Inferring AS Relationships from BGP Attributes

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Introduction

- The Internet is a *Network of Networks*

Routers Topology
Introduction

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Introduction

• The Internet is a *Network of Networks*
Why AS Topology?

• Two levels of routing
  – Intra-domain routing
  – Inter-domain routing – Border Gateway Protocol (BGP)

• Performance
• Traffic Engineering
• Security
• Business policies/economics
Autonomous Systems Business Relationships

• Customer-to-Provider (c2p)
  – Paid transit

• Peer-to-Peer (p2p)
  – Free bilateral transit, routing restrictions

• Sibling-to-Sibling (s2s)
  – Free bilateral transit, no restrictions
Why AS Relationship?
Why AS Relationship?
Valley-Free Paths

\[ n \geq 0 \quad m \geq 0 \]

\[ n \geq 0 \quad m \geq 0 \]

\[ \cdots \cdots 1 \cdots \]

\[ \text{p2p} \]

\[ \text{p2c} \]
Non Valley-Free Paths
Valley-Free Routing

A C D : Valley-Free
Valley-Free Routing

A C D : Valley-Free
A B E F : Valley-Free

UCL
Valley-Free Routing

- A C D : Valley-Free
- A B E F : Valley-Free
- B A C : Non Valley-Free
Valley-Free Routing

A C D : Valley-Free
A B E F : Valley-Free
B A C : Non Valley-Free
A C D F: Non Valley-Free
AS Relationship Inference Problem

- AS relationships are not publicly disclosed

- How to assign AS relationships to AS edges given the publicly available BGP/traceroute data?
AS Relationship Inference: Existing Approaches

- **AS Topology + Heuristics**
  - Maximize the number of valley-free paths
  - p2p relationships are agreed between ASes of comparable degree
    - All p2c AS edges will cross the Tier-1
    - All long-lived paths (> 2 days) are valley-free
AS Relationship Inference: Existing Approaches

- AS Topology + Heuristics

  Different Algorithms result in significantly conflicting results!

  - comparable degree
    - All p2c AS edges will cross the Tier-1
    - All long-lived paths (> 2 days) are valley-free
BGP Communities

• Optional BGP attribute that encodes meta-data on an AS Path
  – AS Relationships, Routing policies, Geographical information

• Non-standardized values, each AS defines its own 32-bit values xxxx : yyyy
  – xxxx: Autonomous System Number
  – yyyy: Community value
BGP Communities

Sample of BGP entry

TYPE: TABLE_DUMP_V2/IPV4_UNICAST
PREFIX: 1.22.73.0/24
FROM: 206.223.115.10 AS4589
ORIGIN: IGP
ASPATH: 4589 15412 18101 45528
NEXT_HOP: 206.223.115.10
BGP Communities

Sample of BGP entry

```
TYPE: TABLE_DUMP_V2/IPV4_UNICAST
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FROM: 206.223.115.10 AS4589
ORIGIN: IGP
ASPATH: 4589 15412 18101 45528
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```
## BGP Communities

A sample of a BGP entry:

<table>
<thead>
<tr>
<th>Type</th>
<th>Prefix</th>
<th>From</th>
<th>Origin</th>
<th>AsPath</th>
<th>Next Hop</th>
<th>Community</th>
</tr>
</thead>
</table>
Interpretation of BGP Communities

Two-digit communities

Customers can set two-digit communities to control which local preference prefixes receive.

<table>
<thead>
<tr>
<th>Community</th>
<th>Local Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>4589:10</td>
<td>50</td>
</tr>
<tr>
<td>4589:20</td>
<td>100</td>
</tr>
<tr>
<td>4589:25</td>
<td>130</td>
</tr>
<tr>
<td>4589:30</td>
<td>150</td>
</tr>
<tr>
<td>4589:35</td>
<td>170</td>
</tr>
</tbody>
</table>

(equiv. to last resort transit)
(equiv. to peering and transit)
(depreferred customer route)
(default for customers)
(preferred customer route)

Three-digit communities

Prefixes coming from peers and transit will be tagged with three-digit community values, e.g. a prefix received at DECIX will be tagged with 4589:641. Only the most specific community is added, e.g. a route from DECIX will not have 4589:640 set. Additionally prefixes from peers will be tagged with a 4xx community based on speed of the interconnection.

<table>
<thead>
<tr>
<th>Community</th>
<th>Entry point</th>
</tr>
</thead>
<tbody>
<tr>
<td>4589:4xx</td>
<td>Special Markings</td>
</tr>
<tr>
<td>4589:410</td>
<td>From a high capacity IXP or Private Peer</td>
</tr>
<tr>
<td>4589:420</td>
<td>From a low capacity IXP or Private Peer</td>
</tr>
</tbody>
</table>

Network Operation Centers (NOCs) (e.g. lg.easynet.com/bgppolicy.php)
Interpretation of BGP Communities

| remarks: 15412:1514 Amsterdam |
| remarks: 15412:7xx Customer |
| remarks: 15412:701 Aggregate |
| remarks: 15412:702 Statistically Routed |
| remarks: 15412:703 BGP Routed |
| remarks: 15412:705 BGP Routed (Suppress MED to upstreams) |

Internet Routing Registries (e.g. whois -h whois.radb.net AS15412)
Data Collection Architecture

- **RouteViews RIPE RIS BGP data**
  - AS Paths
  - Connectivity Information
  - AS Relationships

- **Communities Values**
  - Policy Information

- **Communities Information**

- **IRR NOCs**
Results (February 2011)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of observed links</td>
<td>109,807</td>
</tr>
<tr>
<td>Number of inferred relationships</td>
<td>38,704 (35%)</td>
</tr>
<tr>
<td>c2p links</td>
<td>23,012</td>
</tr>
<tr>
<td>p2p links</td>
<td>15,375</td>
</tr>
<tr>
<td>s2s links</td>
<td>174</td>
</tr>
</tbody>
</table>
“Special” Relationship Types

- Relationships not described by the c2p, p2p, s2s model
- Little attention, difficult to detect
  - Partial transit: 1,828
  - Indirect peering: 811
  - Hybrid relationships: 1,034
Partial Transit

- International ASes
- National ASes
- Full Provider
- Partial Provider
- Multihomed Customer
Indirect Peering

AS20965 \rightarrow AS11537 \rightarrow AS20080
Educational/Research Networks (e.g. Internet2)

AS5524 \rightarrow AS6777 \rightarrow AS9002
Public peering At IXPs (e.g. AMS-IX)
Hybrid Links

IPv4

AS6939

IPv6

AS3549

IP-version depended

3548:4354 – customer
3549:30840 - USA

3548:2771 – peer
3549:31208 - Denmark

Location depended
IPv6 Relationships

• 7,618 **AS links** carry both IPv4 and IPv6 traffic
  – 13% of these have different relationship between IPv4 and IPv6
• 47% of the IPv6 **AS paths** contain at least one hybrid AS link
• 10% of the IPv6 **AS paths** are non valley-free
  – Same during IPv6 day
Conclusions

• Unexploited wealth of BGP attribute data

• Complex relationship types widely disregarded become increasingly popular

• IPv6 relationships should be studied separately
Conclusions & Future Work

- Extend the interpretation of Communities values
- Extend to more AS links
- Use traceroute data to verify/evaluate inferences
- Performance impact on IPv6
THANK YOU!