MAPPING PEERING INTERCONNECTIONS TO A FACILITY

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The AS-level topology is too coarse for complex networking problems
The building-level topology captures rich semantics of peering interconnections.
Motivation

- Increase traffic flow transparency
- Assessment of resilience of peering interconnections
- Diagnose congestion or DoS attacks
- Inform peering decisions
- Elucidate the role of colocation facilities, carrier hotels, and Internet exchange points (IXPs)
Challenges

- IP addresses are logical and region-independent
- BGP does not encode geographic information
- Existing methods are accurate for city-level granularity, not for finer granularities:
  - Delay-based
  - Hostname heuristics
  - Database-driven
What buildings do we need to consider for locating peering interconnections?

- **Interconnection facilities**: special-purpose buildings used to co-locate routing equipment.
What buildings do we need to consider for locating peering interconnections?

- **Interconnection facilities**: special-purpose buildings used to co-locate routing equipment

**Key Intuition 1**: To locate a peering interconnection, search the facilities where the peers are present.
Develop a map of interconnection facilities

- Compile a list of interconnection facilities and their address
- Map ASes and IXPs to facilities
- Public data sources:
  - PeeringDB
  - AS/IXP websites

<table>
<thead>
<tr>
<th>April 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities 1,694</td>
</tr>
<tr>
<td>ASes 3,303</td>
</tr>
<tr>
<td>AS-facility connections 13,206</td>
</tr>
<tr>
<td>IXPs 368</td>
</tr>
<tr>
<td>IXP-facility colocations 783</td>
</tr>
</tbody>
</table>
Interconnection facilities are concentrated in hub cities.
Complexity of peering interconnections

Remote public peering

Private peering cross connect

Private peering tethering

Public peering

Public peering
Complexity of peering interconnections

Key Intuition 2: The different peering interconnection types can be used as constrains in the facility search.
Constrained Facility Search (CFS)

For a target peering interconnection ASA- ASB:

- **Step 1**: Identify the type of peering interconnection
- **Step 2**: Initial facility search
- **Step 3**: Constrain facilities through alias resolution
- **Step 4**: Constrain facilities by repeating steps 1-3 with follow-up targeted traceroutes
- **Step 5**: Facility search in the reverse direction
Constrained Facility Search (CFS)

For a target peering interconnection ASA- ASB:

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Identifying the peering type

Private peering

Facility search between the facilities of the peering ASes

Public peering

Facility search between the IXP and the peering ASes
Constrained Facility Search (CFS)

For a target peering interconnection ASA- ASB:

- **Step 1**: Identify the type of peering interconnection
- **Step 2**: Facility search
- **Step 3**: Constrain facilities through alias resolution
- **Step 4**: Constrain facilities by repeating steps 1-3 with follow-up targeted traceroute
- **Step 5**: Facility search in the reverse direction
Facility search: single common facility

- The common facility is inferred as the location of the interface of the peer at the near end.
Facility search: single common facility

The common facility is inferred as the location of the interface of the peer at the near end.
No inference possible

- Incomplete facility dataset or remote peering
- Run algorithm in [Castro 2014] to detect remote peering
- Run traceroutes changing the target peering links

Facility search: multiple common facilities

Possible facilities are constrained but no inference yet
Facility search: multiple common facilities

- Possible facilities are constrained but no inference yet
Constrained Facility Search (CFS)

For a target peering interconnection ASA- ASB:

- **Step 1:** Identify the type of peering interconnection
- **Step 2:** Initial facility search
- **Step 3:** Derive constraints through alias resolution
- **Step 4:** Constrain facilities by repeating steps 1-3 with follow-up targeted traceroutes
- **Step 5:** Facility search in the reverse direction
Derive constraints through alias resolution

- Parse additional traceroutes containing peering interconnections of the peer at the near end
Derive constrains through alias resolution

- De-alias interfaces of AS A (IPA_1, IPA_2)

<table>
<thead>
<tr>
<th>Facilities</th>
<th>AS A</th>
<th>F1</th>
<th>F2</th>
<th>F5</th>
</tr>
</thead>
<tbody>
<tr>
<td>IXP x</td>
<td>F4</td>
<td></td>
<td>F2</td>
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Possible IPA_1 facilities

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<tr>
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<td></td>
</tr>
<tr>
<td>AS C</td>
<td></td>
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Possible IPA_2 facilities
If two interfaces belong to the same router, find the intersection of their possible facilities.
Derive constrains through alias resolution

- Multi-purpose router
  - Used to establish both private and public peering

Facilities

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Constrained Facility Search (CFS)

For a target peering interconnection ASA- ASB:

- Step 1: Identify the type of peering interconnection
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- Step 3: Constrain facilities through alias resolution
- **Step 4:** Constrain facilities by repeating steps 1-3 with follow-up targeted traceroutes
- Step 5: Facility search in the reverse direction
Follow-up CFS iterations

- If CFS has not converged to a single facility:
  - Execute a new round of traceroutes with different set of targets
  - Repeat steps 1-3 (a CFS iteration)

- ‘Clever’ selection of the new traceroute targets can help CFS to narrow down the facility search
Traceroute target selection

Trace 1

Trace 2

Facilities

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Targeting public peerings over the same IXP offers no additional constrains because CFS still compares the same sets of facilities.
Traceroute target selection

Trace 1

Trace 3

Facilities

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<tbody>
<tr>
<td>AS E</td>
<td>F9</td>
<td>F1</td>
<td>F2</td>
<td>F5</td>
</tr>
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</table>
Traceroute target selection

Targeting private peers or IXPs with presence in all the possible facilities for $\text{IPA}_1$ does not offer additional constrains.
Traceroute target selection

Trace 1

IP_{A1} → IXP_X → IP_{B1}

AS A → IXP X → AS B

Trace 3

IP_{A5} → IP_{E1}

AS A → AS F

Facilities

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<tr>
<td>AS A</td>
<td>F1</td>
<td>F2</td>
<td>F5</td>
</tr>
<tr>
<td>AS E</td>
<td>F2</td>
<td>F6</td>
<td></td>
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Traceroute target selection

Targeting peers or IXPs with presence in **at least one but not in all** the possible facilities for $IP_{A1}$ can offer additional constrains (depending on alias resolution)
Constrained Facility Search (CFS)

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Facility inference for the far-end peer

- Facility search for the peer at the far-end may not converge to a single facility
- Last resort: switch proximity heuristic
Projecting the facilities on the IXP topology can help us reason about the actual facility of the peer at the far end.
Switch proximity heuristic

IXPs prefer to exchange traffic over the backhaul switches instead of the core if possible.
We infer the facility of the far-end peer to be the one most proximate to the facility of the near-end peer.
Evaluation

- Targeted the peerings of 5 CDNs and 5 Tier-1 ASes:
  - Google (AS15169), Yahoo (AS10310), Akamai (AS20940), Limelight (AS22822), Cloudflare (AS13335)
  - NTT (AS2914), Cogent (AS174), Deutsche Telekom (AS3320), Level 3 (AS3356), Telia (AS1299)
- Queried one active IP per prefix for each of their peers
- Executed 100 iterations of the CFS algorithm
Collecting traceroute paths

- Combine traceroute platforms to maximize coverage:
  - Active: RIPE Atlas, Looking Glasses (LGs)
  - Archived: CAIDA Ark, iPlane

<table>
<thead>
<tr>
<th></th>
<th>RIPE Atlas</th>
<th>LGs</th>
<th>iPlane</th>
<th>Ark</th>
<th>Total Unique</th>
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<tbody>
<tr>
<td>VPs</td>
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<td>1,877</td>
<td>147</td>
<td>107</td>
<td>8,517</td>
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<tr>
<td>ASNs</td>
<td>2,410</td>
<td>438</td>
<td>117</td>
<td>71</td>
<td>2,638</td>
</tr>
<tr>
<td>Countries</td>
<td>160</td>
<td>79</td>
<td>35</td>
<td>41</td>
<td>170</td>
</tr>
</tbody>
</table>
CFS inferred the facility for 70% of collected peering interfaces.
10% of the inferences validated to 90% correctness
Ongoing and future work

- Extend the facility dataset
  - Collaborate with the operational community
  - Utilize third-party datasets e.g. UW Internet Atlas¹
- Combine geolocation methods to further constrain facilities in unresolved cases
- Integrate CFS with CAIDA’s Ark and Sibyl²

¹ http://internetatlas.org/
Conclusions

- Constrained Facility Search (CFS) maps peering interconnections to facilities based on public data:
  - Traceroute paths
  - Interconnection facility maps
- Evaluated CFS for 5 large CDNs and Tier-1 Ases
  - Pinpoint 70% of collected IP interfaces
  - Validated 10% of inferences to ~90% correctness
Additional results
ASes and IXPs are present at multiple facilities.
We compared the facility information between PDB and NOCs for 152 ASes:

- 2,023 AS-to-facility connections in PDB
- 1,424 AS-to-facility connections missing from PDB involving 61 ASes
Majority of interconnection facilities are located in Europe and North America.
Diverse peering strategies between CDNs and Tier-1 ASes
Missing facility data affect the completeness of CFS inferences