Interactive Access to Internet Topology Data

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Internet maps can be grouped into three levels.

1. **IP addresses** that connect devices on to the Internet.
2. **Routers**, machines that route the traffic, interconnect via **IP addresses**.
3. **Point of Presence (PoP)** geographic location with
4. **Autonomous Systems (AS)** are numbers used to route groups of **IP addresses**.
- **Henya** primarily concerned with querying **IP paths**
- **AS Rank** primarily concerned with querying **AS topology**
traceroute paths

source → 13.5.1.8 → 10.0.1.5 → 10.0.1.1 → 9.0.1.1

source → 13.5.1.8 → 10.0.1.5

source → 13.5.1.8 → 5.5.1.28 → 10.0.1.5 → 10.0.1.1 → 9.0.1.1

source → 13.5.1.8
• 9+ years of CAIDA traceroute data
  - 47 billion traces in 20.3 TB of files
  - now growing by \textbf{20 billions traces/year}

• useful for studying global Internet connectivity, evolution, performance, censorship, ...

• basis for higher-level Internet maps
● CAIDA's large-scale topology query system

● provides **remote search** of traceroute data without requiring data downloads

● built-in **analyses and visualizations**
  - for commonly occurring needs

● **responsive** enough for interactive data exploration
  - goal: query latency of 30 seconds or less
• find occurrences of traceroute path elements

• \textit{\{targets\}} = IP addresses (and other types)

• queries:
  - traceroutes \textit{toward} \textit{\{targets\}}
  - traceroutes \textit{containing} one or more \textit{\{targets\}}

• parameters:
  - measurement vantage points
  - data collection time periods
  - position of \textit{\{targets\}} in path
  - hop distance between sets of \textit{\{targets\}}
• the most complex case:
  - traceroutes containing **two or more** \(\langle \text{targets} \rangle\)
    - precisely: traceroutes containing some hop \(h_1 \in \langle \text{targets}_1 \rangle, h_2 \in \langle \text{targets}_2 \rangle, \ldots\)
  - example: traceroutes containing hops in both \(\langle \text{Germany} \rangle\) and \(\langle \text{Japan} \rangle\)

  ![Diagram showing the intersection of two sets](image)

• harder:
  - traceroutes with hops in \(\langle \text{Germany or UK or France} \rangle\) and hops in \(\langle \text{ATT or Level3 network} \rangle\) and hops in \(\langle \text{Amsterdam Internet Exchange} \rangle\)
challenges

- large target sets
  - Germany = 92,239,360 target IP addresses
  - Japan = 154,025,984 target IP addresses

- multiple \textit{targets} in a single query
  - need the \textit{intersection} of subqueries for \textit{targets}_1 and \textit{targets}_2 and ...}

- these challenges poorly met by existing database systems
  - relational databases not designed/optimized for multi-key searches
    - can't always use column indexes; may need to do table scans on separate columns
  - not a good fit for existing NoSQL databases
    - schema-less document stores (JSON/XML) come the closest
• implemented **custom index data structures**
  - highly tailored and tuned to the characteristics of our data and workload
    - efficiently supports large numbers of targets and subquery intersections
  - gave up generality and flexibility for speed

• built on **RocksDB** key-value store
  - persistent hash table
  - maps binary string (key) to binary string (value)
    - can also traverse keys in sorted order
  - stores both traceroute data and custom indexes

• **custom query engine**
  - written in Python
  - running on 64 cores; may use HPC facilities in future
- user-friendly GUI to query system
  - also built-in analyses and visualizations for commonly occurring needs
    - lower barrier to use; reach casual users

- uses Bokeh for client-side visualizations
  - supports user interaction and offline viewing on client-side
    - data + visualization (JavaScript) loaded entirely in client browser
  - use Python to implement new visualizations on server-side
    - use library of Bokeh visualization primitives
ad-hoc queries

Query Traces for IP Paths

Displays traceroute paths.

**Query**

Target Address/Prefix/AS/Country: 192.168.0.0/24

Second Target for neigh Query:

Separate multiple targets with commas.
Example: 1.2.3.4, 10.0.0.8, as1234, sy

Start Date: 2016-01  End Date: 2016-02

Dates can be YYYY, YYYY-MM, or YYYY-MM-DD. End date is exclusive. Leave start/end (or both) blank for an open-ended range.

Query Method:  
- dest
- addr
- neigh

dest — search by trace destination address
addr — search for responding address (hop or responding destination address)
neigh — search for neighboring addresses (responding hop or destination)

Target Position/Neighbor Separation: 0 3  Max Traces: 10  Reverse Order

- positive position — hop distance relative to beginning of trace
- negative position — hop distance relative to end of trace
- neighbor separation — hop distance between neighboring targets

**Vantage Point**

- ams-nl
- By Continent
- By Country
- By Org Type

Monitors with IPv6 have an asterisk next to their name.
### Neighbor query of **206.223.119.0/24** and **as6939** from **bma-se**

**Download JSON results**

1. Traceroute to **173.218.24.1** on **2016-01-01 00:26:24**

<table>
<thead>
<tr>
<th>Hop</th>
<th>Address</th>
<th>Target Match</th>
<th>Prefix</th>
<th>AS</th>
<th>Location</th>
<th>RTT (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>95.143.207.173</td>
<td>95.143.192.0/20</td>
<td>49770</td>
<td>hudiksvall swe</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>MX-CORE1.internetport.se 95.143.207.229</td>
<td>95.143.192.0/20</td>
<td>49770</td>
<td>hudiksvall swe</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>CO-RO2.internetport.se 95.143.207.186</td>
<td>95.143.192.0/20</td>
<td>49770</td>
<td>hudiksvall swe</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>gige-g2-1.core1.sto1.he.net 192.121.80.162</td>
<td></td>
<td></td>
<td></td>
<td>stockholmswe</td>
<td>18.8</td>
</tr>
<tr>
<td>7</td>
<td>v991.core1.slc1.he.net 72.52.92.81</td>
<td>72.52.64.0/18 (as6939)</td>
<td>72.52.92.0/24</td>
<td>6939</td>
<td>fremont, ca usa</td>
<td>30.0</td>
</tr>
<tr>
<td>8</td>
<td>100ge5-2.core1.par2.he.net 72.52.92.13</td>
<td>72.52.64.0/18 (as6939)</td>
<td>72.52.92.0/24</td>
<td>6939</td>
<td>fremont, ca usa</td>
<td>40.2</td>
</tr>
<tr>
<td>9</td>
<td>100ge10-1.core1.nyc4.he.net 184.105.81.77</td>
<td>184.104.0.0/15 (as6939)</td>
<td>184.104.0.0/15</td>
<td>6939</td>
<td>new york, ny usa</td>
<td>117.4</td>
</tr>
<tr>
<td>10</td>
<td>100ge5-1.core1.chi1.he.net 184.105.223.161</td>
<td>184.104.0.0/15 (as6939)</td>
<td>184.104.0.0/15</td>
<td>6939</td>
<td>chicago, il usa</td>
<td>132.2</td>
</tr>
<tr>
<td>11</td>
<td>equinix-chi.suddenlink.NET 206.223.119.72</td>
<td>206.223.119.0/24 (A)</td>
<td></td>
<td></td>
<td></td>
<td>127.7</td>
</tr>
<tr>
<td>12</td>
<td>173-219-231-169.suddenlink.net 173.219.231.169</td>
<td></td>
<td>173.216.0.0/14</td>
<td>19108</td>
<td>lufkin, tx usa</td>
<td>164.7</td>
</tr>
</tbody>
</table>
Query Traces for RTT Time Series

Plots an RTT time series for target destinations, an RTT histogram, and a time series of target unreachability.

**Query**

Target Address/Prefix/AS/Country: [blank]

Separate multiple targets with commas. Example: 1.2.3.4, 10.0.0.0/8, as1234, .sy

Start Date: [blank]   End Date: [blank]

Dates can be YYYY, YYYY-MM, or YYYY-MM-DD. End date is exclusive. Leave start/end (or both) blank for an open-ended range.

**Vantage Point**

By Name   By Continent   By Country   By Org Type

Monitors with IPv6 have an asterisk next to their name.
pre-made analysis

Henya
• **AS Rank** primarily concerned with querying **AS topology**
To provide a way of examining and comparing Internet Service Provider (ISP).

- **Most ISP have a single dominate AS.**
  
  For many purposes this dominate AS can be used as a proxy for a given organization.

- **AS Rank provides two major views:**
  
  - ranked ordering of ASes (global)
  
  - selected AS and its neighbors (local)
• presents ranking for a target date

  The user selects a single target data from the list of available for the AS topologies.

• annotate with values from secondary datasets
  – heterogeneous dates and values
  – annotate topology with “near in time” datasets

<table>
<thead>
<tr>
<th>AS Topology</th>
<th>Organization</th>
<th>AS Geography</th>
<th>Link Geography</th>
<th>AS Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>selected date</td>
<td>matched org_id</td>
<td></td>
<td>nearest to date</td>
<td></td>
</tr>
</tbody>
</table>
• CGI (Perl) front end
  – cache based on CGI parameters
• visualizations
  – Perl and C scripts
  – generates SVG files
• MySQL server back end
## Global AS Ranking

The global AS ranking is displayed on the page, with datasets for different times:
- Organization dataset (04/01/2016)
- Topology dataset (06/16/2016)
- Type dataset (08/02/2015)

### Table: AS Ranking

<table>
<thead>
<tr>
<th>AS rank</th>
<th>AS number</th>
<th>AS name</th>
<th>Org name</th>
<th>AS Type(s)</th>
<th>ASes</th>
<th>IPv4 Prefixes</th>
<th>IPv4 Addresses</th>
<th>Percentages of all ASes</th>
<th>Percentages of all IPv4 Prefixes</th>
<th>Percentages of all IPv4 Addresses</th>
<th>AS transit degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3356</td>
<td>LEVEL3</td>
<td>Level 3 Communications, Inc.</td>
<td>T/Ad</td>
<td>3356</td>
<td>29,454</td>
<td>224,970</td>
<td>703,401,728</td>
<td>53%</td>
<td>34%</td>
<td>36%</td>
</tr>
<tr>
<td>2</td>
<td>174</td>
<td>COGENT-174</td>
<td>Cogent Communications</td>
<td>T/Ad</td>
<td>174</td>
<td>23,259</td>
<td>172,963</td>
<td>616,423,936</td>
<td>42%</td>
<td>26%</td>
<td>28%</td>
</tr>
<tr>
<td>3</td>
<td>1299</td>
<td>TELIANET</td>
<td>TeliaSonera AB</td>
<td>T/Ad</td>
<td>1299</td>
<td>21,954</td>
<td>191,391</td>
<td>667,346,176</td>
<td>40%</td>
<td>29%</td>
<td>31%</td>
</tr>
<tr>
<td>4</td>
<td>2914</td>
<td>NTT-COMMUN...</td>
<td>NTT America, Inc.</td>
<td>T/Ad</td>
<td>2914</td>
<td>18,961</td>
<td>174,304</td>
<td>642,432,768</td>
<td>34%</td>
<td>26%</td>
<td>29%</td>
</tr>
<tr>
<td>5</td>
<td>3257</td>
<td>GTT-BACKBONE</td>
<td>Tinet Spa</td>
<td>T/Ad</td>
<td>3257</td>
<td>18,140</td>
<td>161,377</td>
<td>565,089,024</td>
<td>33%</td>
<td>24%</td>
<td>26%</td>
</tr>
<tr>
<td>6</td>
<td>6762</td>
<td>SEABONE-NET</td>
<td>TELECOM ITALIA SPARKLE S.p.A.</td>
<td>T/Ad</td>
<td>6762</td>
<td>14,394</td>
<td>123,771</td>
<td>329,530,624</td>
<td>26%</td>
<td>18%</td>
<td>15%</td>
</tr>
<tr>
<td>7</td>
<td>6453</td>
<td>AS6453</td>
<td>TATA COMMUNICATIONS (AMERICA) INC</td>
<td>T/Ad</td>
<td>6453</td>
<td>12,300</td>
<td>135,127</td>
<td>533,133,824</td>
<td>22%</td>
<td>20%</td>
<td>24%</td>
</tr>
<tr>
<td>8</td>
<td>6939</td>
<td>HURRICANE</td>
<td>Hurricane Electric, Inc.</td>
<td>T/Ad</td>
<td>6939</td>
<td>8,088</td>
<td>79,800</td>
<td>278,942,720</td>
<td>14%</td>
<td>12%</td>
<td>12%</td>
</tr>
<tr>
<td>9</td>
<td>2828</td>
<td>XO-AS15</td>
<td>XO Communications</td>
<td>T/Ad</td>
<td>2828</td>
<td>6,251</td>
<td>60,271</td>
<td>250,568,448</td>
<td>11%</td>
<td>9.2%</td>
<td>11%</td>
</tr>
<tr>
<td>10</td>
<td>1273</td>
<td>CW</td>
<td>Cable and Wireless Worldwide plc</td>
<td>T/Ad</td>
<td>1273</td>
<td>5,878</td>
<td>42,258</td>
<td>173,223,936</td>
<td>10%</td>
<td>8.4%</td>
<td>8.1%</td>
</tr>
</tbody>
</table>
The relationship table below displays the neighbors of AS 3356, and each neighbor's inferred relationship type with AS 3356.

<table>
<thead>
<tr>
<th>Position in Ranking</th>
<th>AS</th>
<th>AS name</th>
<th>AS type(s)</th>
<th>Org name</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>174</td>
<td>COCENT-174</td>
<td>TrAg</td>
<td>Cogent Communications</td>
<td>peer</td>
</tr>
<tr>
<td>3</td>
<td>1299</td>
<td>TELIANET</td>
<td>TrAg</td>
<td>TeliaSonera AB</td>
<td>peer</td>
</tr>
<tr>
<td>4</td>
<td>2014</td>
<td>NTT COMMUN...</td>
<td>TrAg</td>
<td>NTT America, Inc.</td>
<td>peer</td>
</tr>
<tr>
<td>5</td>
<td>3257</td>
<td>GTT-BACKBONE</td>
<td>TrAg</td>
<td>Tinet Spa</td>
<td>peer</td>
</tr>
<tr>
<td>6</td>
<td>6762</td>
<td>SEABONE NET</td>
<td>TrAg</td>
<td>TELECOM ITALIA SPARKLE S.p.A.</td>
<td>peer</td>
</tr>
<tr>
<td>7</td>
<td>6453</td>
<td>AS6453</td>
<td>TrAg</td>
<td>TATA COMMUNICATIONS (AMERICA) INC</td>
<td>peer</td>
</tr>
<tr>
<td>8</td>
<td>6939</td>
<td>H-HURRICANE</td>
<td>TrAg</td>
<td>Hurricane Electrc, Inc.</td>
<td>peer</td>
</tr>
<tr>
<td>9</td>
<td>2828</td>
<td>XO-AS15</td>
<td>TrAg</td>
<td>XO Communications</td>
<td>peer</td>
</tr>
<tr>
<td>12</td>
<td>701</td>
<td>LUNET</td>
<td>TrAg</td>
<td>MCI Communications Services, Inc. d/b/a Verizon Business</td>
<td>peer</td>
</tr>
<tr>
<td>13</td>
<td>6461</td>
<td>ABOVENET</td>
<td>TrAg</td>
<td>Abovenet Communications, Inc</td>
<td>peer</td>
</tr>
</tbody>
</table>
local AS visualizations

This is a geographical representation of AS topology, where each circle represents a single AS. The color represents the AS number, and the size represents the number of customer ASes. Each node represents a single AS, and the size of the node is proportional to the number of customer ASes. The distance from the center of the node represents the AS's geographic location.

We plot ASes based on their country and customer ASes. ASes with the same country are placed close together. The distance between ASes represents the geographic distance. Additionally, we set the angle of each AS by thecardinal direction of the AS's geographic location. Specifically, we use the format of the geographic location of its addresses (latitude, longitude).
AS rank and Hyena represent only a beginning at bringing Internet data to a wider audience.

We are eager to leverage expertise from other designers of gateways and other environments to support high performance computations.

Contact: info@caida.org