AS Rank Reborn
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A ranking of the largest Internet AS by the number of direct and indirect customer ASs.

“Well that’s a lot of numbers” - Sister the Historian
Internet topology can be mapped at four levels.

1. **IP addresses** that connect devices to the Internet.
2. **Routers**, machines that route the traffic, interconnect via **IP addresses**.
3. **POPs**, geographic locations of the **routers** and servers.
4. **Autonomous Systems (AS)** are independently operated networks that route groups of **IP addresses**.
IP level path (traceroute)

traceroute to 137.164.11.8 (137.164.11.8), 64 hops max, 52 byte packets
1  sdsc-rtr          (192.172.226.252)  13.079 ms  0.285 ms  15.696 ms
2  mx0-ae7--thor-ae0.sdsc.edu ( 192.12.207.61)   0.399 ms  0.398 ms  0.361 ms
3  dc-sdg-agg4--sdsc-1.cenic.net ( 137.164.23.129) 0.901 ms  0.892 ms  0.917 ms
4  dc-tus-3-agg4-100ge.cenic.net ( 137.164.11.8) 2.535 ms  2.503 ms  2.592 ms
Build the graph from observed AS paths.
Routes are announced by routers and forwarded toward the collector. So the last AS, the “origin” AS, “owns” (first announces) the prefix.

<table>
<thead>
<tr>
<th>prefix</th>
<th>AS path</th>
<th>origin AS</th>
</tr>
</thead>
<tbody>
<tr>
<td>route 1</td>
<td>5.5.1.0/24</td>
<td>1</td>
</tr>
<tr>
<td>route 2</td>
<td>13.5.1.0/24</td>
<td>1</td>
</tr>
<tr>
<td>route 3</td>
<td>10.0.0.0/16</td>
<td>1</td>
</tr>
<tr>
<td>route 5</td>
<td>9.0.1.0/24</td>
<td>1</td>
</tr>
</tbody>
</table>
Collecting and sharing global routing [Border Gateway Protocol (BGP)] data:

- University of Oregon, Route Views Project
  - [http://www.routeviews.org](http://www.routeviews.org)

- RIPE NCC (Regional Internet Registry for Europe/Middle East)
BGPStream: a software framework for live and historical BGP data analysis

Based on the set of AS paths, different types of degrees may be inferred.

**B’s degrees**

<table>
<thead>
<tr>
<th>type</th>
<th>neighbors</th>
<th>degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>link based</td>
<td></td>
<td></td>
</tr>
<tr>
<td>global</td>
<td>A C E D G</td>
<td>5</td>
</tr>
<tr>
<td>customers</td>
<td>A D</td>
<td>2</td>
</tr>
<tr>
<td>peer</td>
<td>E</td>
<td>1</td>
</tr>
<tr>
<td>providers</td>
<td>G</td>
<td>0</td>
</tr>
<tr>
<td>triplet based</td>
<td></td>
<td></td>
</tr>
<tr>
<td>transit</td>
<td>A E D G</td>
<td>4</td>
</tr>
</tbody>
</table>

paths:
- A → B → G
- B → C
- E → B ← D
- F → E ← B ← D

doesn’t include B

B isn’t in the center
Transit degree is a proxy for the number of ASs whose traffic can cross the AS.
provider
  • you pay them to transit your traffic
    (XO pays AT&T)
peer
  • unpaid exchange of traffic
    (between XO and Google)
customer
  • they pay you to transit their traffic
    (UCSD pays XO)
ASes can be organized into a hierarchical structure based on the type of business relationships they form between themselves.

\[
\begin{align*}
\text{customer} & \quad \rightarrow \quad \text{provider} \\
\text{customer pays provider for transit} \\
\text{peer} & \quad \rightarrow \quad \text{peer} \\
\text{peers do not pay to accept each other’s traffic}
\end{align*}
\]
An AS’s customer cone contains the set of ASs we observe the AS announce to its peers or providers. In practice, this is the set of ASs it can reach through its customers.

<table>
<thead>
<tr>
<th>AS</th>
<th>size</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
</tr>
</tbody>
</table>
ISP only transit traffic if at least one side is paying for it. Customer cones are therefore inferred only from routes announced to peers and providers.

A’s view of B

- B provider full transit
- B peer customers only
- B provider customers only
Customer cone’s definitions is not recursive. It only includes observed paths.

### Paths
- E C D
- F B A C
- E B A

### Table
<table>
<thead>
<tr>
<th>AS</th>
<th>size</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
</tr>
</tbody>
</table>

D is not included in A’s cone.
AS customer cone size

Customer cone size is a measure of influence on the global routing system.
Also calculate the customer cone in terms of BGP prefixes, using the same methodology.
We also calculate the cone in terms of IP addresses covered by its prefixes.
Rank is equal to one greater than the number of ASs with larger customer cone sizes or degrees.

<table>
<thead>
<tr>
<th>rank</th>
<th>cone size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASNs</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>
Organization is parsed from the WHOIS database.
WHOIS contains contact information for Internet IDs, which can include organization information.
New RESTFUL API to the AS Rank data.
all replies are in the following wrapper:

```json
{
    "total": 84741,
    "data": [ "3356", "1299", "174", "2914" ],
    "error": (optional)
}
```

- data and error do not both normally both have values

results are returned in “pages”

- first page (/asns)

```json
{
    "total": 84741,
    "data": [ "3356", "1299", "174", "2914" ]
}
```

- second page (/asns?page=2)

```json
{
    "total": 84741,
    "data": [ "3257", "6762", "6939", "6453" ]
}
```

- first page (/asns?count=6)

```json
{
    "total": 84741,
    "data": [ "3356", "1299", "174", "2914", "3257", "6762" ]
}
```
• queries can be “populated”
  – unpopulated (/asns )
  ```json
  {
  "total": 84741,
  "data": [ "3356", "1299", "174", "2914" ]
  }
  ```
  – first page (/asns?populated=1 )
  ```json
  {
  "total": 84741,
  "data": [ {
    "id": "3356",
    "name": "LEVEL3",
    "latitude": "40.229564067878",
    "country": "US",
    "id": "3356",
    "degree": {
      "siblings": 8,
      "peers": 82,
      "transits": 4976,
      "customers": 4898,
      "globals": 4980
    },
    "clique": "true",
    "longitude": "-96.414102674846",
  }
  ]
  ```
as-rank.caida.org/api/v1/asns/(\d+)

```
{
  "data": {
    "country": "US",
    "id": "1",
    "latitude": "46.9089257297413",
    "longitude": "-101.895560449918",
    "degree": {
      "globals": 11,
      "customers": 2,
      "providers": 8,
      "transits": 4,
      "peers": 1
    },
    "clique": "false",
    "name": "LVLT-1",
    "cone": {
      "addresses": 16128,
      "prefixes": 20,
      "asns": 3
    },
    "rank": "4772",
    "org": { "id": "LVLT-ARIN", "name": "Level 3 Communications, Inc." }
  }
}
```
ASs at the top of the hierarchy are called Tier-1. Together they form the backbone of the Internet.

We infer that the set of “Tier-1” ASs are members of the largest clique, fully connected set, of the largest ASs.
An AS's location is set to the weighted average of the locations assigned by Netacuity to the addresses it announces.

\[ \frac{\sum \text{block}_i \cdot \text{longitude} \cdot \text{block}_i \cdot \text{size}}{\sum \text{block}_i \cdot \text{size}} \]

<table>
<thead>
<tr>
<th>origin AS</th>
<th>prefix</th>
<th>IP block</th>
<th>longitude</th>
<th>weighted average longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>5.5.1.0/24</td>
<td>5.5.1.0 - 5.5.1.255</td>
<td>-103</td>
<td>-103</td>
</tr>
<tr>
<td>1</td>
<td>10.0.0.0/16</td>
<td>10.0.0.0-10.0.127.255</td>
<td>25</td>
<td>37.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.0.128.0-10.0.255.255</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>13.5.1.0/24</td>
<td>13.5.1.0-13.5.1.255</td>
<td>-23</td>
<td>-23</td>
</tr>
<tr>
<td>5</td>
<td>9.0.1.0/24</td>
<td>9.0.1.0-9.0.1.255</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>
as-rank.caida.org/api/v1/asns/(\d+)/links

20 paths were observed crossing the link AS 1 → AS 200612.
Dataset Information

as-rank.caida.org/api/v1/ds

```json
{
    "address_family" : "AF_INET",
    "number_prefixes" : 763838,
    "number_asnes" : 60690,
    "number_addresses" : 2867192832,
    "number_organizes" : 58323,
    "sources" : [
        {
            "date" : "20180209",
            "url" : "https://www.digitalelement.com/solution",
        },
        {
            "name" : "Organization",
            "url" : "https://www.caida.org/data/as-organizations",
            "date" : "20180201",
            "url" : "http://www.caida.org/data/as-relations",
        },
    ],
    "clique" : [174, 209, 286, 701, 1239, 1299, 2828, 2914, 3257, 3320, 3337, 7013, 12001, 12496, 12953, 13072, 13697, 14224, 16384, 2097152, 4194304, 62914576, 104857600, 167772160, 847412800, 1677721600],
    "asn_ixs" : ["1200", "4635", "5507", "6695", "7606", "8714", "9355", "n"],
    "asn_assigned_ranges" : [
        ["1", "23455"],
        ["23457", "64495"],
        ["131072", "139577"],
        ["196608", "207259"],
        ["262144", "268700"],
        ["327680", "328703"],
        ["393216", "397212"],
    ],
    "asn_reserved_ranges" : [
        [0, 0],
        [64496, 65535],
        [420000000, 4294967294],
        [4294967295, 4294967295]
    ],
}
```
Organization Information

as-rank.caida.org/api/v1/orgs/(^[^/]+)

as-rank.caida.org/api/v1/orgs/ORG-TCA23-RIPE

```json
{
  "org_id" : "ORG-TCA23-RIPE",
  "org_name" : "Telia Company AB",
  "country" : "EU",
  "rank" : 2,
  "org_degree_global" : 1572,
  "org_transit_degree" : 1569,
  "customer_cone_addresses" : 850416384,
  "customer_cone_prefixes" : 256780,
  "customer_cone_asnes" : 27302,
  "customer_cone_orgs" : 25242,
  "number_members" : 1,
  "members" : [
    "1299","129"
  ],
  "asn_degree_transit" : 1665,
  "asn_degree_global" : 1668
}
```
as-rank.caida.org/api/v1/paths/\(\d+\)

as-rank.caida.org/api/v1/paths/2914

```json
{
    "path": "3356-2914>23352>36352",
    "prefixes": [
        {
            "monitors": [{"monitor": "rrc03","ip":10.0.0.1}]
        },
        {
            "prefixes": ["14.0.0.0/12","13.0.0.0/18","13.0.0.0/18"]
        }
    ]
}
```

**path**: this string contains the AS path with the gaps between ASes annotated with relationships if known
- A > B : A is a provider of B
- A < B : A is a customer of B
- A - B : A is a peer of B
- A  B : A has no known relationship with B, this occurs when the link's paths or the link itself was rejected

**prefixes**: an array of prefixes that share the same set of monitors.
- each monitor includes its name and the peer IP address that observed this path
- a monitor can have multiple IPs, but it is not very common
Path Tags

• **tags**: (optional) An array of additional tags to apply to the path
  - **index** or **indexes**: single value, or array, of integers
  - **type**: "IX", "loop", "duplicate"
    - **IX** (-A-): The ASN at the index is an Internet EXchange (IX), and should be removed
    - **loop** (A-B-C-D): a loop was detected and all parts of the loop are removed from the path
    - **duplicate** (-A): removes duplicate ASNs
  - **add**: (-): (optional) value of to add
• **used**: the clean path used to infer AS Relationships
as-rank.caida.org/api/v1

```
{
    "path": "3356-2914 64496 23352>36352",
    "prefixes": [
        {
            "monitors": [{"monitor": "rrc03", "ip": 10.0.0.1}]
        },
        {
            "prefixes": ["14.0.0.0/12", "13.0.0.0/18", "13.0.0.0/18"]
        }
    ],
    "rejected": {
        "index": 1,
        "type": "reserved"
    }
}
```

- **rejected** (optional) this signals the whole path was rejected and encodes the reason why
  - **type** reasons for path rejection
    - **poison**: a non-clique ASN was observed between two clique ASNs
    - **unassigned**: an unassigned ASN was observed in the path
    - **reserved**: a reserved "private" ASN was observed in the path
  - **index** or **indexes** location of the ASN that caused the path to be rejected
<table>
<thead>
<tr>
<th></th>
<th>tagged (1.7%)</th>
<th>rejected (0.07%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>total</td>
<td>IX</td>
</tr>
<tr>
<td>paths</td>
<td>16M</td>
<td>95%</td>
</tr>
</tbody>
</table>

- vast majority of paths unaffected
- most “tagged” paths were caused by IX ASs
- most “rejected” paths were caused by “reserved” ASs
filter effects

<table>
<thead>
<tr>
<th></th>
<th>total</th>
<th>gained</th>
<th>lost</th>
<th>degree changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>links</td>
<td>268K</td>
<td>5.9%</td>
<td>1.8%</td>
<td>-</td>
</tr>
<tr>
<td>ASs</td>
<td>61K</td>
<td>0%</td>
<td>0.07%</td>
<td>4.6%</td>
</tr>
</tbody>
</table>

- larger fraction of links effected than ASs
- more links gained as links formed across, rather than with, IX
All of this data is also available for direct download as flat files in JSONL format.