ASRank

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CAIDA

SDSC/UCSD

IIJ Lab Seminar
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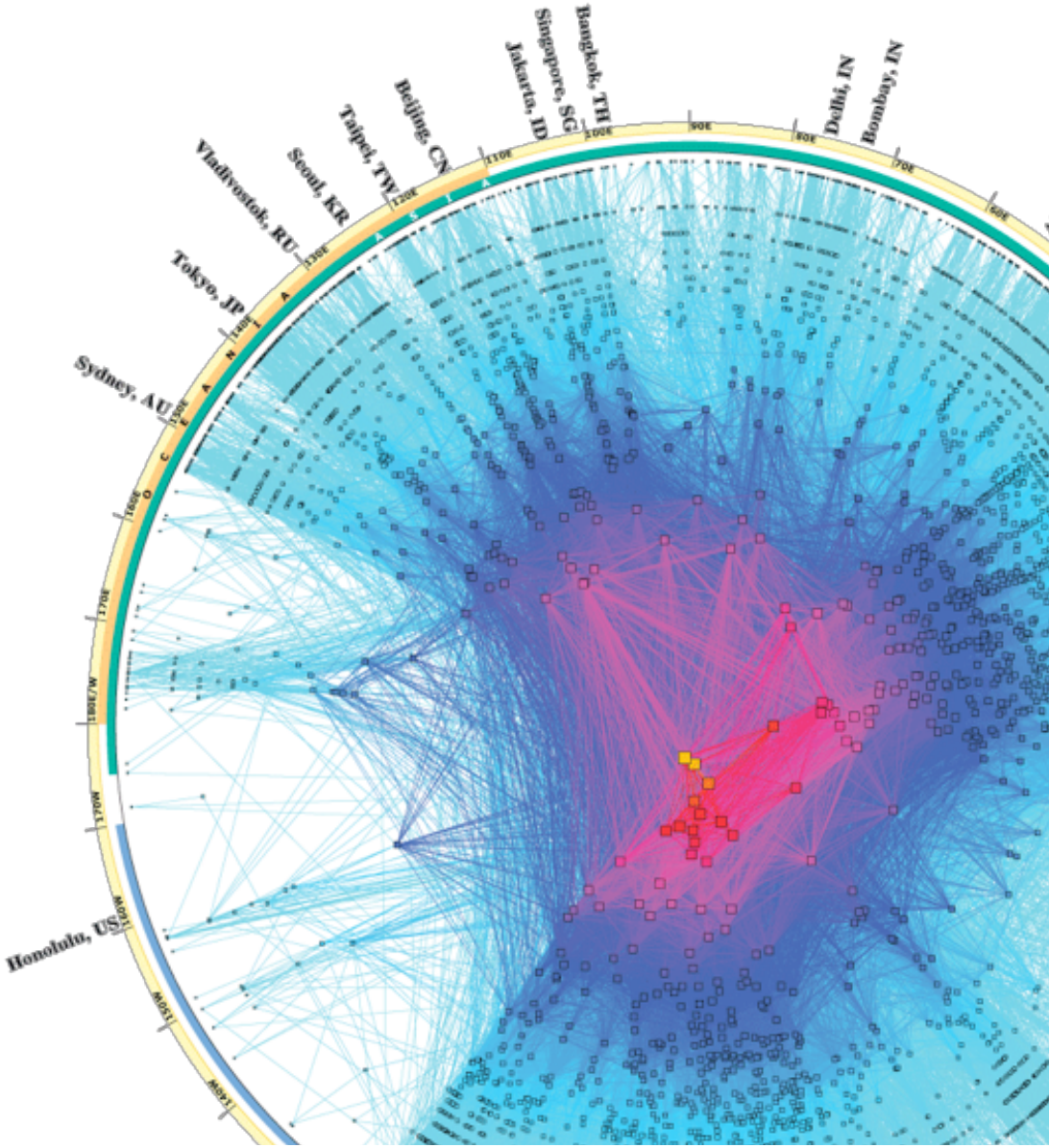

what is AS Rank?

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AS Rank ▲	AS Number	Organization		cone size ▽
1	3356	Level 3 Parent, LLC		32759
2	1299	Telia Company AB		28902
3	174	Cogent Communications		26664
4	2914	NTT America, Inc.		24578
5	3257	GTT Communications Inc.		22113
6	6762	TELECOM ITALIA SPARKLE S....		15131
7	6453	TATA COMMUNICATIONS (A...		14688
8	6939	Hurricane Electric LLC		14527
9	3491	PCCW Global, Inc.		7961
10	3549	Level 3 Parent, LLC		6680
11	1273	Vodafone Group PLC		6406
12	6461	Zayo Bandwidth		6145
13	9002	RETN Limited		5703
14	209	Qwest Communications Com...		4588
15	12956	Telefonica International Whole...		4253

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

Internet of layers

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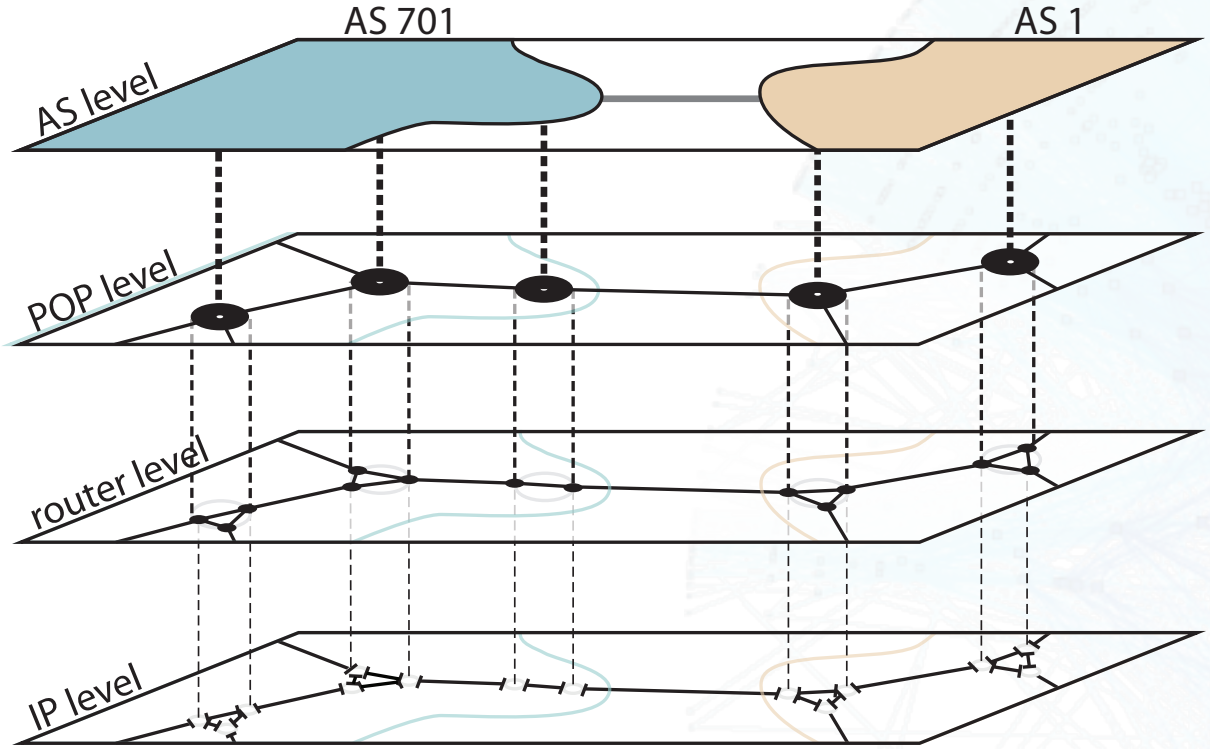
Internet topology can be mapped at four levels.

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

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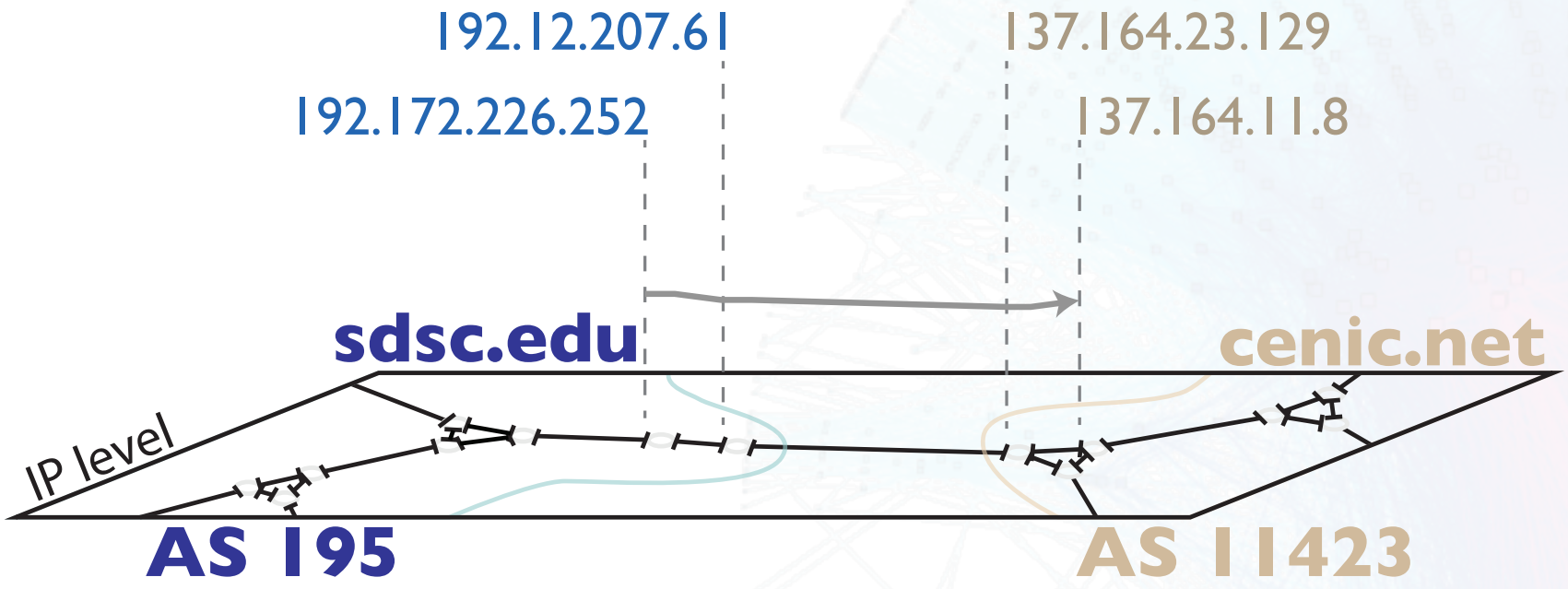
IP level path (traceroute)

```
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
```



AS level graph

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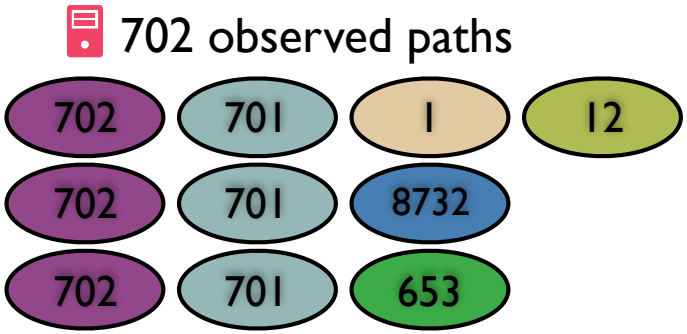
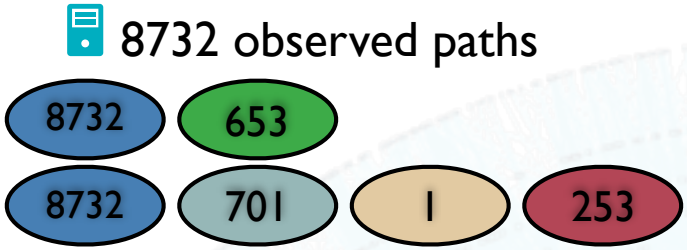
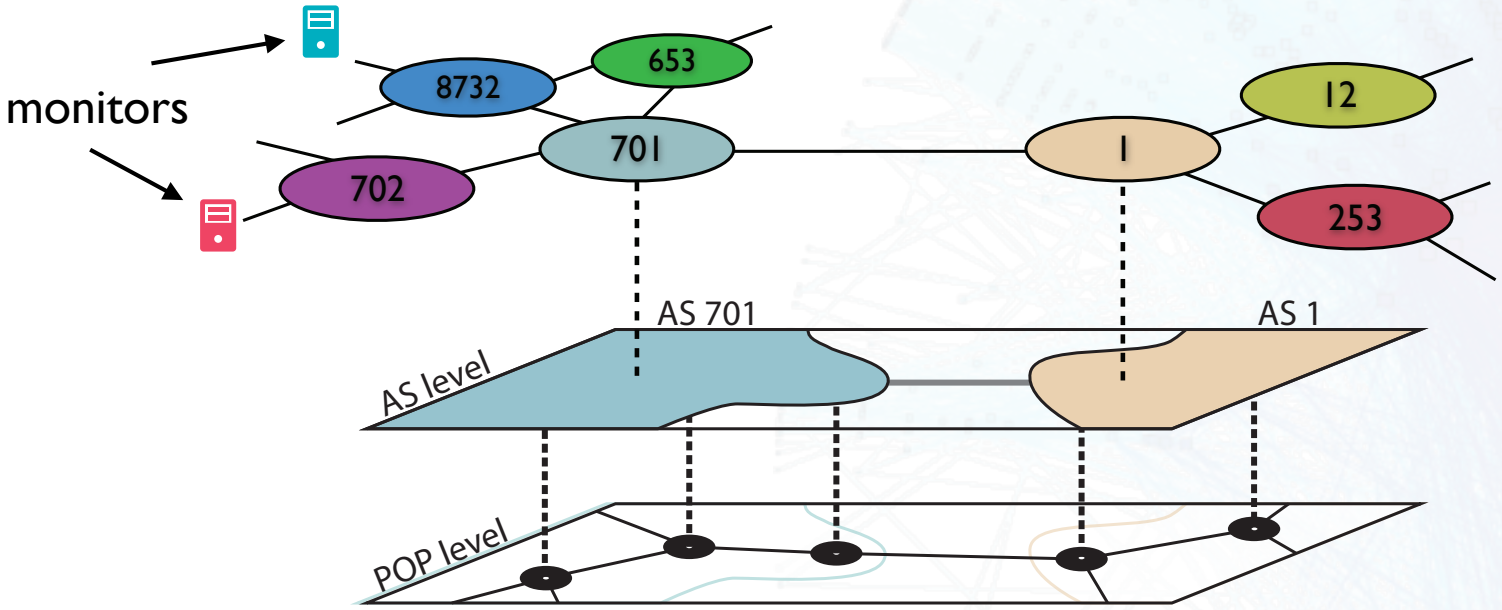




Build the graph from observed AS paths.



BGP Routes

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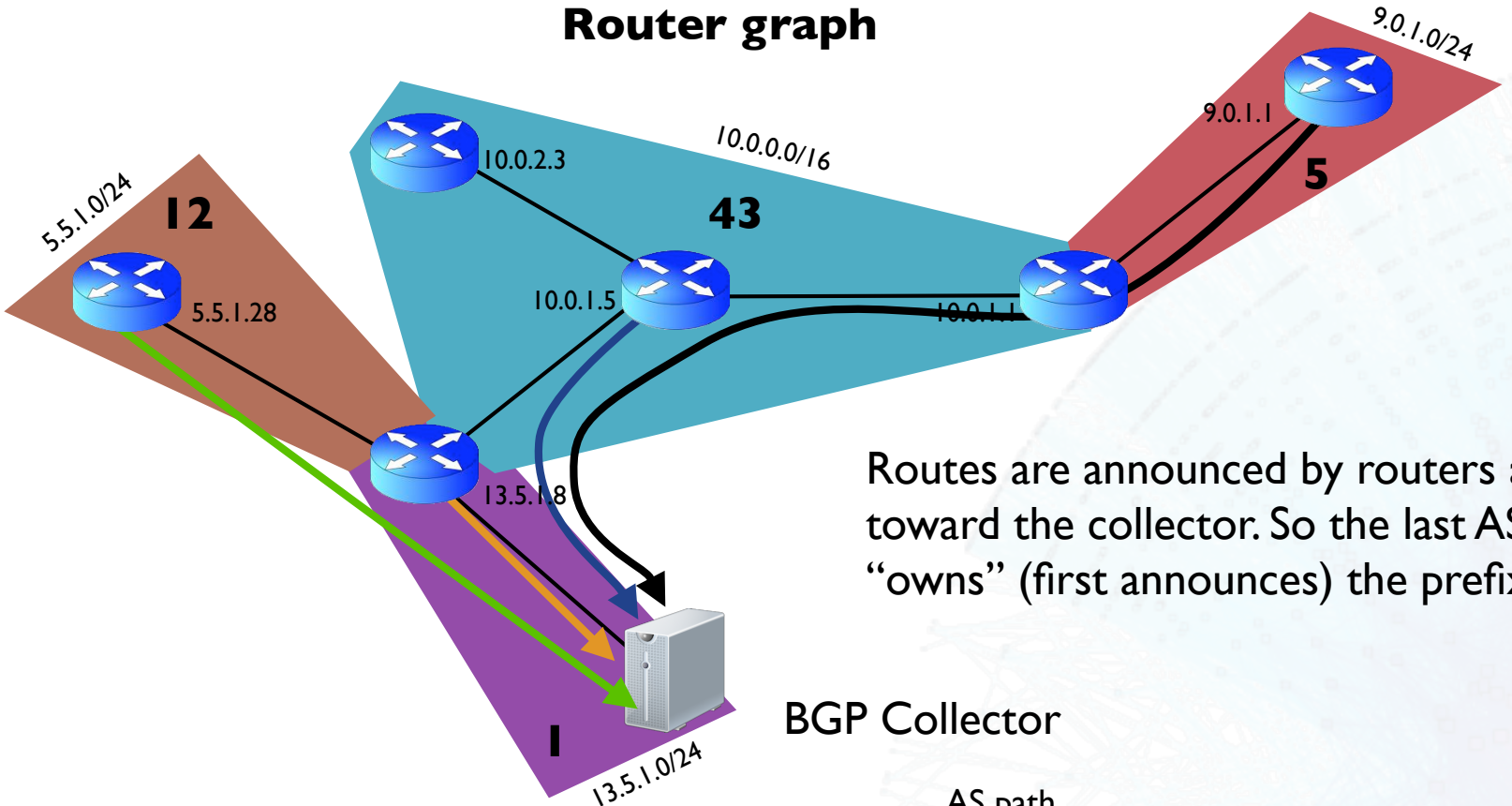

Routes are announced by routers and forwarded toward the collector. So the last AS, the "origin" AS, "owns" (first announces) the prefix.

BGP Collector

	prefix	AS path		origin AS
route 1	5.5.1.0/24		1	12
route 2	13.5.1.0/24			1
route 3	10.0.0.0/16		1	43
route 5	9.0.1.0/24	1	43	5

BGP Collectors

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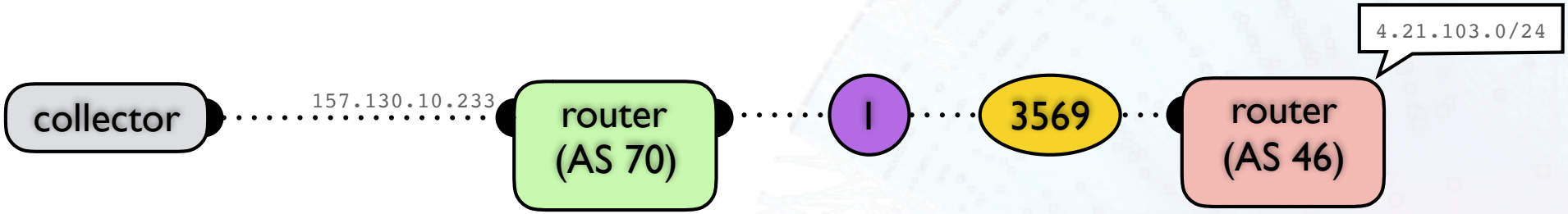
Collecting and sharing global routing [Border Gateway Protocol (BGP)] data:

- University of Oregon, Route Views Project
  - http://www.routeviews.org
- RIPE NCC (Regional Internet Registry for Europe/Middle East)
  - http://www.ripe.net/data-tools/stats/ris/ris-raw-data



BGP dump

origin AS

```
TABLE_DUMP2 | 127  1 649600 | B | 157.130.10.233 |   70    | 4.21.103.0/24 |  70 1 3549 46
TABLE_DUMP2 | 127  1 649600 | B | 203.62.252.186 |  122    | 4.21.103.0/24 | 122 1  4637 3549 46
TABLE_DUMP2 | 127  1 649600 | B | 12.0.1.63      | 7018    | 4.21.103.0/24 | 7018 3549 46133
                                  source IP      source AS     prefix          AS path
```

BGP Stream

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BGPSTREAM

bgpstream.caida.org

BGPStream: a software framework for live and historical BGP data analysis

C. Orsini, A. King, D. Giordano, V. Giotsas, and A. Dainotti, "BGPStream: a software framework for live and historical BGP data analysis", in Internet Measurement Conference (IMC), Nov 2016.

wait there's more

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as-rank.caida.org/asns

additional information

AS Rank ▲	AS Number	Organization		Customer Cone						Transit ASN Degree ▽
					Number of		Percentages of All			
				ASNs ▽	Prefixes ▽	Addresses ▽	ASNs	Prefixes	Addresses	
1	3356	Level 3 Parent, LLC		32759	238712	795625728	52.69%	28.93%	27.37%	5396
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11	1273	Vodafone Group PLC		6406	52364	159440384	10.3%	6.35%	5.48%	336
12	6461	Zayo Bandwidth		6145	39528	116280320	9.88%	4.79%	4%	1746

That's a lot of numbers…. - my sister the historian

degree types

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

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

B's degrees

type	neighbors	degree
link based		
global	A C E D G	5
customers	A D	2
peer	E	1
providers	G	0
triplet based		
transit	A E D G	4

A → B
B → G
E — B
B ← D

F → E ← doesn't include B
E — B
B ← D

B isn't in the center

A → B → G
E — B ← D

F → E — B
E — B ← D

transit degree

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Transit degree is a proxy for the number of ASs whose traffic can cross the AS.

AS Rank ▲	AS Number	Organization		Customer Cone						Transit ASN Degree ▽
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AS relationships (simplified)

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provider

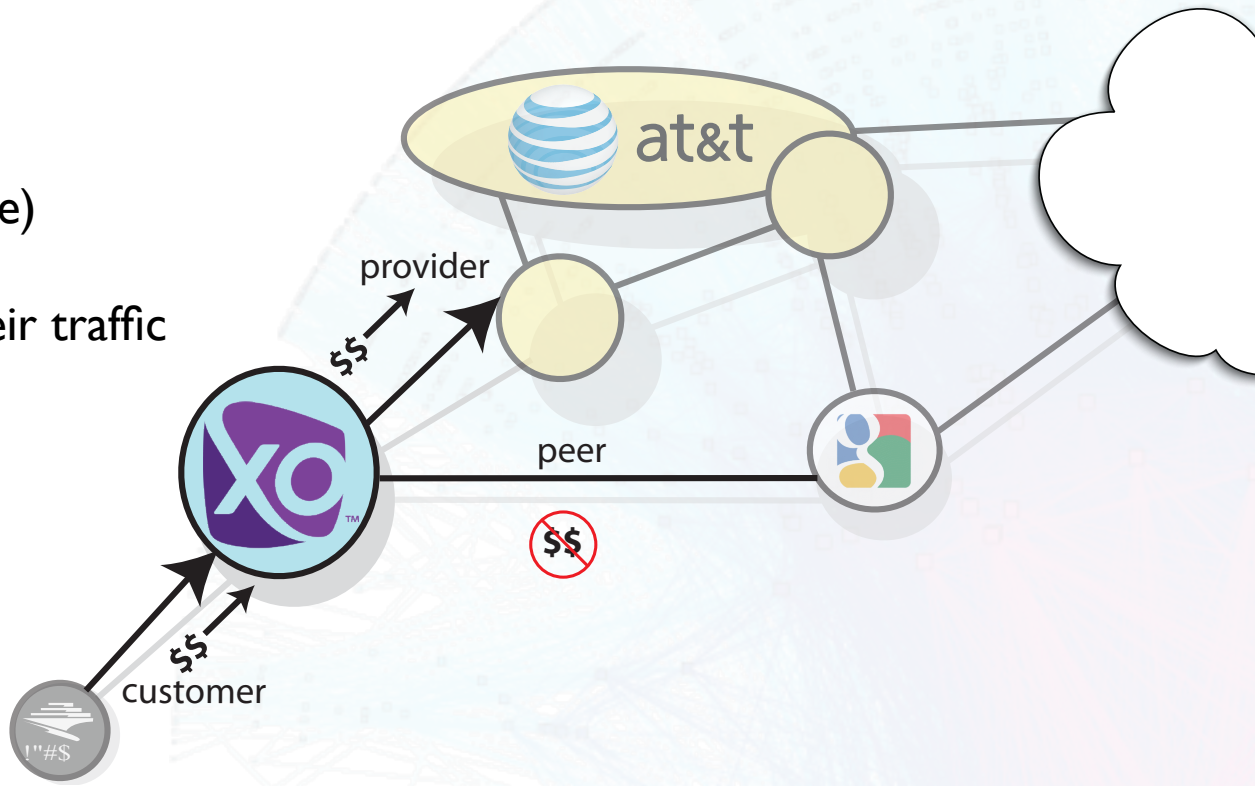
- you pay them to transit your traffic (XO pays AT&T)

peer

- unpaid exchange of traffic (between XO and Google)

customer

- they pay you to transit their traffic (UCSD pays XO)



AS hierarchy

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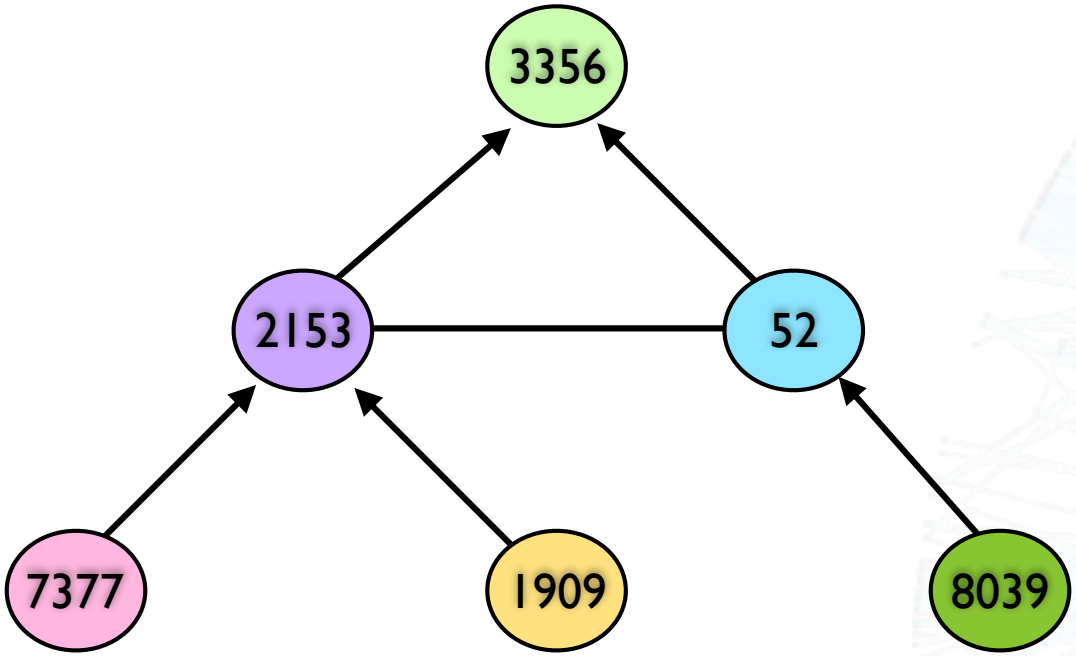
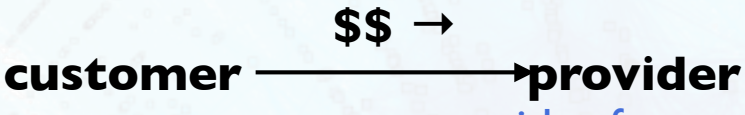
ASes can be organized into a hierarchical structure based on the type of business relationships they form between themselves.





customer pays provider for transit

peers do not pay to accept each other's traffic

AS customer cone

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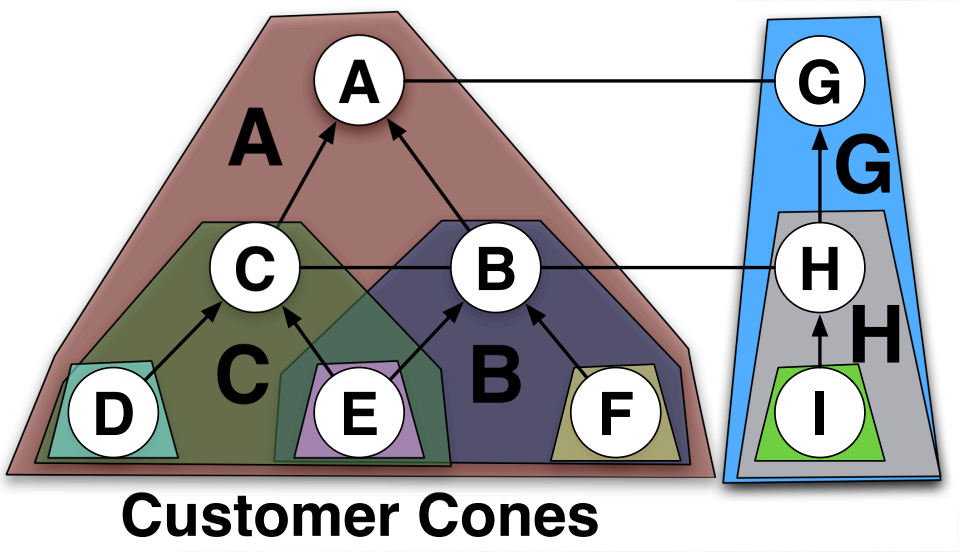
An AS's customer cone contains the set of ASs we observe the AS announce to its peers or providers. In practice, this is the set of ASs it can reach through its customers.

AS	size
A	6
B	3
D	1



Customer Cones

AS customer cone

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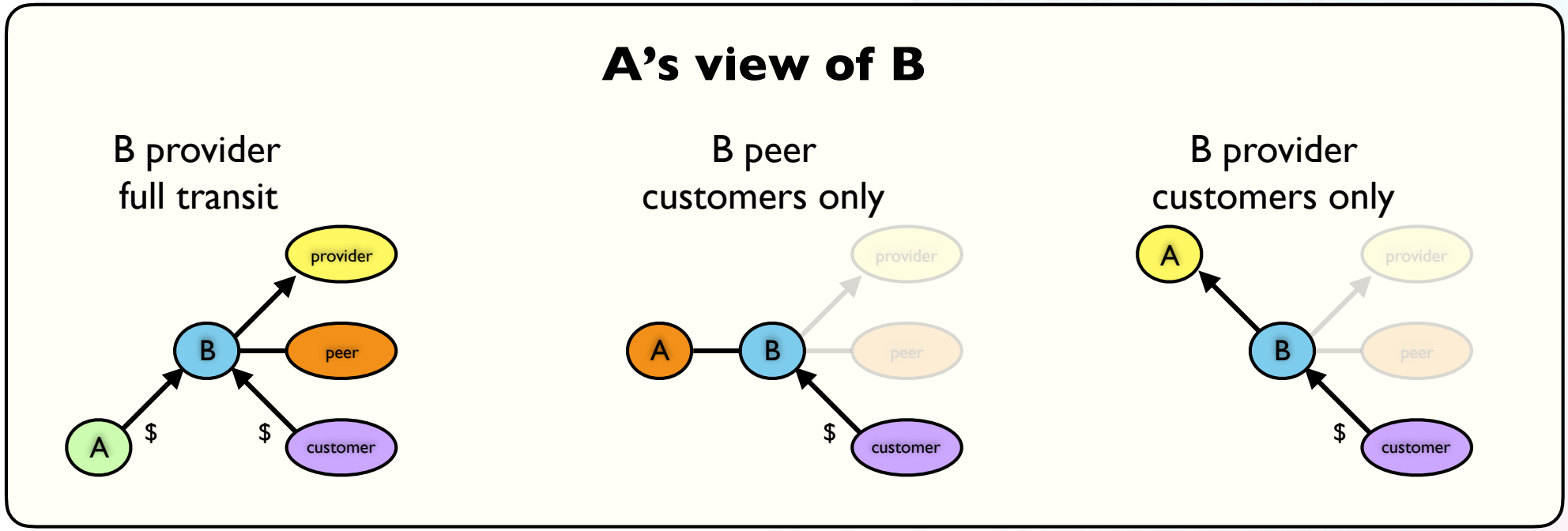
ISPs only transit traffic if at least one side is paying for it. Customer cones are therefore inferred only from routes announced to peers and providers.



AS customer cone

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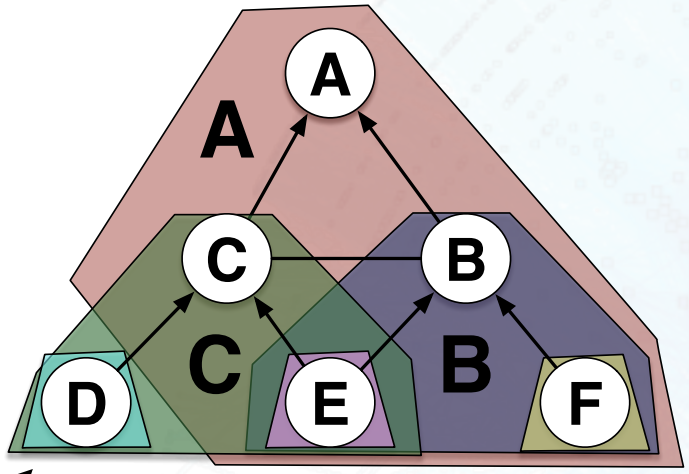
Customer cone's definitions is not recursive. It only includes observed paths.

paths: E C D
F B A C
E B A

AS	size
A	5
B	3
D	1



Customer Cones

D is not included in A's cone

AS customer cone size

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Customer cone size is a measure of influence on the global routing system.

AS Rank ▲	AS Number	Organization		Customer Cone						Transit ASN Degree ▽
				Number of			Percentages of All			
				ASNs ▽	Prefixes ▽	Addresses ▽	ASNs	Prefixes	Addresses	
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AS customer cone size

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Also calculate the customer cone in terms of BGP prefixes, using the same methodology.

AS Rank ▲	AS Number	Organization		Customer Cone						Transit ASN Degree ▽
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				ASNs ▽	Prefixes ▽	Addresses ▽	ASNs	Prefixes	Addresses	
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AS customer cone size

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We also calculate the cone in terms of IP addresses covered by its prefixes.

AS Rank ▲	AS Number	Organization		Customer Cone						Transit ASN Degree ▽
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AS customer cone size

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sort order →

AS Rank ▲	AS Number	Organization		Customer Cone: Number of ASNs ▽	Number of Prefixes ▽	Number of Addresses ▽	Percentages of All ASNs	Percentages of All Prefixes	Percentages of All Addresses	Transit ASN Degree ▽
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Rank is equal to one greater than the number of ASs with larger customer cone sizes or degrees.

rank	cone size	
	ASNs	prefixes
1	10	30
2	9	40
3	8	30
3	8	30
5	7	28
6	7	25
7	6	20

organization

as-rank.caida.org

Organization and country
parsed from WHOIS database

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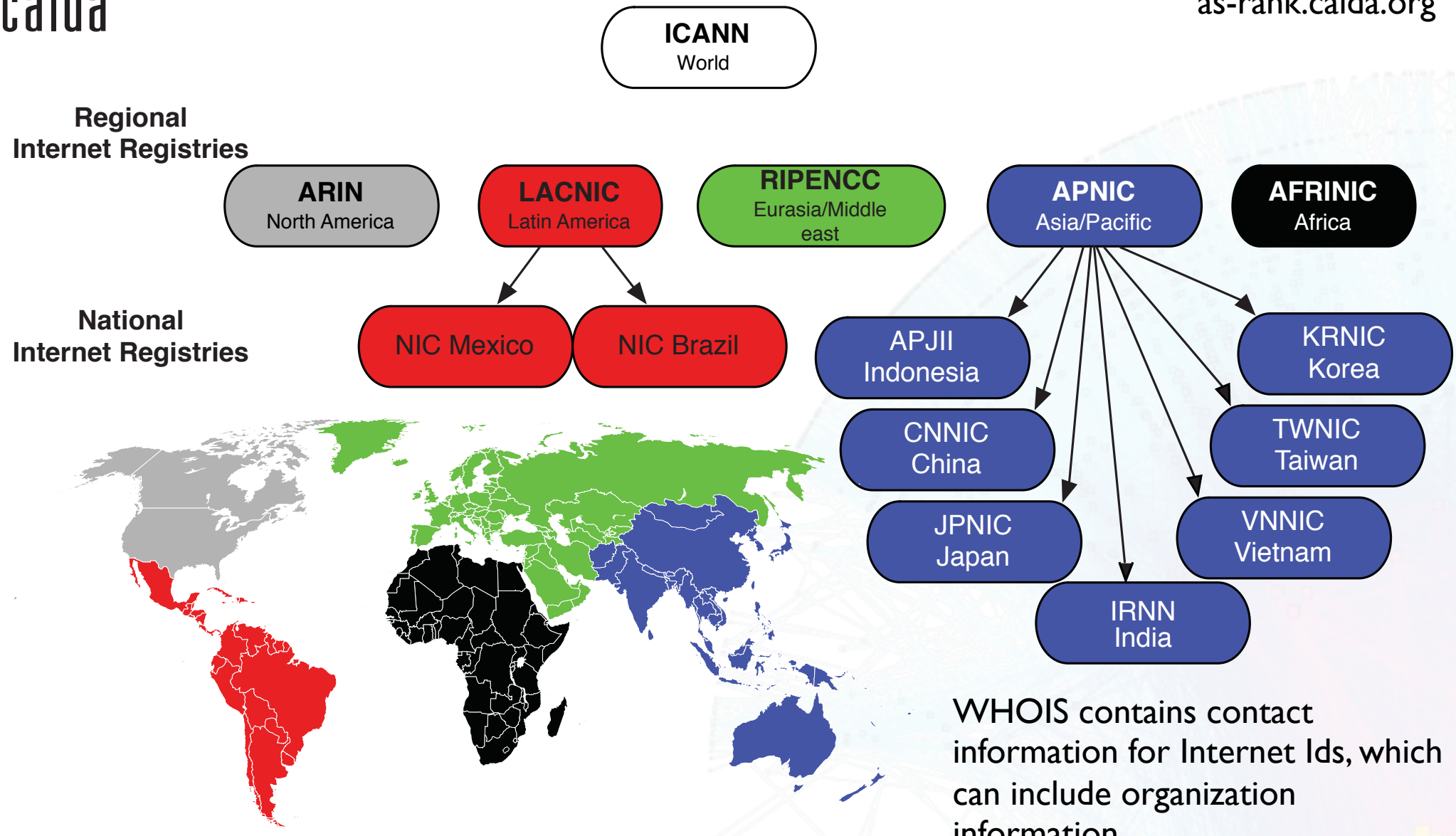
Internet Registries (WHOIS)

as-rank.caida.org

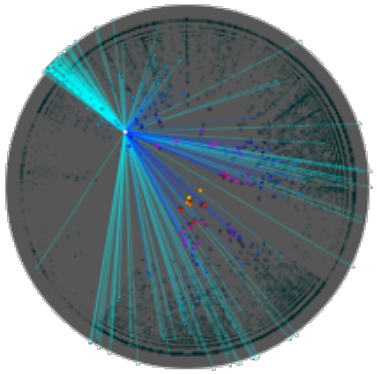


WHOIS contains contact information for Internet Ids, which can include organization information.

individual AS info.

as-rank.caida.org

as-rank.caida.org/asns/2497



AS number	2497
AS name	IIJ
organization	Internet Initiative Japan Inc.
country	Japan
customer cone	463 asn, 5496 prefix, 44357888 address
AS rank	78
AS degree	325 global, 320 transit, 2 provider, 138 peer, 185 customer

1 2 3 4 .. 9

AS Rank ▲	AS neighbors	Organization		AS customer cone ▽	number of paths	relationship
4	2914	NTT America, Inc.		24578	40748	provider
23	701	MCI Communications S...		2510	5546	provider
1	3356	Level 3 Parent, LLC		32759	49855	peer
2	1299	Telia Company AB		28902	24524	peer
5	3257	GTT Communications I...		22113	22446	peer
7	6453	TATA COMMUNICATIO...		14688	19642	peer
8	6939	Hurricane Electric LLC		14527	15898	peer
9	3491	PCCW Global, Inc.		7961	4210	peer

IIJ's AS Core

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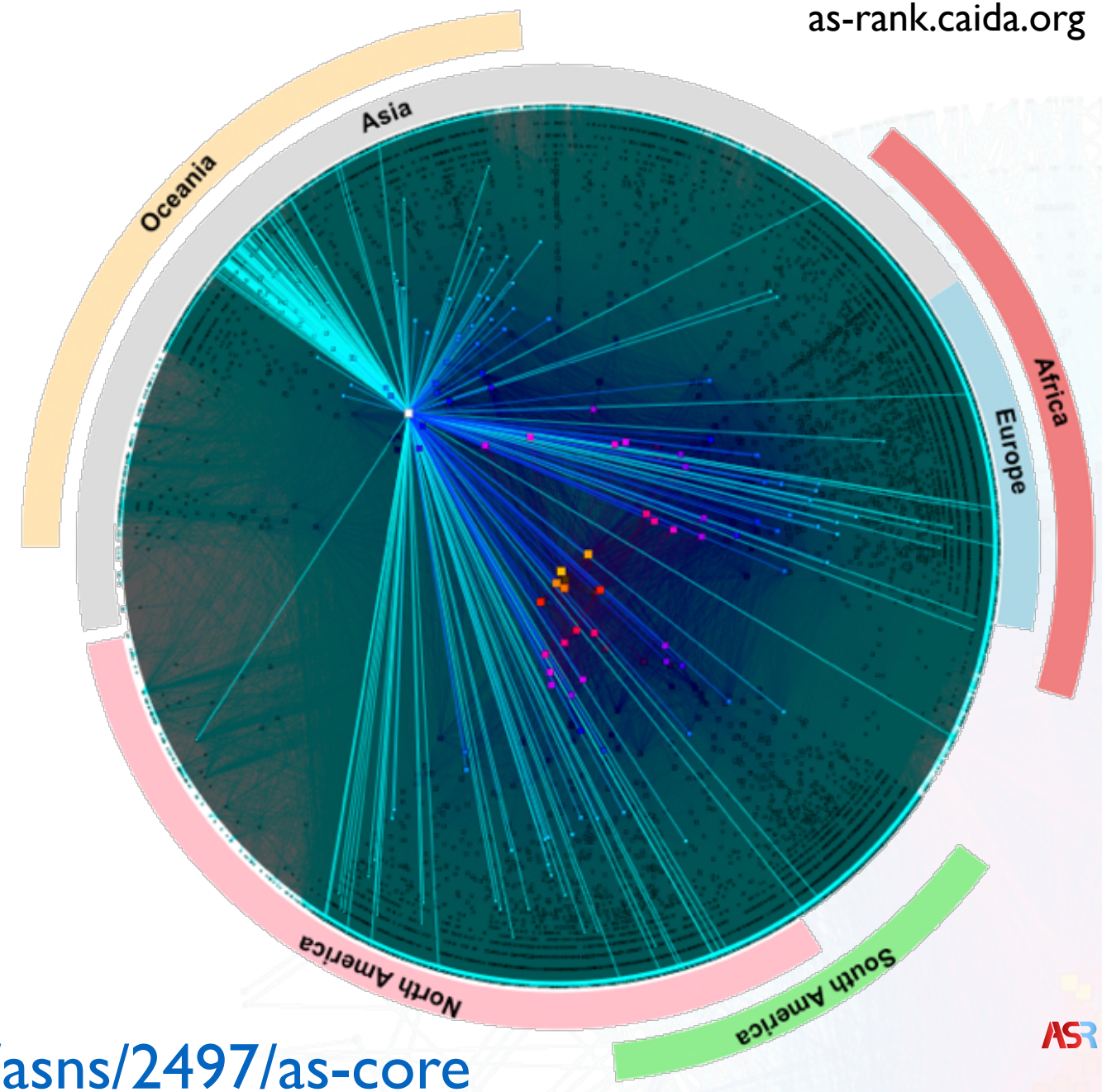
AS Core is a visualization of the ASes' geographic location and customer cone.



as-rank.caida.org/asns/2497/as-core

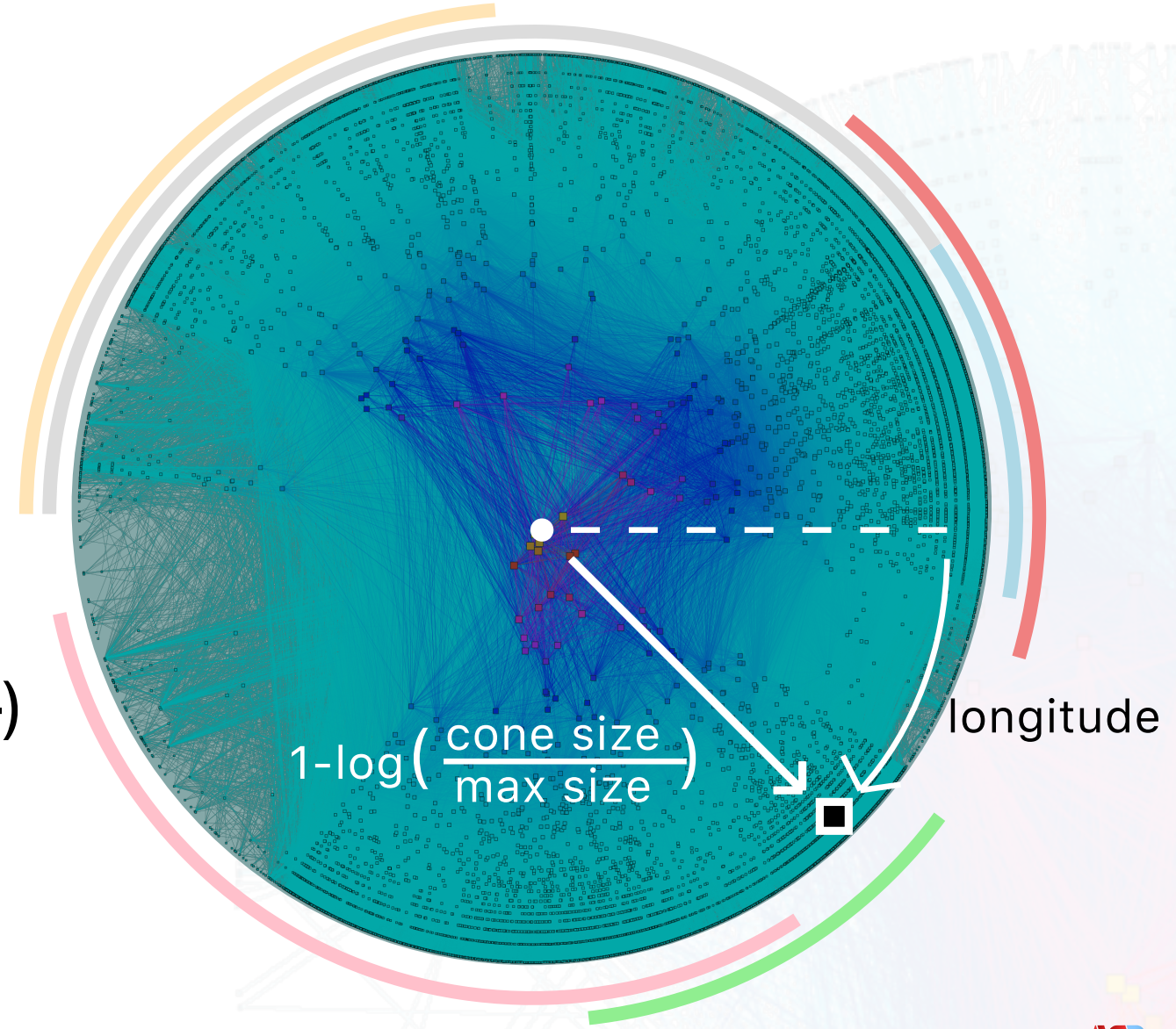
AS Core

as-rank.caida.org

AS's **angle** is set the centroid of the its BGP prefixes in Netacuity.

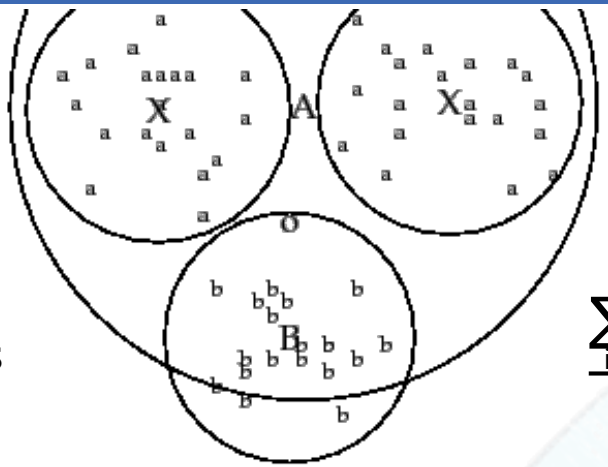
AS's **radius** is set by log of the inverse of their customer cone.

$$1 - \log\left(\frac{\text{number of ASes in cone} + 1}{\text{max. number of ASes in cone} + 1}\right)$$



geolocation to longitude

as-rank.caida.org



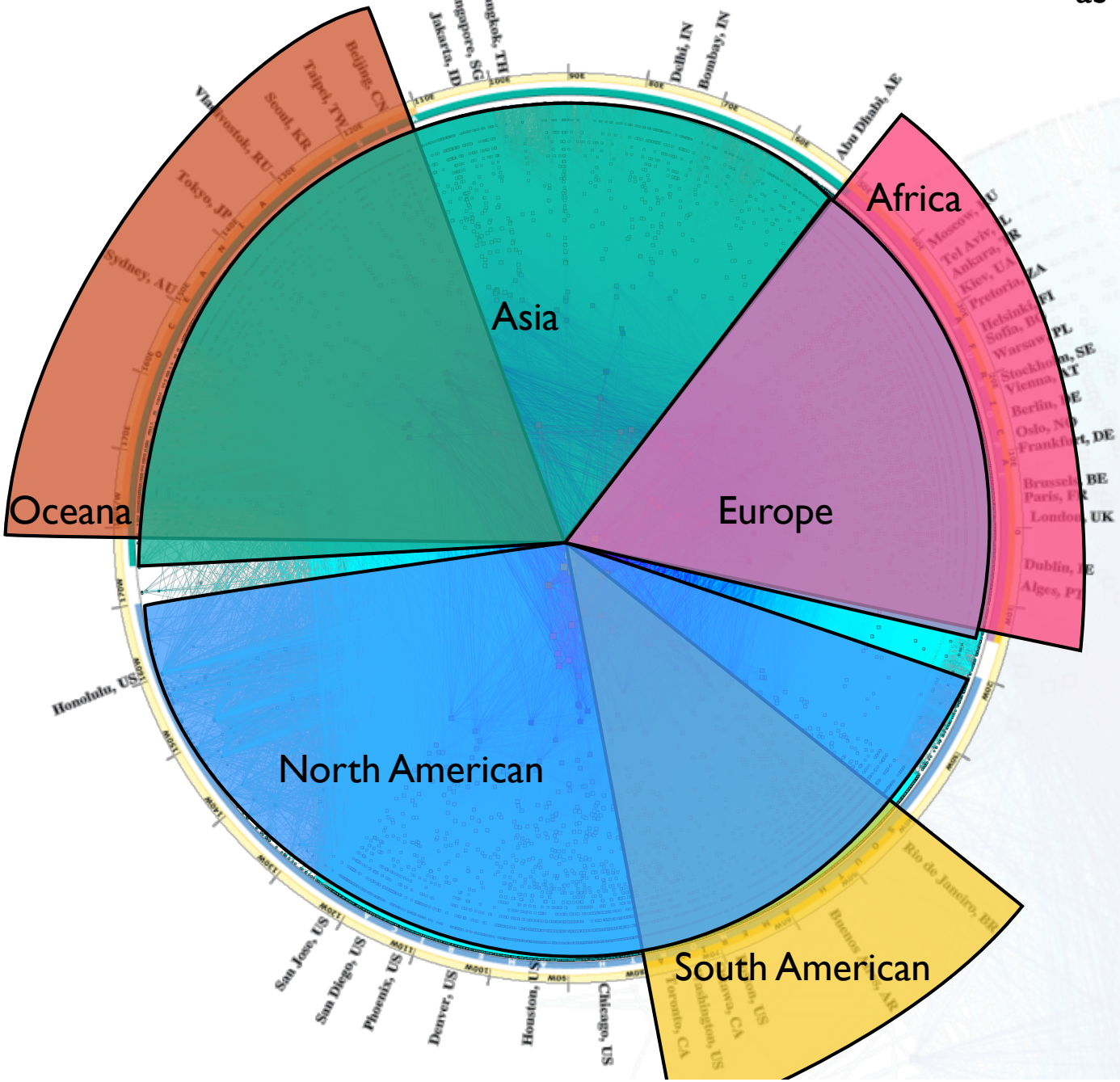
An AS's location is set to the weighted average of the locations assigned by Netacuity to the addresses it announces.

$$\frac{\sum_i block_i.longitude * block_i.size}{\sum_i block_i.size}$$

origin AS	prefix	geolocation blocks: IP block	geolocation blocks: longitude	weighted average longitude
12	5.5.1.0/24	5.5.1.0 - 5.5.1.255	-103	-103
1	10.0.0.0/16	10.0.0.0-10.0.127.255	25	37.5
		10.0.128.0-10.0.255.255	50	
43	13.5.1.0/24	13.5.1.0-13.5.1.255	-23	-23
5	9.0.1.0/24	9.0.1.0-9.0.1.255	45	45

geographic regions

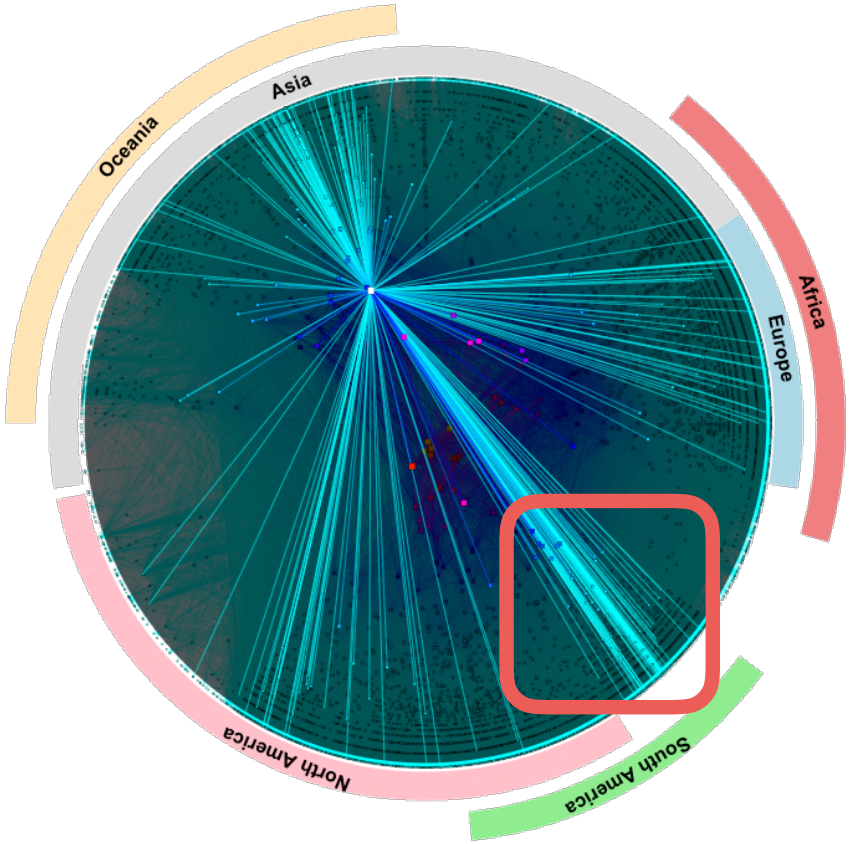
as-rank.caida.org



AS Core comparison

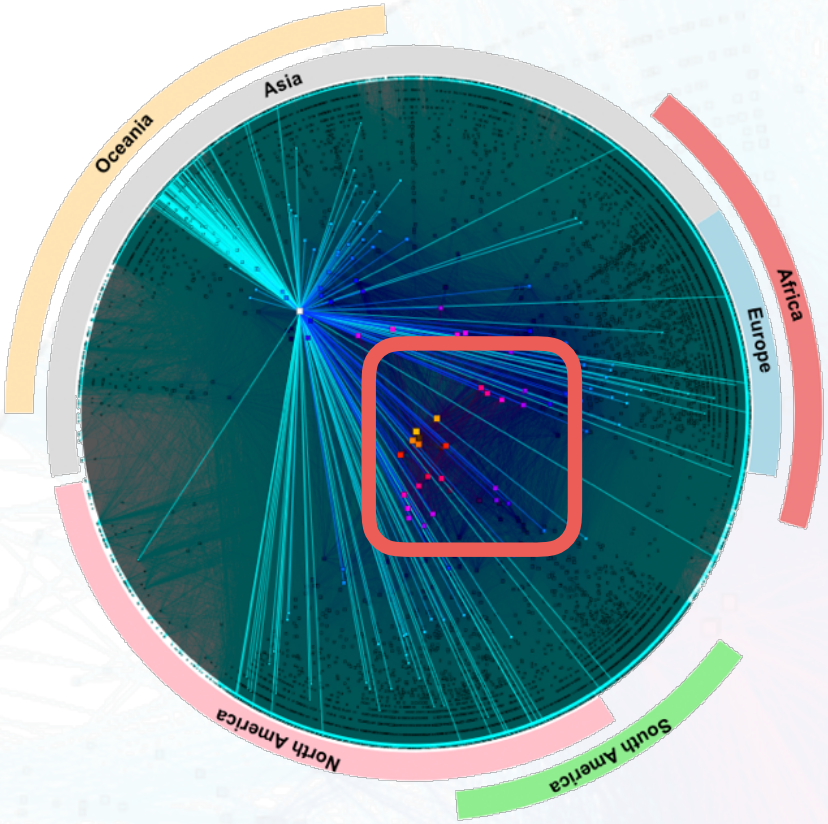
as-rank.caida.org

5809 (China Telecom Next Generation)



more South American neighbors

2497 (Internet Initiative Japan Inc)

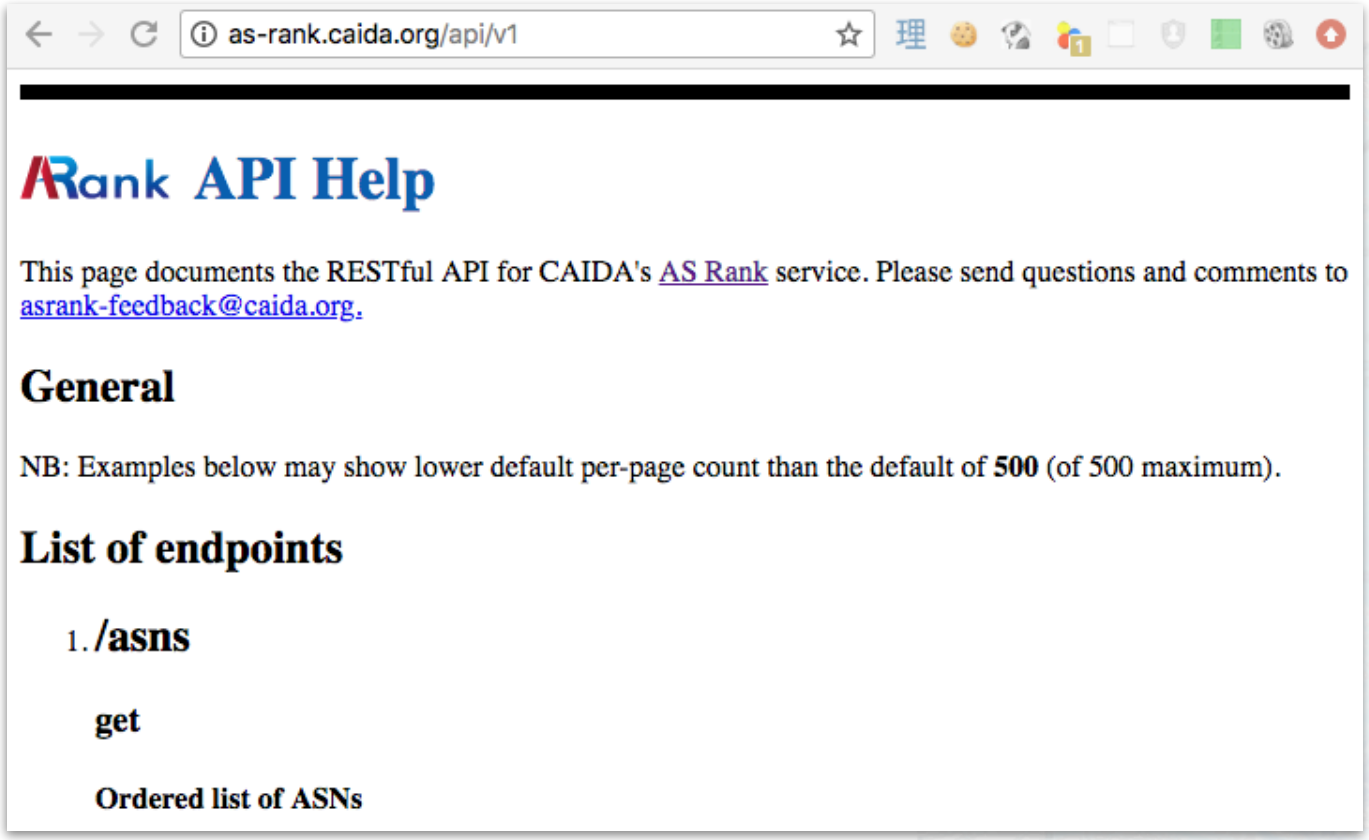


more large central neighbors

AS Rank API

as-rank.caida.org/api/v1

as-rank.caida.org/api/v1



New RESTFUL API to the AS Rank data.

general commands

as-rank.caida.org/api/v1

- all replies are in the following wrapper:

```
{
    "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)

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

  - second page (/asns?page=2)

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

  - first page (/asns?count=6)

```
{
  "total": 84741,
  "data": [ "3356", "1299", "174", "2914", "3257","6762" ]
}
```

general commands (2)

as-rank.caida.org/api/v1

- queries can be "populated"
  - unpopulated (/asns)


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


  - first page (/asns?populated=1)


```
{
  "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 information

as-rank.caida.org/api/v1

as-rank.caida.org/api/v1/asns/(\d+)

as-rank.caida.org/api/v1/asns/1


```
{
    "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." }
    }
}
```

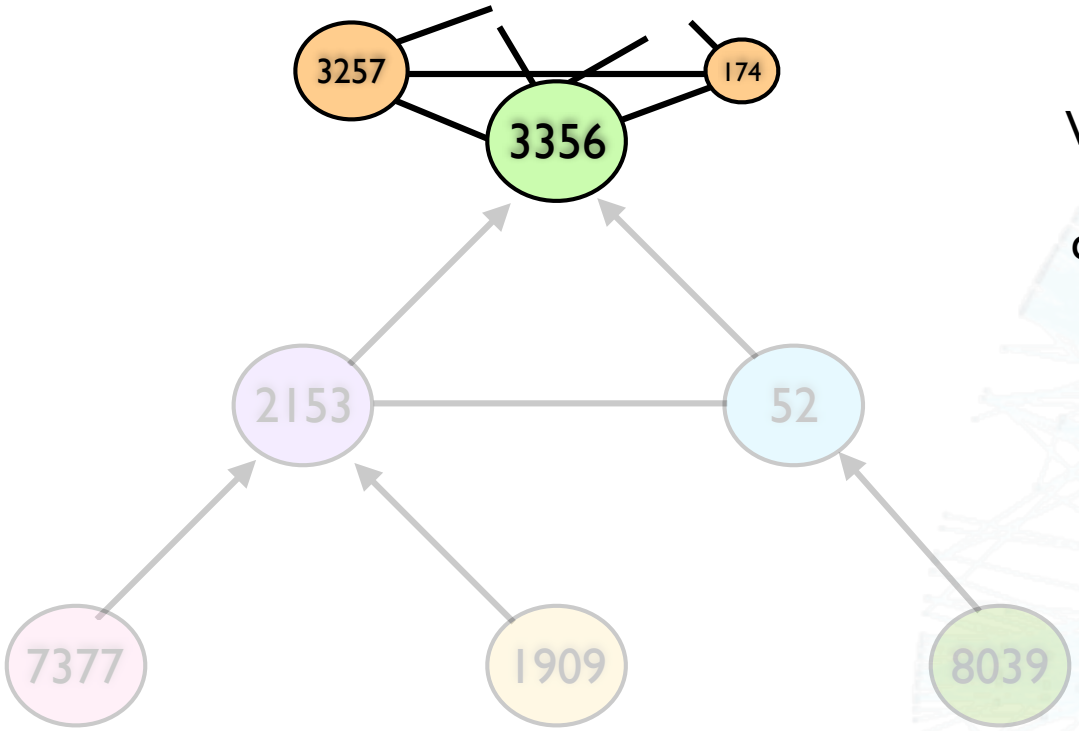

geographic

clique member

AS hierarchy (clique)

as-rank.caida.org

ASs at the top of the hierarchy are call 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.

AS information

as-rank.caida.org/api/v1

as-rank.caida.org/api/v1/asns/(\d+)/links

as-rank.caida.org/api/v1/asns/1

```
[
  {
    "relationship": "provider",
    "asn": 200612,
    "paths": 20
  },
  {
    "relationship": "provider",
    "asn": 53059,
    "paths": 5
  },
  {
    "relationship": "provider",
    "asn": 27932,
    "paths": 174
  },
  {
    "relationship": "provider",
    "asn": 27822,
    "paths": 359
  }
]
```

number of paths

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

dataset information

as-rank.caida.org/api/v1

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


```
{
   "address_family" : "AF_INET",
   "number_prefixes" : 763838,
   "number_asnes" : 60690,
   "number_addresses" : 2867192832
   "number_organizes" : 58323,
   "sources" : [
      { "date" : "20180209", "url" : "https://www.digitalelement.com/solut
      { "name" : "Organization", "url" : "https://www.caida.org/data/as-or
      { "date" : "20180201", "url" : "http://www.caida.org/data/as-relatio
   ],
   "clique" : [ 174, 209, 286, 701, 1239, 1299, 2828, 2914, 3257, 3320, 33
   ],
   "asn_ixs" : [ "1200", "4635", "5507", "6695", "7606", "8714", "9355", "
   ],
   "asn_assigned_ranges" : [
      [ "1", "23455" ],
      [ "23457", "64495" ],
      [ "131072", "139577" ],
      [ "196608", "207259" ],
      [ "262144", "268700" ],
      [ "327680", "328703" ],
      [ "393216", "397212" ]
   ],
   "asn_reserved_ranges" : [
      [ 0, 0 ],
      [ 64496, 65535 ],
      [ 4200000000, 4294967294 ],
      [ 4294967295, 4294967295 ]
   ],
}
```


data sources and dates

list of IXP ASs

ranges of assigned ASs

ranges of ASs reserved for private use

organization information

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

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


```
{
   "org_id" : "ORG-TCA23-RIPE",
   "org_name" : "Telia Company AB",
   "country" : "EU",
   "rank" : 2,
   "org_degree_glboal" : 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
}
```

path information

coming soon

as-rank.caida.org/api/v1

as-rank.caida.org/api/v1/paths/(\d+)

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


```
{
  "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

coming soon

as-rank.caida.org/api/v1

as-rank.caida.org/api/v1/paths/(\d+)

```
{
  "path": "3356 1200 2914>23352>36352",
  "used": “3356-2914>23352>36352",
  "tags": [
    { "type": "IX", "index": 1 },
    { "type:"add", value:”-"}
  ],
   "prefixes":[
        { "monitors":[{"monitor":"rrc02","ip":10.0.0.1"}],
          "prefixes":["14.0.0.0/12","13.0.0.0/18","13.0.0.0/18"] }
   ]
},
```

- **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

path prefixes

coming soon

as-rank.caida.org/api/v1

as-rank.caida.org/api/v1/paths/(\d+)

```
{
  "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

paths filtered

as-rank.caida.org/api/v1

		tagged (1.7%)			rejected (0.07%)		
	total	IX	loop	IX/loop	reserved	unallocated	poisoned
paths	16M	95%	4.6%	0.04%	79%	15%	6%

- vast majority of paths unaffected
- most "tagged" paths were caused by IX ASs
- most "rejected" paths were caused by "reserved" ASs

filter effects

as-rank.caida.org/api/v1

	total	gained	lost	degree changed
links	268K	5.9%	1.8%	-
ASs	61K	0%	0.07%	4.6%

- larger fraction of links effected then ASs
- more links gained as links formed across, rather then with, IX

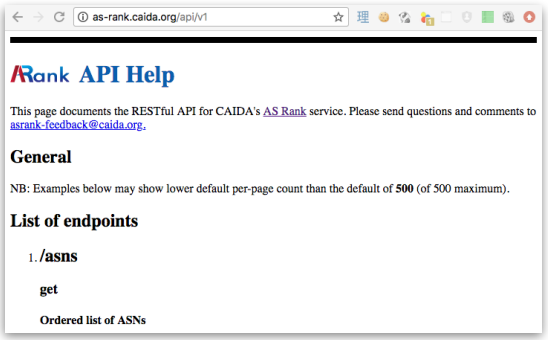
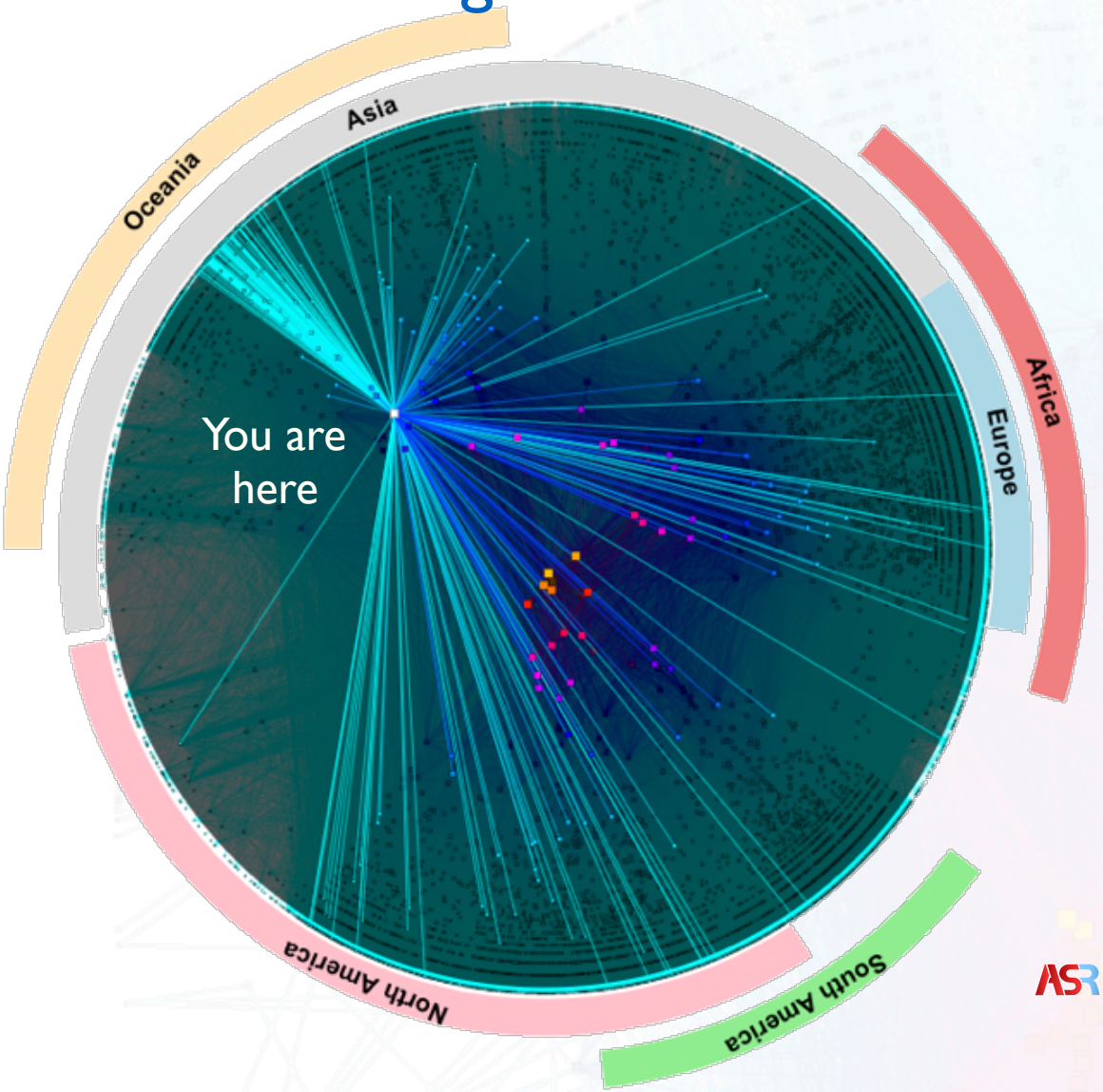
questions

www.caida.org/data/as-rank

as-rank.caida.org

AS Rank ▲	AS Number	Organization		cone size ▽
1	3356	Level 3 Parent, LLC		32759
2	1299	Telia Company AB		28902
3	174	Cogent Communications		26664
4	2914	NTT America, Inc.		24578
5	3257	GTT Communications Inc.		22113
6	6762	TELECOM ITALIA SPARKLE S....		15131
7	6453	TATA COMMUNICATIONS (A...		14688
8	6939	Hurricane Electric LLC		14527
9	3491	PCCW Global, Inc.		7961
10	3549	Level 3 Parent, LLC		6680
11	1273	Vodafone Group PLC		6406
12	6461	Zayo Bandwidth		6145
13	9002	RETN Limited		5703
14	209	Qwest Communications Com...		4588
15	12956	Telefonica International Whole...		4253

as-rank.caida.org/api/v1



as-rank.caida.org/asns/2497/as-core