In Search for an Appropriate Granularity to Model Routing Policies

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Complex due to
- topology size
- interaction of intra- and interdomain routing protocols
- routing policies

Understanding required to
- build models of the Internet
- predict selected paths
- ...

Our contribution: Granularity of routing policies
Understanding Internet Routing requires

- notion of **topology**
- notion of **policy**

Prefix / network destination

Route map
match ip route-source
set local-preference
Sigcomm ’06: Add routers if AS chooses multiple paths to a prefix
Routing Policies

- decided locally by each AS
- global impact on route propagation
Bounds on Policy Granularity

- **Fine**: Per-prefix
  - Route selection done per-prefix

- **Coarse**: Per-neighbor
  - Reflects commercial peering agreements
Studying the Granularity of Routing Policies

**Idea:**
- Rely on observed BGP data
- Observed routes give hints on policies

**Related work:**
- BGP atoms
- AS relationships

**Our approach:**
1. Per-prefix filters
2. AS relationships: Consistency with path propagation?
3. Next-Hop Atoms
Data Sets

- BGP table dumps
  - RIPE, RouteViews, ...
  - > 1,300 observation points throughout the Internet
  - 4,730,222 distinct AS paths

- Infer AS graph
  - ASs: 21,178
  - AS-level edges: 58,903
BGP Atoms - “Similar” prefixes

**Definition:**
- 2 prefixes in same atom if all observed AS paths are the same

**Problems:**
- Biased by used observation points
- Little insights on policies
  - BGP atoms only aggregate policies originated by *same* AS
AS Relationships

- **Granularity: Per-neighbor**
- Reflect business agreements between ASs
  - customer-provider
  - peering
- **Properties:**
  - *Valley-free*: Don’t export provider routes to providers
  - *Route Preference*: Prefer customer over peering over provider routes
Per-Prefix Filters

- Allow for consistency between
  - routes in model
  - routes observed in data
- Infer per-prefix filter rules
  - Filter routes that prevent selection of observed route
  - Many possible solutions ⇒ Identify filter candidates
- Analyze obtained filter candidates

![Diagram showing AS 1, AS 2, and AS 3 with routes and filter actions]
Simulate route choice with C-BGP
Identify “mismatches” between
   - paths observed in data
   - paths selected in model
For each mismatch: Determine set of filter candidates
Per-Prefix Filters – Popularity

- **Experiment**
  - Select randomly 50,000 prefixes (> 2,000,000 AS paths)
  - Infer filter candidates

- **Filter Popularity**
  - Filter identified as candidate for how many prefixes?

- **Result**: Filter popularity varies
  - 25% of detected filters: candidate for less than 236 prefixes
  - 5% of detected filters: candidate for at least 8,000 prefixes

(popular per-prefix filters)
Simple Experiment:
- Infer AS relationships for our topology
- Run simulation with C-BGP

Results:
- Check if observed paths are selected in simulations
- AS-paths which agree: 14.5%

Causes?
- Topology too simplistic?
- AS relationships “wrong”?
AS Relationships – Reason for Inconsistency

**Valley-free property**: Correlation between valleys and our popular per-prefix filters!
- 99.9% of popular filters are on valleys

**Route Preference**: Insufficient to predict path choice
- C-BGP simulation: # “equally” good routes to choose from? (e.g., # learned customer routes)
- For more than 10% of observed paths: More than 50 “equally good paths” learned
Studying the Granularity of Routing Policies

**Related work:**
- BGP atoms → *Only for prefixes originated at same AS*
- AS relationships → *Too coarse?*

**Our approach:**
1. Per-prefix filters → *Consistent with observed route propagation, but too-detailed?*
2. AS relationships: Consistency with path propagation? → *Bad at predicting path choice*
3. Next-Hop Atoms
Next-Hop Atoms (NHA)

- New abstraction to describe granularity of path choices for an AS
  - Sets of neighboring ASs an AS uses for its best routes
- Possible next-hop atoms: Power set of all neighbor ASs

<table>
<thead>
<tr>
<th>NHA</th>
<th>Prefix</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>p1</td>
</tr>
<tr>
<td>B</td>
<td>p2, p3</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>A, B</td>
<td>-</td>
</tr>
<tr>
<td>A, C</td>
<td>-</td>
</tr>
<tr>
<td>B, C</td>
<td>p4</td>
</tr>
<tr>
<td>A, B, C</td>
<td>-</td>
</tr>
</tbody>
</table>
Number of ASs in Next-Hop Atoms (NHA)

- NHAs consist of only a few neighboring ASs
- But: Non-negligible fraction of NHAs has more than 1 AS
  ⇒ Strict preferences not sufficient!

![Graph showing the cumulated fraction of next-hop atoms versus the number of neighboring ASs in next-hop atoms for different providers: UUNET, AT&T, Level3, AOL, and FT. The x-axis represents the number of neighboring ASs, ranging from 1 to 7, and the y-axis represents the cumulated fraction of next-hop atoms, ranging from 0 to 1. The graph illustrates the distribution of ASs in next-hop atoms for each provider.]
Summary

- **Contributions:**
  - Inference of *per-prefix candidate filters*
  - New abstraction: *Next-hop atoms*

- **Insights:**
  - Per-neighbor granularity as with AS relationships appropriate
  - Challenge: How to capture route choice/preference?

- **Future work:**
  - Topology model?
  - Policy model?