Layer-1 Informed Internet Topology Measurement

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Introduction

• Understanding Internet topology is important
  – Informs performance, security, risk, etc.

• Internet topology mapping is fraught with challenges
  – Huge size and distributed ownership
  – Always in a state of flux
Existing Approaches

• TTL-limited layer 3 traceroute-like probes
  – Rely on location hints in domain names
  – E.g., CAIDA’s Ark, Rocketfuel
Existing Approaches (cont.)

- Search based
  - Maps available at ISP’s website
  - E.g., Internet Atlas, Internet Topology Zoo
Topology measurement challenges

• Problems with TTL-based approaches
  – Management policies/Objectives of providers
  – Lack of visibility of lower layers

• Problems with Search-based approaches
  – ISP acquisition/merge
  – May not be up to date or complete
Research questions

Can physical maps be used to guide and reinforce the process of collecting network-layer data?

• How do physical maps compare to and contrast with network-layer maps?
  – Atlas vs. Ark comparison study

• How can probe methods be improved to reveal a larger portion of physical infrastructure?
  – POPsicle probing heuristic
How do physical maps compare to and contrast with network-layer maps?
Targets for comparison

• We consider 50 networks with footprint in North America

• Atlas
  – 7 Tier-1 and 43 regional ISPs
  – 2507 POPs and 3477 links

• Ark
  – Use DNS data and traceroute data
  – PathAudit (Chabarek et al., HotPlanet ‘13) to decode location hints
    • E.g., for A.B.C.LAX2.D.NET, location code is LAX
Physical vs. network maps – results I

- More nodes and links in physical maps.

- 32% IP not seen
- 42% IP seen, no location hints
- 26% IP seen, location hints seen

More nodes and links in physical maps.
Physical vs. network maps – results 2

- Sampling bias in network topology measurements (Shavitt et. al., IEEE Infocom 2009)

Number of probes sent across Internet Service Providers

Number of Probes

Internet Service Providers

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Physical vs. network maps – results 3

• Network map utility
  – 448 distinct networks in North America
    • Greater than physical maps in (worldwide) Atlas repository!
  – Dynamic properties

Results from network-layer maps can be used as guidance for searching physical maps
Implications

• Differences suggest opportunities for reinforcement
  – Networks in network-layer data
    • Clues for searching new maps
    • Engineering problem
  – Networks in physical data
    • Targets for additional probing
    • Calls for a coordinated topology mapping approach
How can layer 3 probe campaigns be designed to reveal a larger portion of physical infrastructure?
Considerations for targeted probes

• **Source-destination selection**
  – Vantage point (probing source or VP) and destination selection
    • Internal to an ISP or external to an ISP?

• **Scalability**
  – Exploit IXPs to aid in node identification
  – Vantage points for multiple networks?
    • Due to layer 2 connectivity
Source-destination selection

• Leverage publicly available vantage points
  – Planetlab, looking glass and traceroute servers

• Three modalities
  – \( VP_{\text{out}} \) to \( t_{\text{in}} \)
  – \( VP_{\text{in}} \) to \( t_{\text{out}} \)
  – \( VP_{\text{in}} \) to \( t_{\text{in}} \)

• Source-destination selection based on geographical proximity

• 25 ISPs containing 596 target POPs
Effects of source-destination selection

Sources and destinations within the same AS based on geographic proximity

• Effects of routing
  – $\text{VP}_{\text{in}}$ to $\text{t}_{\text{in}}$
    • Greater diversity, more info. on paths, flexible routing
  – $\text{VP}_{\text{in}}$ to $\text{t}_{\text{out}}$ and $\text{VP}_{\text{out}}$ to $\text{t}_{\text{in}}$
    • Interdomain routing

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Scaling perspective with IXPs

IXPs could be the starting point for comprehensive mapping of physical infrastructure

• Enormous amount peering at IXPs
• VPs co-located with IXPs
  – 14 out of 65 have co-located VPs
  – Unique ISPs that peer at 14 IXPs is 625 (from PeeringDB)
  – So, 625 ISPs from these 14 IXPs alone
Pulling it all together

• **Goal:** use physical maps to enhance network-layer node identification

• **Sources:**
  – VP located within a target AS
  – VP co-located with IXPs offers broader perspective

• **Destinations**
  – Send probes toward a target with a known geographic location based on physical map

**POPsicle:** Probing heuristic based on these insights
POPsicle details

Service Provider Network

Source VP

Destination VP

Target POPs

Links

Probe path

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POPsicle - results

• 30 looking glass servers from Atlas
  – server co-located with an IXP
  – ground truth available

<table>
<thead>
<tr>
<th></th>
<th>POPs</th>
<th>Datacenters</th>
<th>DNS</th>
<th>NTP</th>
<th>IXPs</th>
<th>Total</th>
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<td>55</td>
<td>25</td>
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<td>Ground truth</td>
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<td>641</td>
<td>13</td>
<td>827</td>
<td>65</td>
<td>1790</td>
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<td>Improvement</td>
<td>1.04x</td>
<td>1.54x</td>
<td>9x</td>
<td>11.4x</td>
<td>1.48x</td>
<td>2.42x</td>
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Multiplexing VPs at IXPs

Service Provider A

Service Provider B

Service Provider C

LG

IXP

Destination VP
Target POPs
Links
→ Probe path
## Multiplexing VPs at IXPs

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<tr>
<th>ISP</th>
<th>POPsicle</th>
<th>Ground Truth</th>
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Summary

• First-of-its-kind comparison of physical vs. network-layer maps
• Source-destination pairs within the same AS reveals most physical infrastructure
• POPsicle-based probing identifies 2.4x additional nodes
• IXPs can aid in broadening perspective
• Deployed and demonstrated POPsicle in a real IXP setting
Thank you!
Questions?

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