Exposing the Complexity of the AS Relationships

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• BGP routing = topology + policies
• AS Relationships: determine how routes are imported and exported
• Why reheat an old subject?
  – AS Relationship datasets are conflicting
  – Simulations yield poor results
Challenges

• Inference from topology data $\rightarrow$ Heuristics
• Ground-truth information is hard to find $\rightarrow$ Difficult evaluation
• Fundamental structural changes (hierarchical to flat, IXPs, densification) $\rightarrow$ Re-evaluation of existing algorithms
• Two “parallel” Internets (IPv4/IPv6) $\rightarrow$ Separate inference
Goals

• Rigorous analysis of BGP attributes that express policy information
  – Communities
  – Local Preference

• Try to infer complex relationship types
  – p2c, p2p, s2s
  – hybrid, indirect peering, partial-transit, backup
Methodology

RouteViews RIPE RIS

AS Paths

AS Connectivity Information

BGP Communities

AS Policy Information

Local Preference

AS Relationships
Methodology

Goal is *Reliability, not Completeness*
Hybrid Relationships

IPv4 - IPv6

AS 6939

AS 3549

IP-version depended

USA

Denmark

AS 3549

AS 3292

Location depended

3549:4354: customer
3549:30840: USA

3549:2771: peer
3549:31208: Denmark
Partial Transit
Partial Transit

- European ASes
- Non-European ASes
- Full Provider
- AS A

AS3300
3300:2100
Partial Transit

What about BGP Wedgies?
Indirect Peering

AS20965 → AS11537 → AS20080

Educational/research Networks (e.g. Internet2)

AS5524 → AS6777 → AS9002

Public peering at IXPs (e.g. AMS-IX)
### Results (February 2011)

<table>
<thead>
<tr>
<th></th>
<th>IPv4</th>
<th>IPv6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of AS Links</td>
<td>109,807</td>
<td>10,535</td>
</tr>
<tr>
<td>Inferred Relationships</td>
<td>42,385 (39%)</td>
<td>7,651 (72%)</td>
</tr>
<tr>
<td>Relationship Type</td>
<td></td>
<td>IPv4 &amp; IPv6</td>
</tr>
<tr>
<td>P2C</td>
<td>26,075</td>
<td></td>
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<tr>
<td>P2P</td>
<td>18,603</td>
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<tr>
<td>S2S</td>
<td>177</td>
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<tr>
<td>Hybrid Links</td>
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<tr>
<td>Indirect peering</td>
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<td></td>
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<tr>
<td>Partial transit</td>
<td>1,828</td>
<td></td>
</tr>
<tr>
<td>Backup transit</td>
<td>1,205</td>
<td></td>
</tr>
</tbody>
</table>
IPv6 Relationships

• 13% of the AS links that serve both IPv4 and IPv6 are hybrid

• 47% of the IPv6 AS paths contain at least one AS link with hybrid IPv4/IPv6 relationship

• Around 10% of the IPv6 AS paths are non valley-free (daily)
  – 11% during the IPv6 World Day
Conclusions/Future Work

• Unexploited wealth of policy information
• Complex relationship types become increasingly popular
• IPv6 relationships should be studied separately (at least until convergence)

• Extend the interpretation of Communities values
• Extend to 100% of AS links
• Combine BGP/traceroute data
• Performance impact on IPv6
Thank you!