset

create request model

simulate content delivery traffic with peer selection algorithms

peer selection algorithm

create AS-level topology

divide peers into demanders/suppliers by IP address during the simulation

Every node has 20Mbps capacity for both upload and download.

suppliers
- peers which appeared in first one hour
- have already downloaded the content (piece)

#piece=100

demanders
- peers which appear in the list for the first time start to download