Peering Strategy Adoption by Transit Providers in the Internet: A game Theoretic Approach

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Peering Strategy Adoption by Transit Providers in the Internet: A Game Theoretic Approach

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Background

- All networks over the world are connected through interconnection as one. (tree structure)
Background - Interconnection

• Peering
  – Networks exchange traffic between each other's users freely, and for mutual benefit

• Transit
  – The network operator pays money (or settlement) to another network for Internet access (or transit).
Introduction

• The fact that 64% of NSPs (transit providers) use Open peering is especially surprising since transit providers prefer other Autonomous Systems (ASes) as their customers rather than peers.

Why do transit providers tend to peer openly?
Introduction

• In that work they find that peering decisions are interdependent and myopic decisions and lack of coordination among ASes results in Open peering as an attractor among peering strategies for transit providers.
  – When transit providers have complete information about co-located providers they can optimize their economic fitness by adopting Selective peering strategy.

• Further, any uncertainty in the system causes the providers to gravitate towards Open peering, a suboptimal equilibrium.
Model Description

• Each component of the model
  – **Co-location**: Two nodes are “co-located” if they are present in at least one common geographic location. Co-location is necessary to establish any type of link between two nodes.

  – **Traffic components**:

    \[
    V'_{mn} = V_{mn} + V_{nm}
    \]

    Traffic is routed using the real world Valley-free customer-prefer-then-peer routing policy.
Model Description

- Each component of the model
  - Economic attributes:
    - Transit cost \( TC_n = P_m \times V'_{Tn} \)
    - Peering cost \( PC_m = P_P \times V'_{pm} \)

  Fitness = Transit Revenue - Transit cost - Peering cost

- The objective of each node is to maximize its fitness by choosing the best peering strategy.
Model Description

• Each component of the model
  – Settlement-free peering
    1. Restrictive (R) : A node that uses this policy does not peer with any other node.

    2. Selective (S) : A node x that uses this strategy agrees to peer with nodes of similar “size”. We use total traffic volume as a measure of similarity of the nodes.

    3. Open (O) : A node that uses this strategy agrees to peer with any other co-located node except direct customers.
Reference network and parameters

- Transit provider = T, x, y
- Stub = a, b
- x and y must choose peering strategy (R,S,O)
  - Restrictive (R) = Green
  - Selective (S) = Red
  - Open (O) = Blue

- In the Internet, transit costs generally exceed peering costs for the same volume of traffic.
- Thus, they assume that \[ P_i > P_p \forall i \in (x, y) \]
Results - Static Game of Complete Information

<table>
<thead>
<tr>
<th>Player y</th>
<th>Player x</th>
<th>R</th>
<th>S</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>$\pi_x = P_x \times (V_{ya} + V_{ab}) - P_T \times V_{Tx}$</td>
<td>$\pi_x = P_x \times (V_{ya} + V_{ab}) - P_P \times V_{Tx}$</td>
<td>$\pi_x = P_x \times (V_{ya} + V_{ab}) - P_P \times V_{Tx}$</td>
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</tr>
<tr>
<td></td>
<td>$\pi_y = P_y \times (V_{xb} + V_{ab}) - P_T \times V_{Ty}$</td>
<td>$\pi_y = P_y \times (V_{xb} + V_{ab}) - P_P \times V_{Ty}$</td>
<td>$\pi_y = -P_P \times (V_{xy} + V_{yb})$</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>$\pi_x = P_x \times (V_{ya} + V_{ab}) - P_T \times V_{Tx}$</td>
<td>$\pi_x = P_x \times (V_{ya} + V_{ab}) - P_P \times V_{Tx}$</td>
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<td>$\pi_x = -P_P \times (V_{xy} + V_{xb})$</td>
<td>$\pi_x = P_x \times V_{ba} - P_P \times (V_{xy} + V_{xb} + V_{ba})$</td>
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</tr>
</tbody>
</table>

Payoff dominant equilibrium

Risk dominant equilibrium

- In the absence of any uncertainty about the other player’s actions, X and Y should choose strategy S, leading to the optimal equilibrium.
- With any uncertainty in how the other player will play, X and Y will both choose strategy O, leading to a sub-optimal equilibrium.
Results - Dynamic Game of Complete Information

- Sequential game
  - First player: x
  - Second player: y

- The payoffs for each pair of moves are the same as payoffs static game of complete information

- Thus, both providers optimize their fitness by choosing selective strategy even if they play sequentially.
Results - Static Game of Incomplete Information

<table>
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<tr>
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<th>Player y</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td></td>
</tr>
<tr>
<td>$E[\pi_x(S)] = \theta_y S \times {P_x \times (V'<em>{ya} + V'</em>{ab}) - P_P \times (V'<em>{T,x})} + (1 - \theta_y S) \times {-P_P \times (V'</em>{xy} + V'_{xb})}$</td>
<td>$E[\pi_y(S)] = \theta_x S \times {P_y \times (V'<em>{yb} + V'</em>{Ty}) - P_P \times (V'<em>{Ty})} + (1 - \theta_x S) \times {P_y \times (V'</em>{yb}) - P_P \times (V'<em>{xy} + V'</em>{ya})}$</td>
</tr>
<tr>
<td>O</td>
<td></td>
</tr>
<tr>
<td>$E[\pi_x(O)] = \theta_y S \times {P_x \times (V'<em>{ya} + V'</em>{ab}) - P_P \times (V'<em>{T,x})} + (1 - \theta_y S) \times {P_x \times (V</em>{ba}) - P_P \times (V'<em>{xy} + V'</em>{xb} + V_{ba})}$</td>
<td>$E[\pi_y(O)] = \theta_x S \times {P_y \times (V'<em>{yb} + V'</em>{Ty}) - P_P \times (V'<em>{Ty})} + (1 - \theta_x S) \times {P_y \times (V'</em>{yb} + V_{ab}) - P_P \times (V'<em>{xy} + V'</em>{ya} + V_{ab})}$</td>
</tr>
</tbody>
</table>

- Given that transit costs (and revenue) are much higher than peering costs, the uncertain player will always choose Open peering so as to avoid a complete loss in revenue.

- Therefore, the uncertainty about each other’s payoffs leads to both providers adopting Open peering strategy.
Conclusion

• They showed that in the presence of complete information, transit providers optimize their economic fitness by adopting Selective peering strategy.

• They showed that in the absence of complete information about other providers, transit providers adopt Open peering which leads to a suboptimal equilibrium.
Q&A

THANK YOU 😊