The (in)Completeness of the Observed Internet AS-level Structure

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What are the main contributions?

**Conceptual Contribution:** Accuracy of Autonomous System (AS) maps can be assessed through spot-checking a few ASes (“case studies”)

![Image](http://as2914.net/)

**Technical Contribution:** A method for establishing “ground truth” of what links a given AS has (though sounds very tedious, possibly not generalizable)
What problem is the paper addressing?

**Problem:** Existing AS-level maps of the internet are known to be imperfect because they are built using data from traceroutes or BGP monitoring. Both methods have widely recognized limitations.

Who cares?

- These imperfect maps are being used by the research community anyway.
- Spurious conclusions are being drawn!
The BGP approach - background

The BGP approach - background

123.123.123.0/24: A

Invisible link
Who cares if AS map is imperfect?

Example 1: Research that examines graph metrics, e.g. network diameter

*Network diameter* is the shortest distance between the two most distant nodes in the network. In this case, the distance between A and D is 3 (or is it 4?)
Who cares if AS map is imperfect?

Example 2: Research into the resiliency of the network to failures

If link G-E fails, what are the consequences?
Problem: Existing AS-level maps of the internet are known to be imperfect because they are built using data from traceroutes or BGP monitoring. Both methods have widely recognized limitations.

Paper’s Solution: As a first step, let’s assess how bad these AS maps really are.

How?

The Approach: Perform case-studies of a few ASes for which we have “ground truth” and compare that to the results from publicly available BGP data such as RouteViews.
How do we get the “ground truth?”

Pick a few ASes to examine
• One Tier-1 network
• One Tier-2 network
• Two research networks
• One content provider
• Four simple stub networks
  (universities and small companies)
How do we get the “ground truth?”

Examine them in *excruciating* detail
- “show ip bgp summary” command
- Talk to operators
- Examine router configuration files
- Examine router syslog data
- Create a peering model
- Develop severe alcohol dependency
Results: Public view vs. Tier-1 ground truth

“The Tier-1 AS’s links are covered fairly completely by the public view over time. All the peer-peer and sibling links are covered.”

Fig. 6. Connectivity of the Tier-1 network (since 2007).
Results: Public view vs. Tier-2 ground truth

Fig. 8. Tier-2 network connectivity.

“The Tier-2 AS’s links are covered fairly completely by a single customer over time, which can be considered representative of the entire public view.”

Anyone see any problems?

They don’t really have ground truth at all for this one.
Results: Public view vs. content provider ground truth

The public view misses about 90% of C’s connectivity, and we believe all of them are invisible peer-peer links.

From discussion with operators, learned that this content provider peers with 80-95% of the participants at each IXP.

"The public view misses about 90% of C’s connectivity, and we believe all of them are invisible peer-peer links.”
A monitor covers upstream ASes

ASes covered
G

Links observed
G-E  F-D
G-F  F-C

Invisible link
(peer)
A monitor covers upstream ASes

ASes covered
G
F

Links observed
G-E  F-D
G-F  F-C
    F-E
Results: how many ASes are covered?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Full tables</th>
<th>Full+partial tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. monitored ASes</td>
<td>121</td>
<td>411</td>
</tr>
<tr>
<td>Covered ASes</td>
<td>1,101 / 28,486 ≈ 4%</td>
<td>1,552 / 28,486 ≈ 5%</td>
</tr>
</tbody>
</table>

**TABLE III**

Coverage of BGP monitors.

<table>
<thead>
<tr>
<th>Type</th>
<th>ASes</th>
<th>Monitored ASes</th>
<th>Covered ASes aggregated</th>
<th>Covered ASes by covering type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier-1</td>
<td>9</td>
<td>8</td>
<td>9 (100%)</td>
<td>8</td>
</tr>
<tr>
<td>Large ISP</td>
<td>436</td>
<td>45</td>
<td>337 (77.3%)</td>
<td>954</td>
</tr>
<tr>
<td>Small ISP</td>
<td>1,829</td>
<td>36</td>
<td>629 (34.4%)</td>
<td>269</td>
</tr>
<tr>
<td>Stubs</td>
<td>26,209</td>
<td>37</td>
<td>126 (0.5%)</td>
<td>160</td>
</tr>
</tbody>
</table>

**TABLE IV**

Coverage of BGP monitors for different network types.
The one thing you should take away?

ASes don’t announce peer links to providers nor to other peers.