

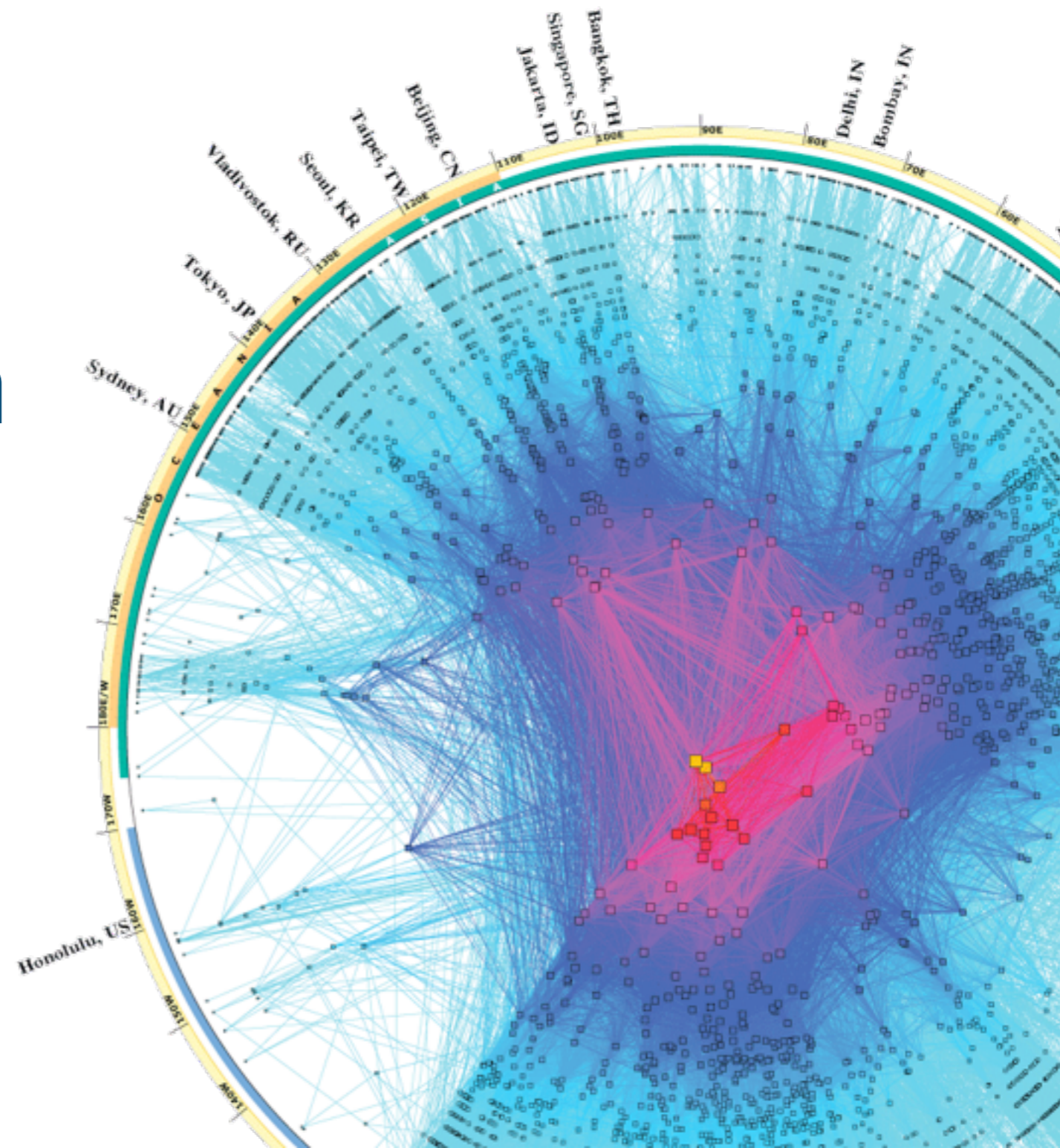
AS Rank Reborn

Bradley Huffaker

CAIDA

SDSC/UCSD

syslunch
7 March 2018





what is AS Rank?

as-rank.caida.org

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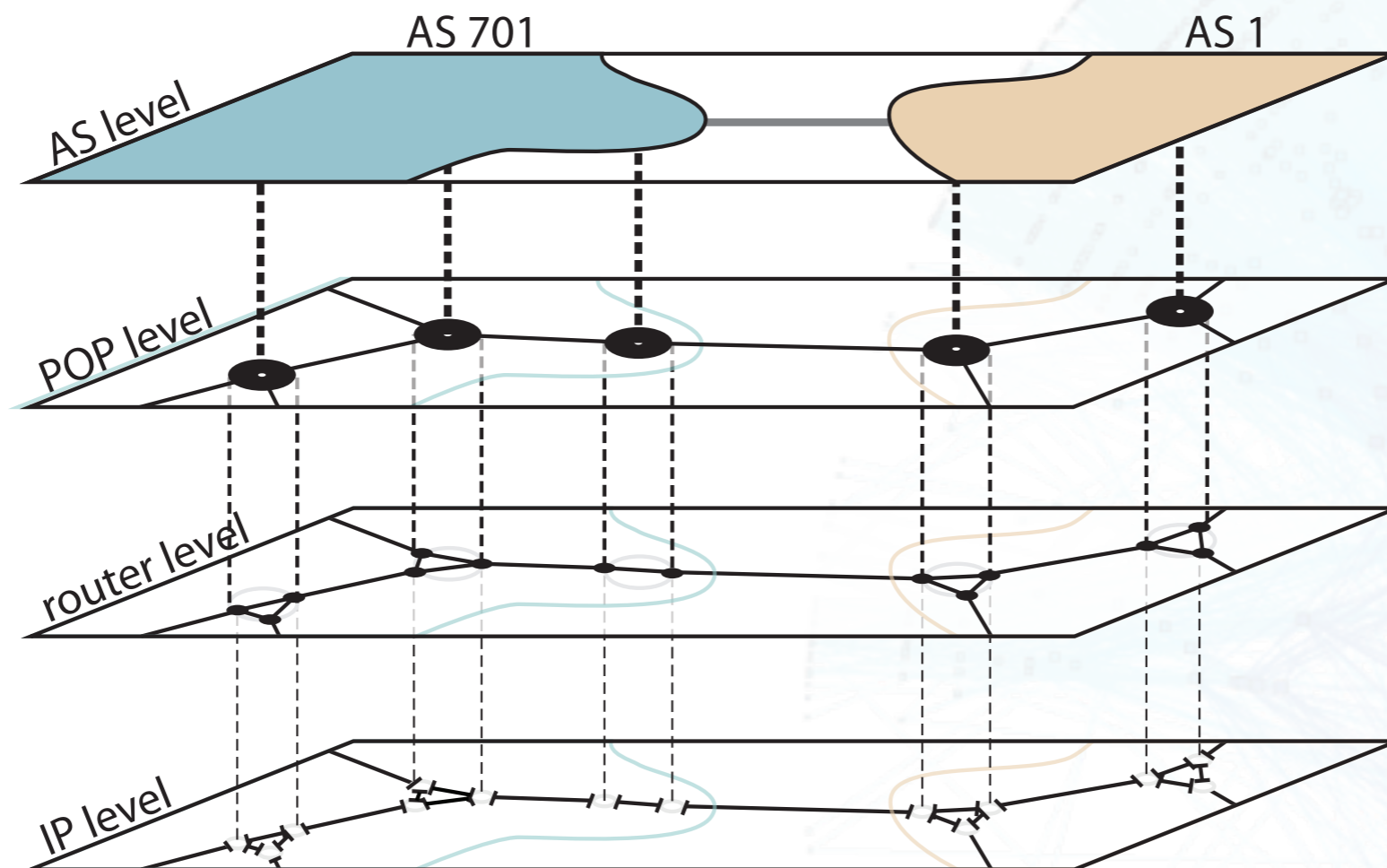
AS rank	AS number	organization	ASNs	number of addresses	customer count			transit ASN degree	
					prefixes	ASNs	percentages of all addresses		
1	3356	Level 3 Communications, Inc.	33340	860864258	736561	54.93%	30.07%	32.28%	4976
2	1299	Telia Company AB	27902	650416384	250700	44.99%	29.60%	30.02%	1004
3	174	Cogent Communications	23394	787148800	189920	39.56%	27.46%	24.86%	6862
4	2914	NTT America, Inc.	23153	731699200	225547	38.15%	25.52%	29.53%	1714
5	3257	GTT Communications Inc.	21724	589743872	211014	35.8%	20.57%	27.7%	1576
6	6782	TELECOM ITALIA SPARKLE S...	16026	320064256	140636	26.4%	11.16%	18.41%	482
7	6939	Huawei Electric, Inc.	14952	356878048	127693	24.64%	12.44%	16.72%	7061
8	6450	TATA COMMUNICATIONS (AM...	14147	590101760	166529	23.21%	20.50%	21.0%	724
9	3481	PCCW Global, Inc.	7640	172164112	83076	12.42%	6%	10.88%	680
10	3519	Level 3 Communications, Inc.	6732	57746132	41112	11.09%	2.01%	5.78%	2636
11	1279	Vodafone Group PLC	6484	176670032	55347	10.05%	6.19%	6.98%	372
12	8002	BTN Limited	5226	27676684	25231	8.61%	0.97%	3.3%	1381
13	6481	Zayo Bandwidth	4819	110520320	32945	7.94%	3.85%	4.31%	1718
14	209	Qwest Communications Comp...	4745	289974338	46511	7.82%	10.08%	6.09%	1888
15	12558	Telefonica International Whole...	4422	124056672	35285	7.29%	4.36%	4.75%	304
16	3320	Deutsche Telekom AG	4014	176298196	24182	6.61%	6.15%	3.17%	581

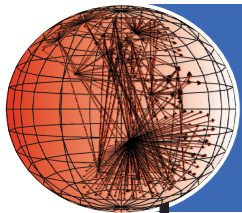
A ranking of the largest Internet AS by the number of direct and indirect customer ASs.

“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

caida

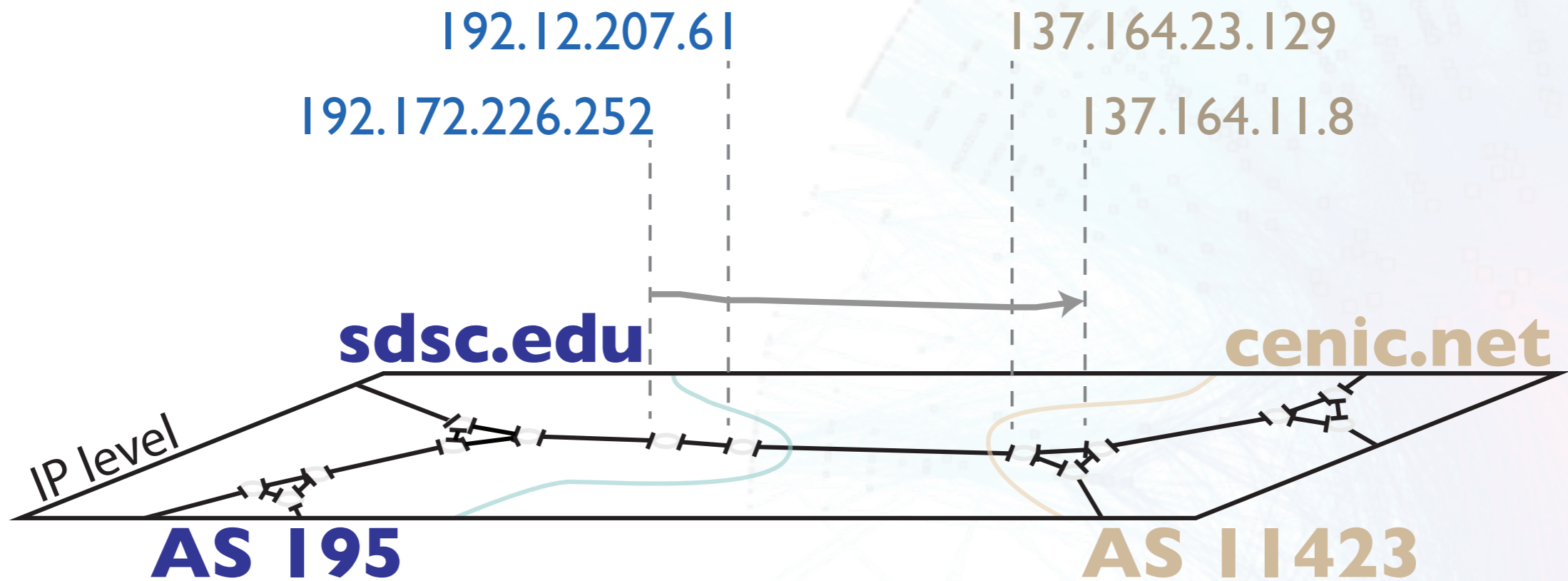
as-rank.caida.org

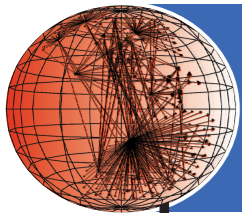
IP level path (traceroute)

```

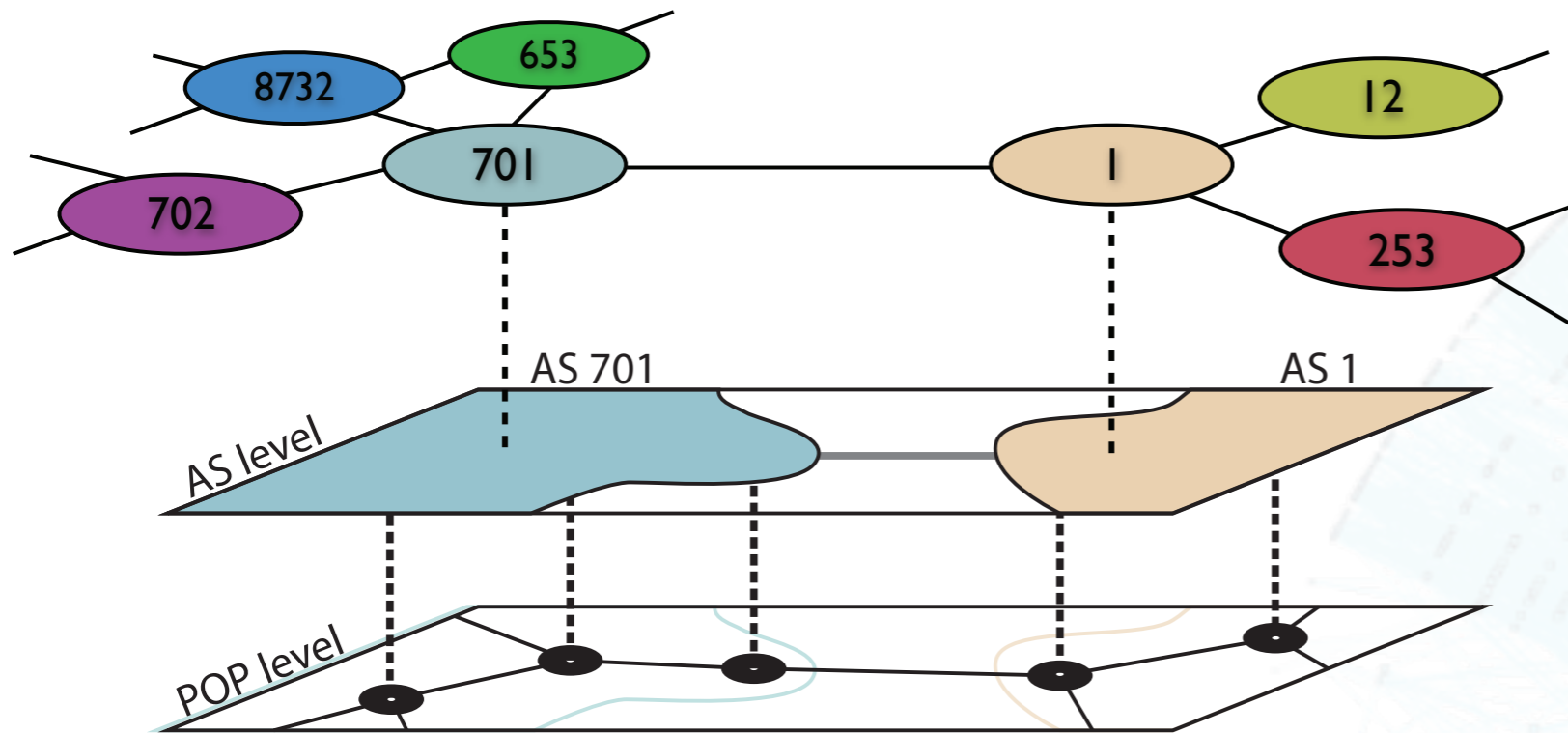
traceroute to 137.164.11.8 (137.164.11.8), 64 hops max, 52 byte packets
 1  sdsc-rtr (192.172.226.252) 13.079 ms 0.285 ms 15.696 ms
 2  mx0-ae7--thor-ae0.sdsc.edu ( 192.12.207.61) 0.399 ms 0.398 ms 0.361 ms
 3  dc-sdg-agg4--sdsc-1.cenic.net ( 137.164.23.129) 0.901 ms 0.892 ms 0.917 ms
 4  dc-tus-3-agg4-100ge.cenic.net ( 137.164.11.8) 2.535 ms 2.503 ms 2.592 ms

```



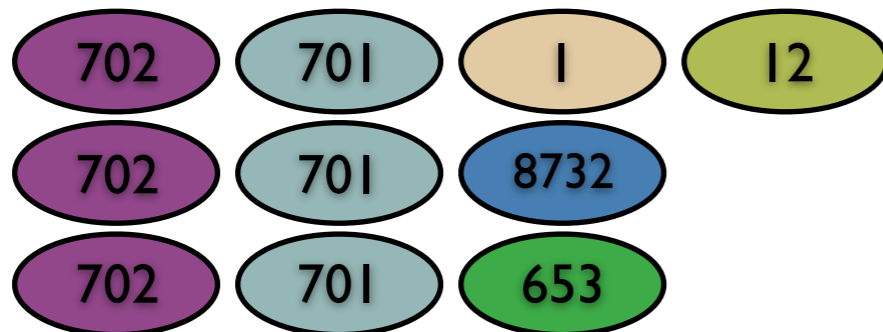


AS level graph

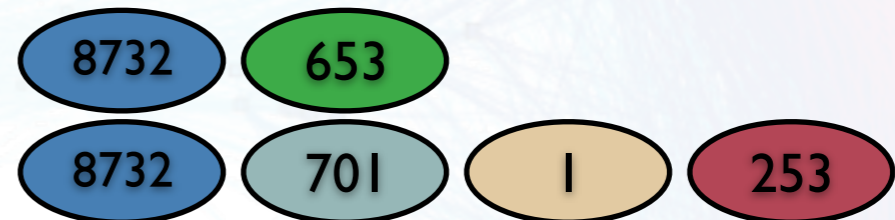


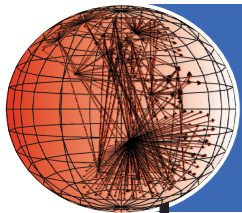
Build the graph from observed AS paths.

702 observed paths



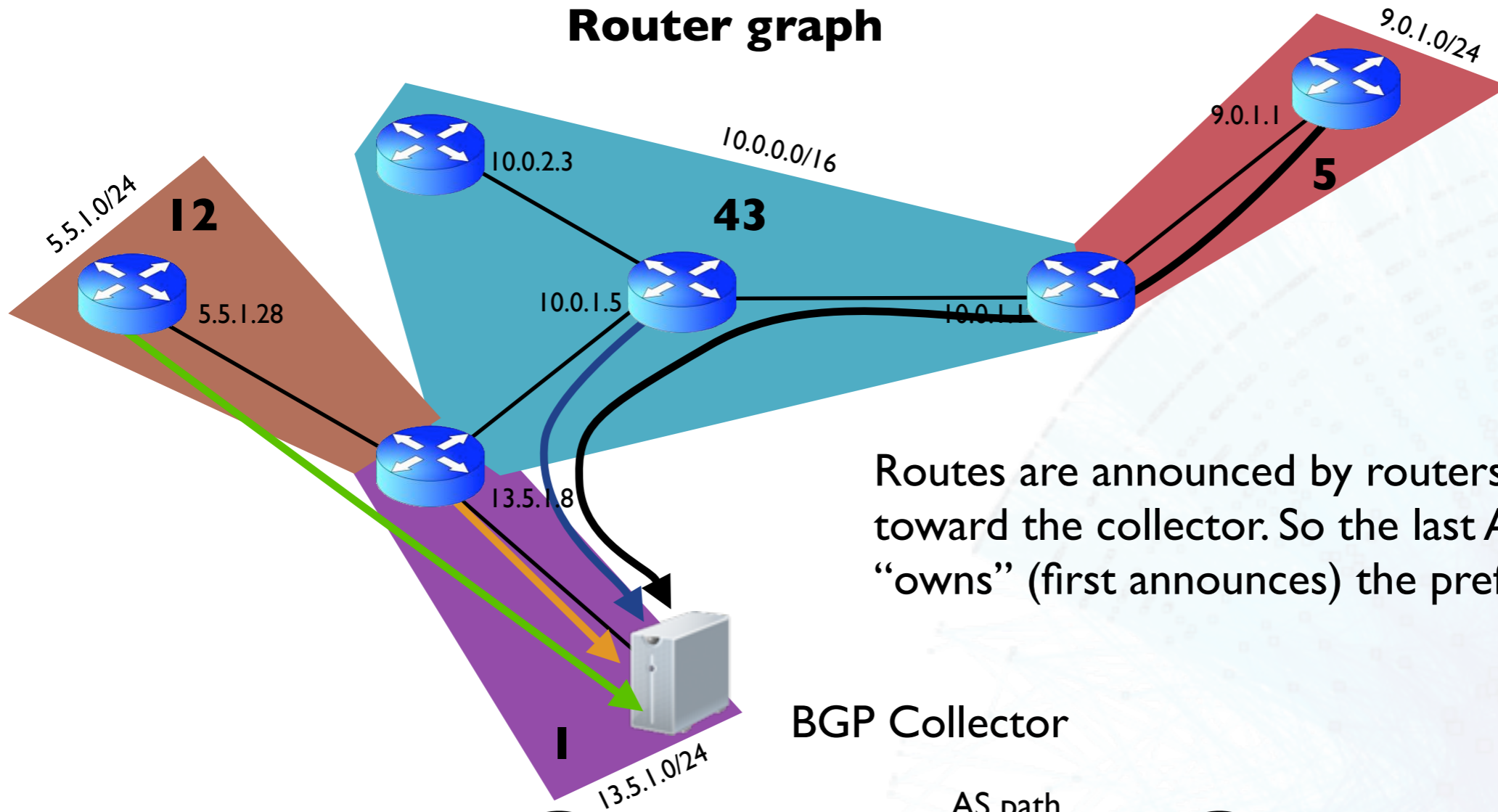
8732 observed paths





BGP Routes

Router graph



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

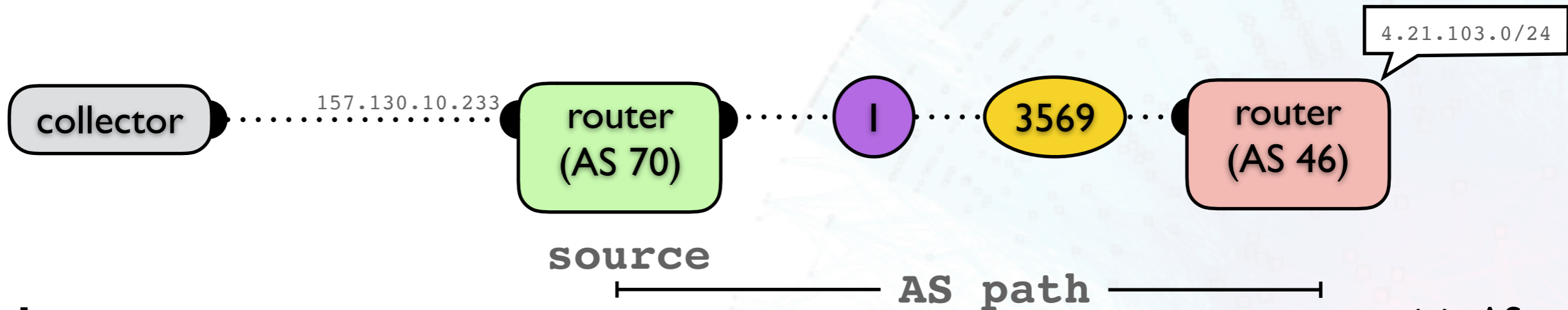


BGP Collectors

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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

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		
								<u>source IP</u>		<u>source AS</u>		<u>prefix</u>				<u>AS path</u>		



BGP Stream

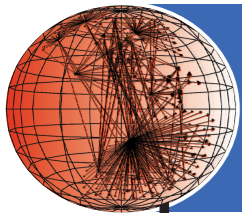
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BGP  **TREAM**

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.



degree types

caida

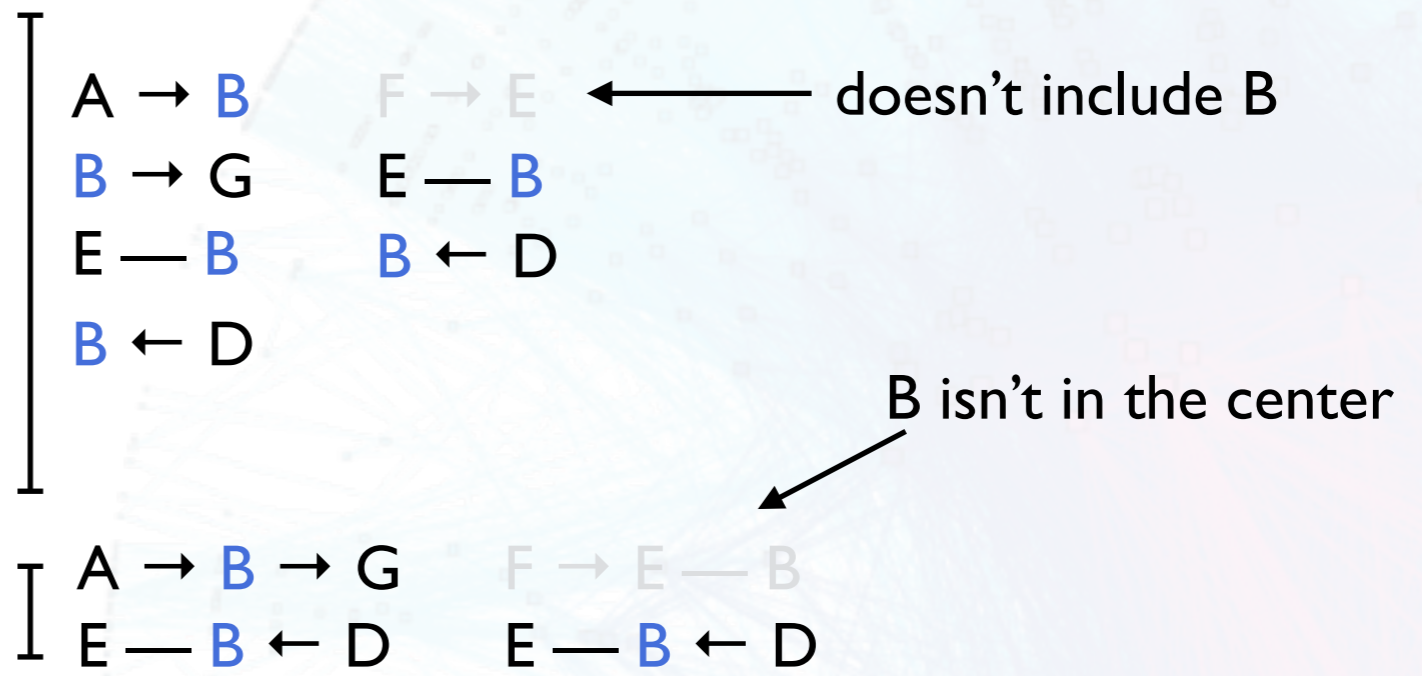
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Based on the set of AS paths, different types of degrees may be inferred.

paths: $A \rightarrow B \rightarrow G$
 $B \rightarrow C$
 $E - B \leftarrow D$
 $F \rightarrow E - B \leftarrow D$

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





transit degree

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AS Rank About Search Contact Data

ASN name or number

sort: rank, transit degree, customer conc asns, customer conc prefixes, customer conc addresses
1 2 3 4 .. 1517

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16	3320	Deutsche Telekom AG	4014	176298496	24182	6.61%	6.15%	3.17%	581

2018/02/01 AS Rank IPv4 Support for this work is provided by the U.S. Department of Homeland Security's Science and Technology Directorate (Project NSAC01-08-C-0009), the National Science Foundation (number: laboratory for Empirical Research Science Project CNS-0969642), and Clute's University Research Program.

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

AS Relationships (simplified)

provider

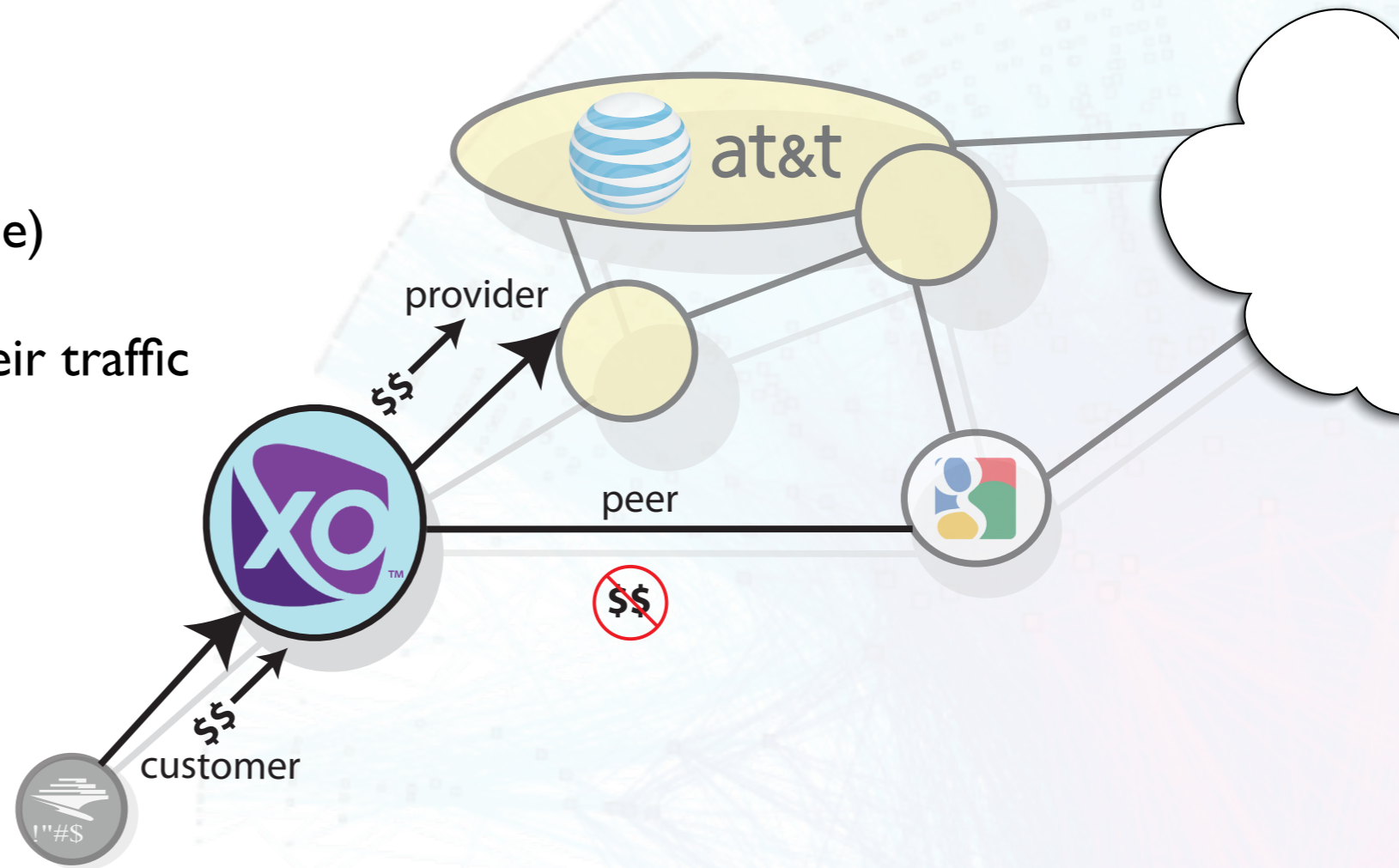
- you pay them to transit your traffic
(XO pays AT&T)

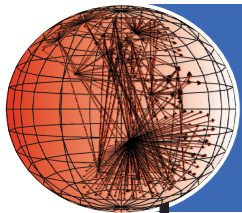
peer

- unpaid exchange of traffic
(between XO and Google)

customer

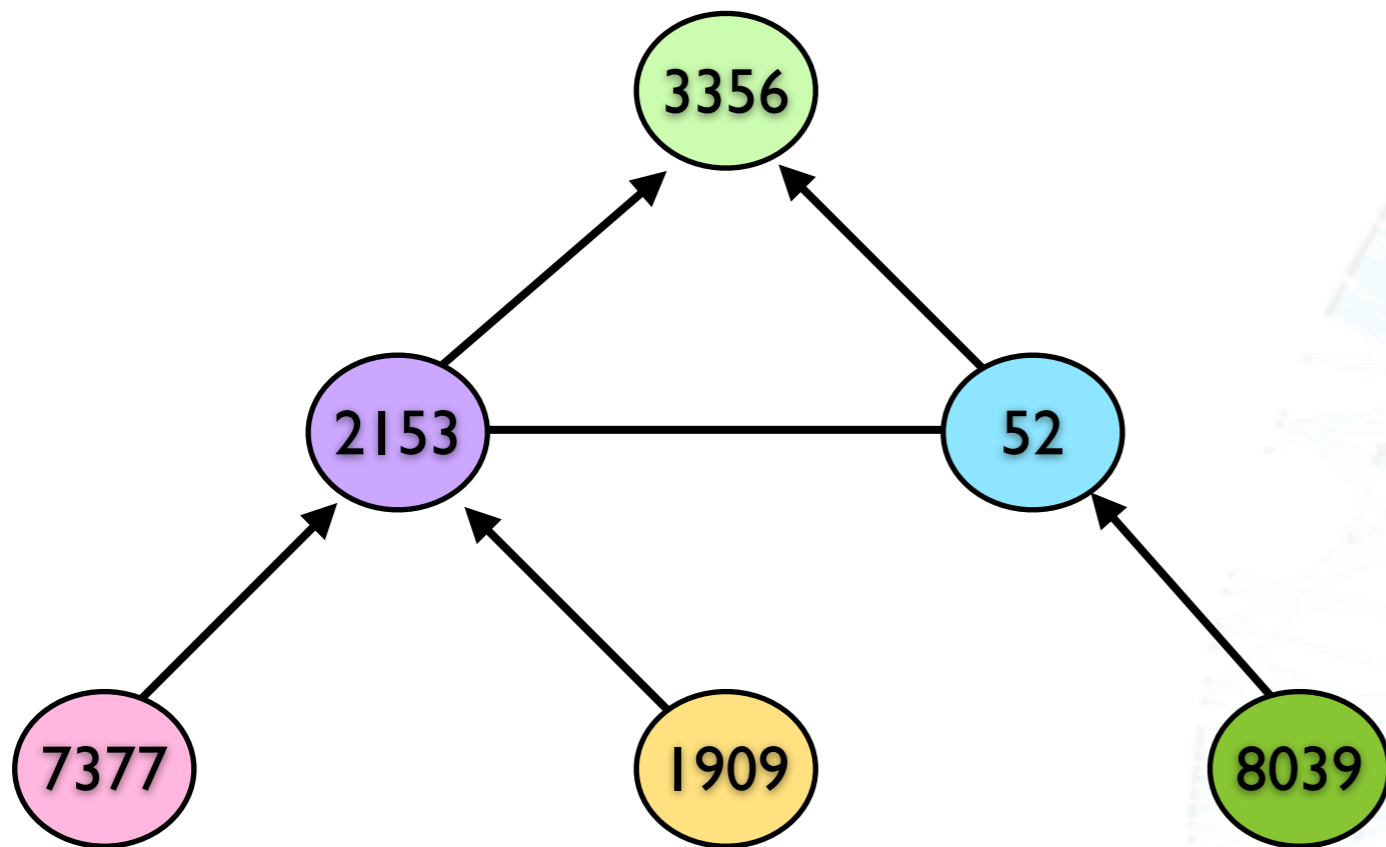
- they pay you to transit their traffic
(UCSD pays XO)





AS hierarchy

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

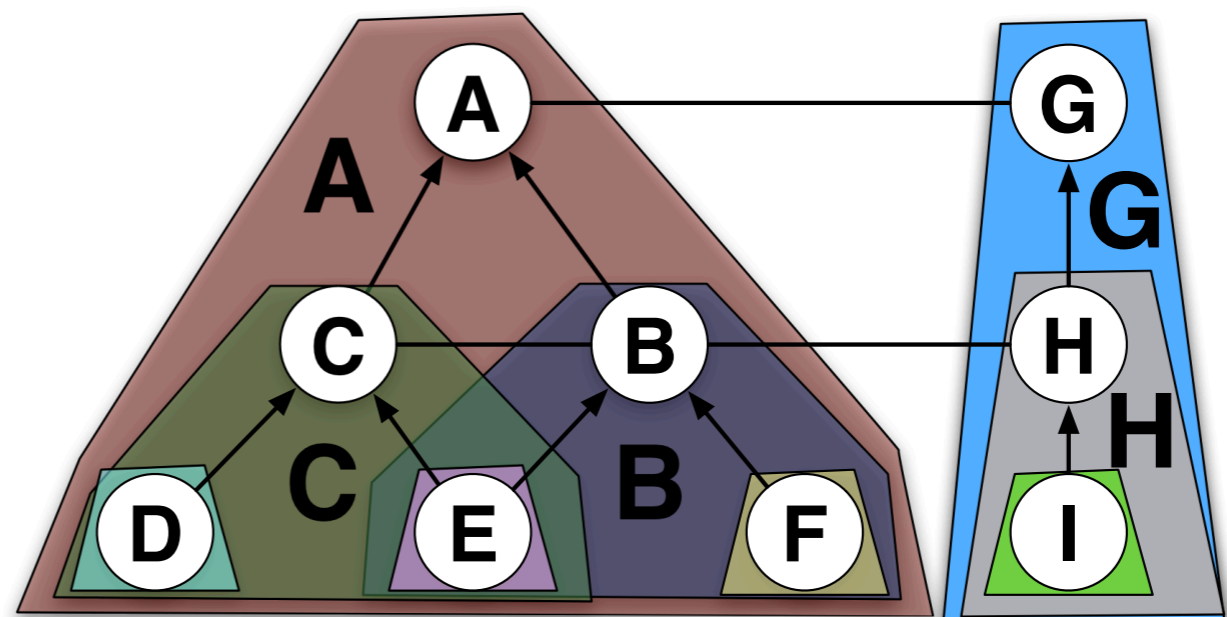


customer $\xrightarrow{\text{\$ \$}}$ **provider**
customer pays provider for transit

peer $\xrightarrow{\text{\$ \$}}$ **peer**
peers do not pay to accept each other's traffic

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

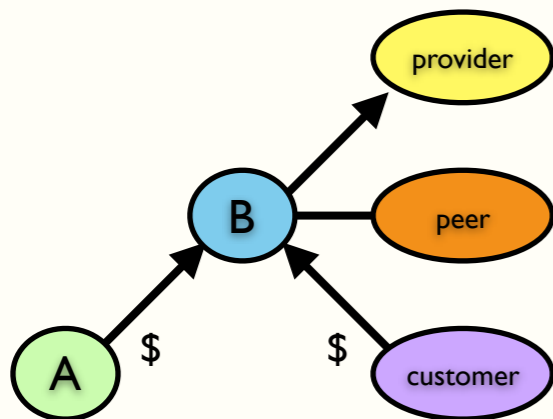


Customer Cones

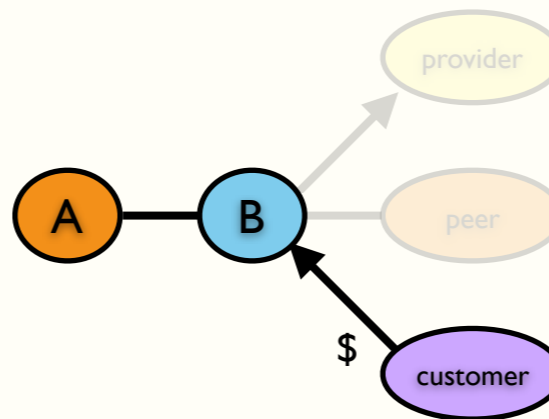
ISPs only transit traffic if at least one side is paying for it. Customer cones are therefore inferred only from routes announced to peers and providers.

A's view of B

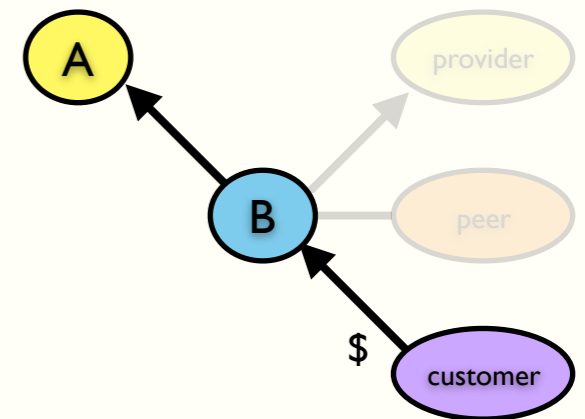
B provider full transit



B peer customers only



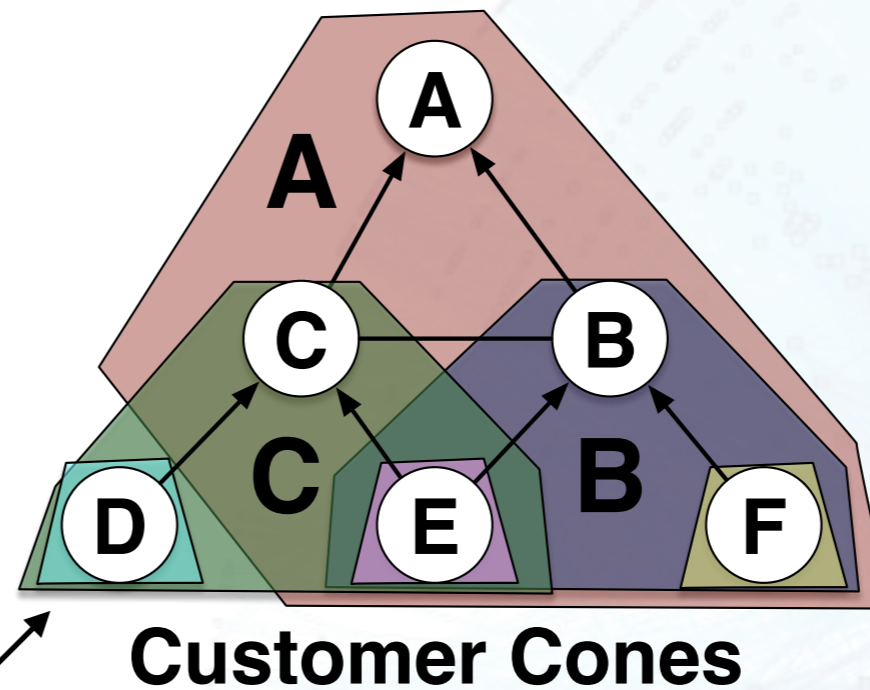
B provider customers only



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

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

AS	size
A	5
B	3
D	1



D is not included in A's cone



AS customer cone size

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AS Rank About Search Contact Data

ASN name or number search go to

sort: rank, transit degree, customer cone asns, customer cone prefixes, customer cone addresses
1 2 3 4 ... 1517

AS rank	AS number	organization	customer cone						transit ASN degree
			ASNs	number of addresses	prefixes	ASNs	percentages of all addresses	prefixes	
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2018/02/01 AS Rank IPv4

Support for this work is provided by the U.S. Department of Homeland Security's Science and Technology Directorate (Project N92001-09-C-0009), the National Science Foundation (number 1145944), and the University of Pennsylvania's Center for Applied Research in Science (Project 15-0169942), and Clute's University Research Program.

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



AS customer cone size

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AS Rank About Search Contact Data

ASN name or number

sort: rank, transit degree, customer cone asns, customer cone prefixes, customer cone addresses
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Also calculate the customer cone in terms of BGP prefixes, using the same methodology.



AS customer cone size

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AS Rank About Search Contact Data

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AS customer cone size

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AS Rank About Search Contact Data

ASN name or number search go to

sort: rank, transit degree, customer cone asns, customer cone prefixes, customer cone addresses
1 2 3 4 .. 1517

sort order customer cone

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13	6461	Zayo Bandwidth	4919	110520320	32945	7.94%	3.85%	4.31%	1718
14	209	Qwest Communications Comp...	4745	288974336	48511	7.82%	10.08%	6.09%	1888
15	12556	Telefonica International Wholes...	4422	124956672	35285	7.29%	4.36%	4.75%	304
16	3320	Deutsche Telekom AG	4014	176298496	24182	6.61%	6.15%	3.17%	581

2018/02/01 AS Rank IPv4

Support for this work is provided by the U.S. Department of Homeland Security's Science and Technology Directorate (Project NS2001-08-C-0009), the National Science Foundation (number: 1445434), and CluMx University Research Program.

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

AS Rank About Search Contact Data

ASN name or number search go to

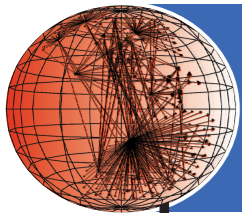
sort: rank, transit degree, customer conc asns, customer conc prefixes, customer conc addresses
1 2 3 4 ... 1517

AS rank	AS number	organization	ASNs	number of addresses	customer conc			transit ASN degree	
					prefixes	percentages of all ASNs	percentages of all addresses		
1	3356	Level 3 Communications, Inc.	33340	860864258	746561	54.93%	30.07%	32.28%	4976
2	1296	Telia Company AB	27302	650416384	256700	44.99%	29.60%	33.62%	1064
3	174	Cogent Communications	22394	787148800	189920	39.66%	27.46%	24.86%	6362
4	2914	NTT America, Inc.	23153	731699200	225547	38.35%	25.52%	29.53%	1714
5	3257	GTT Communications Inc.	21724	589743872	211614	35.8%	20.57%	27.7%	1576
6	6762	TELECOM ITALIA SPARKLE S...	16026	320064256	140636	26.4%	11.16%	18.41%	482
7	6939	Hurricane Electric, Inc.	14952	356878048	127693	24.64%	12.44%	16.72%	7061
8	6453	TATA COMMUNICATIONS (AM...	14147	590101760	166629	23.31%	20.50%	21.0%	724
9	3491	PCCW Global, Inc.	7640	172164112	83076	12.42%	6%	10.88%	680
10	3519	Level 3 Communications, Inc.	6732	57746132	41112	11.09%	2.01%	5.78%	2536
11	1273	Virginian Group PLC	6464	175970032	55347	10.65%	6.13%	6.58%	372
12	0002	IBETN Limited	5226	27676688	25231	8.61%	0.97%	3.3%	1381
13	6461	Zayo Bandwidth	4919	110520320	32945	7.94%	3.85%	4.31%	1718
14	209	Qwest Communications Comp...	4745	288974336	48511	7.82%	10.08%	6.09%	1888
15	12356	Telefonica International Wholes...	4422	124956672	35285	7.29%	4.36%	4.75%	304
16	3320	Deutsche Telekom AG	4014	176298496	24182	6.61%	6.15%	3.17%	581

2018/02/01 AS Rank IPv4

Support for this work is provided by the U.S. Department of Homeland Security's Science and Technology Directorate (Project NSAC01-08-C-0009), the National Science Foundation (number: 1445434), and Clute's University Research Program.

Organization is parsed from the WHOIS database.

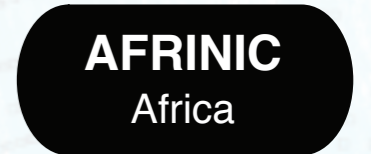


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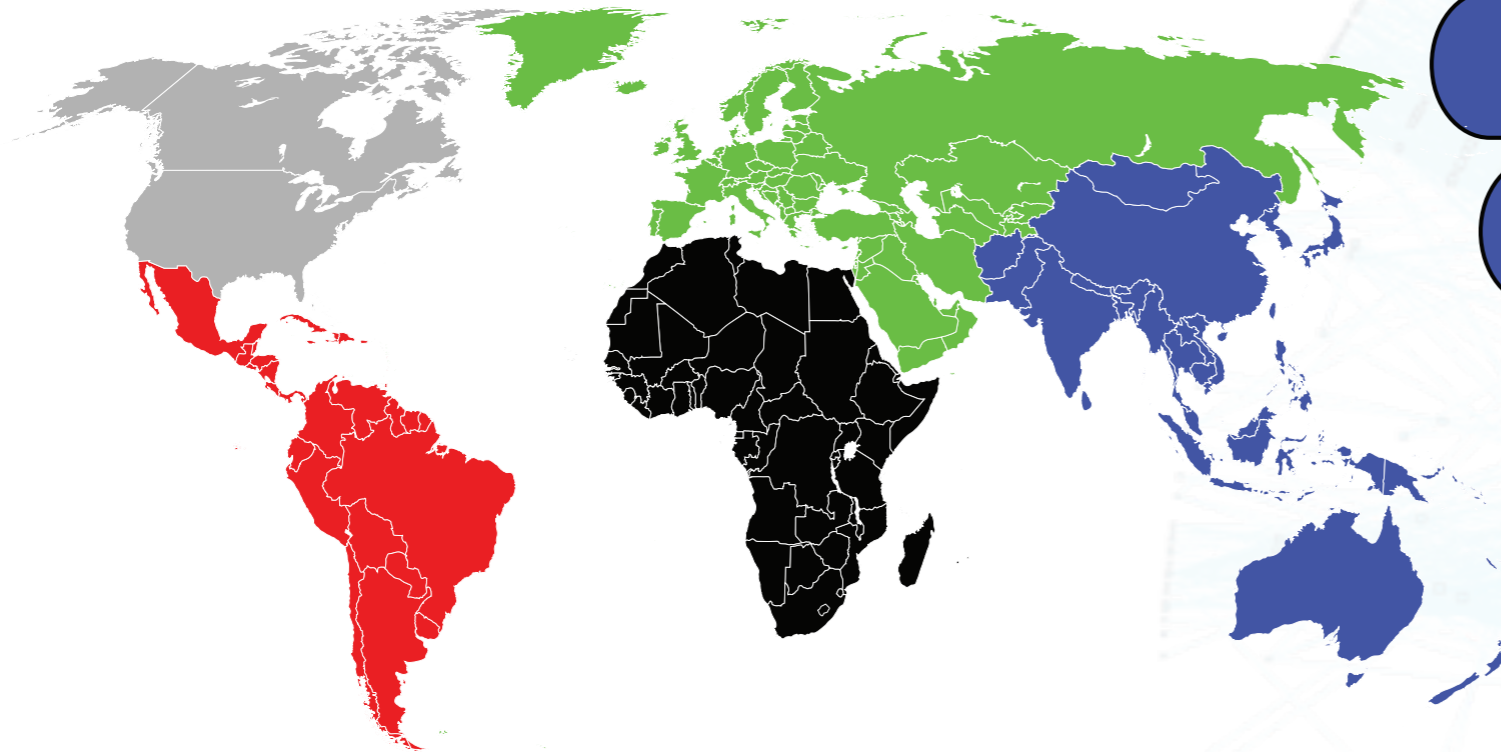
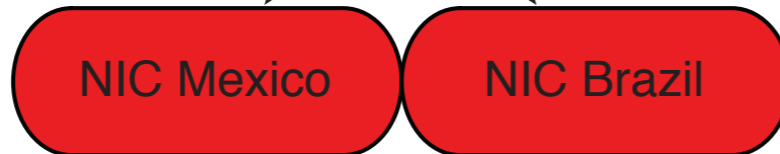
Internet Registries (WHOIS)

as-rank.caida.org

Regional Internet Registries



National Internet Registries



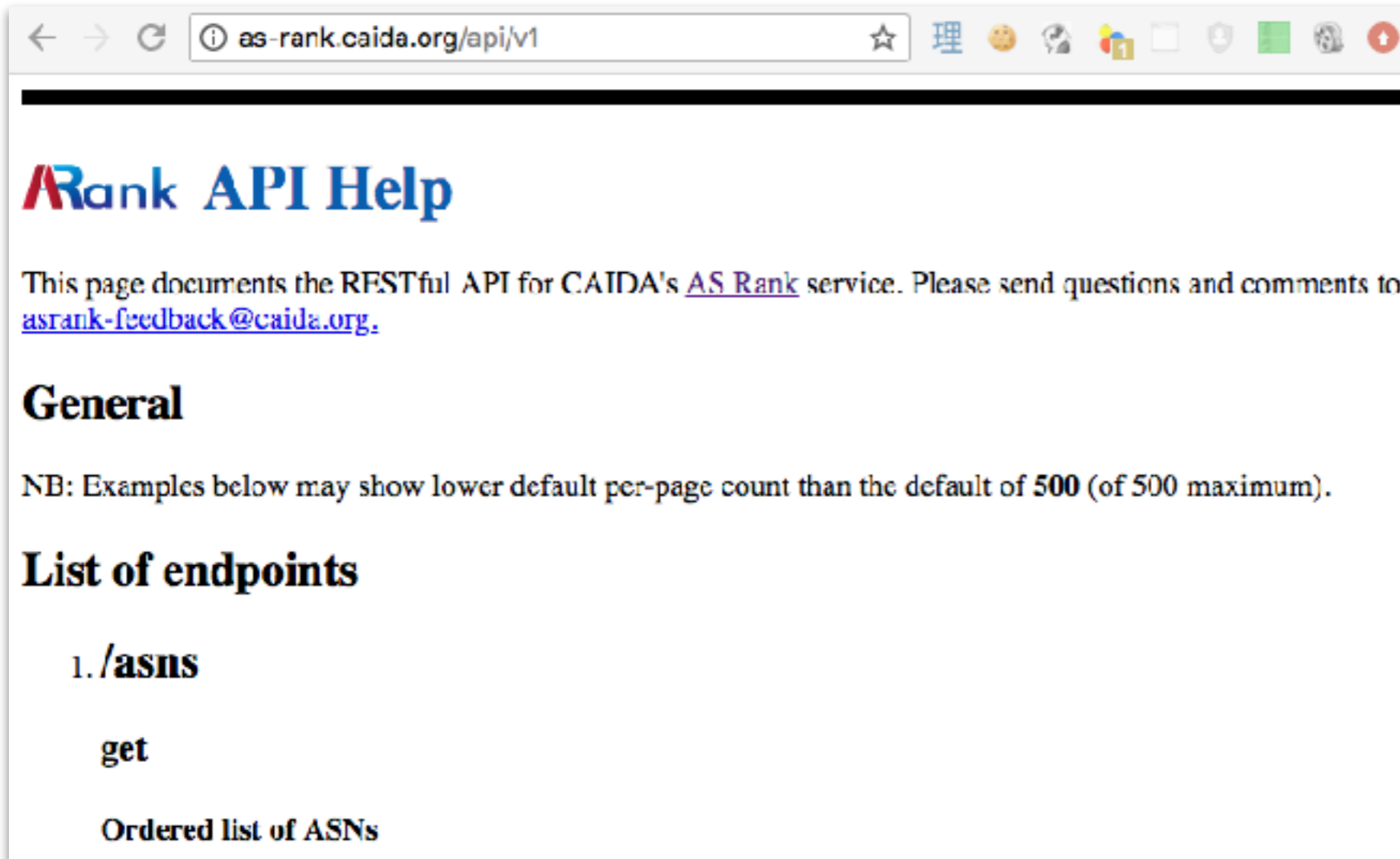
WHOIS contains contact information for Internet Ids, which can include organization information.



AS Rank API new!

as-rank.caida.org/api/v1

as-rank.caida.org/api/v1



Rank API Help

This page documents the RESTful API for CAIDA's [AS Rank](#) service. Please send questions and comments to asrank-feedback@caida.org.

General

NB: Examples below may show lower default per-page count than the default of **500** (of 500 maximum).

List of endpoints

1. **/asns**
get
Ordered list of ASNs

New RESTFUL API to the AS Rank data.

- 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

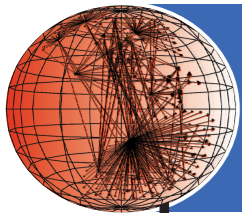
- queries can be “populated”

- 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",  
  }  
]
```

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AS Information

as-rank.caida.org/api/v1

[as-rank.caida.org/api/v1/asns/\(\d+\)](https://as-rank.caida.org/api/v1/asns/(\d+))

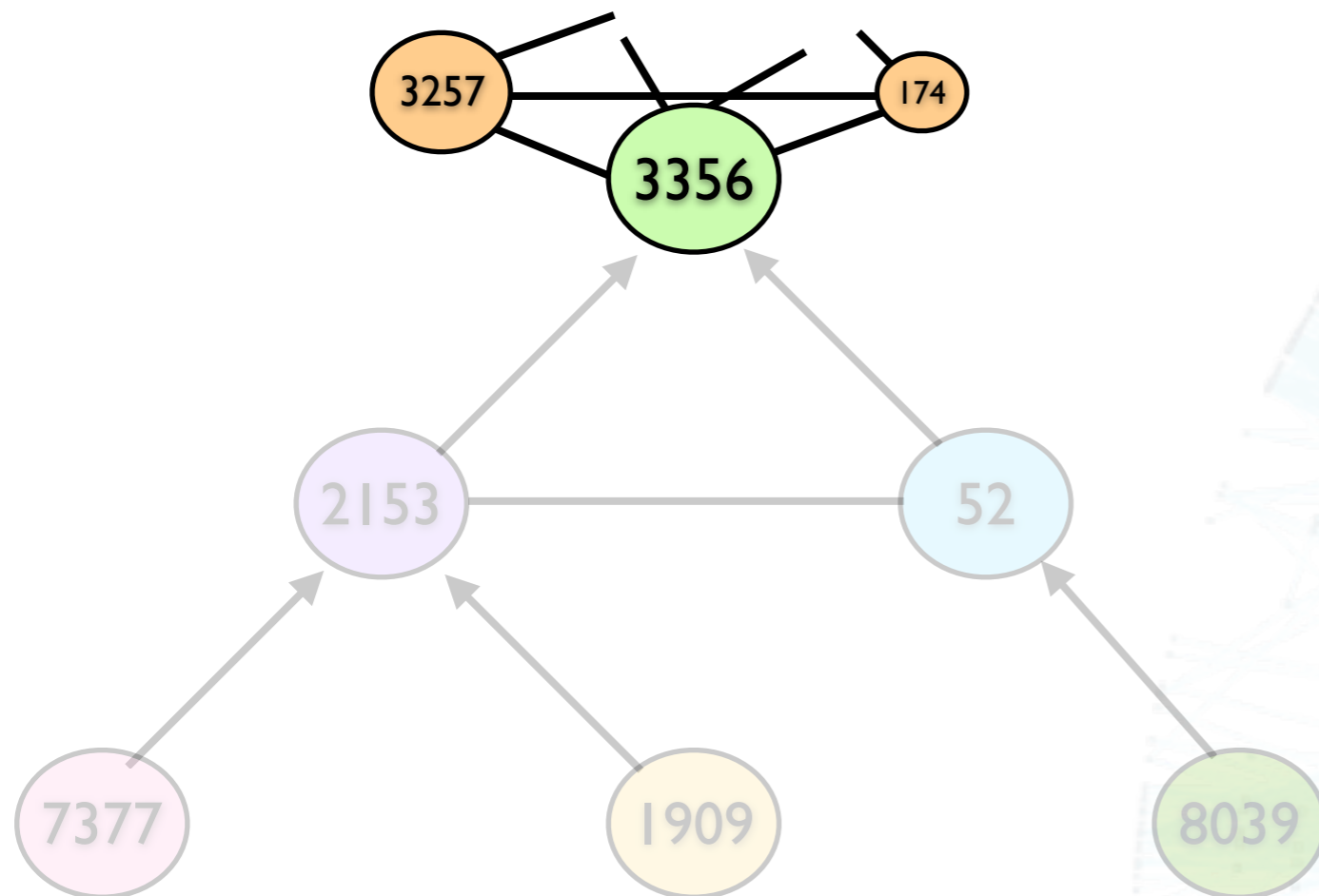
as-rank.caida.org/api/v1/asns/1

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

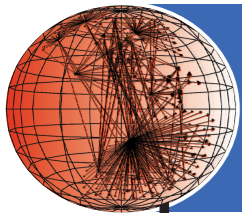


AS hierarchy (clique)

**ASs at the top of the hierarchy are call Tier-I.
Together they form the backbone of the
Internet.**



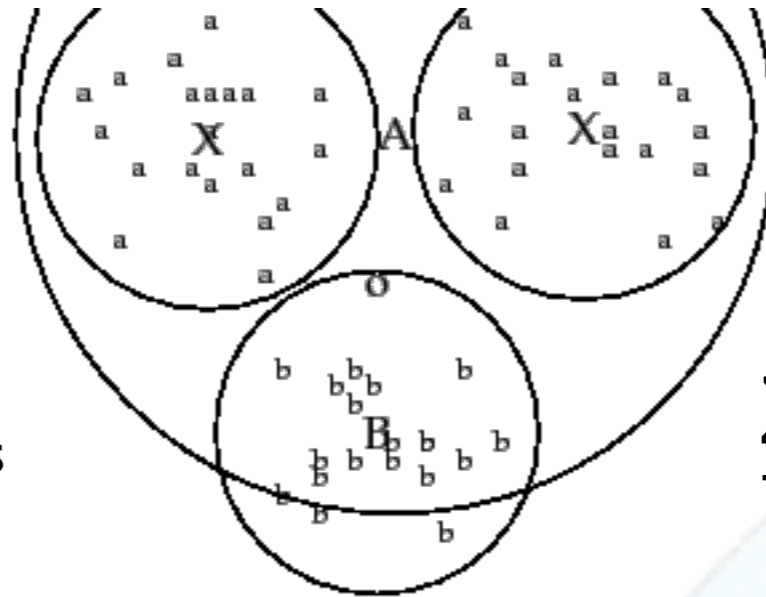
We infer that the set of “Tier-I” ASs are members of the largest clique, fully connected set, of the largest ASs.



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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.

$$\frac{\sum_i \text{block}_i.\text{longitude} * \text{block}_i.\text{size}}{\sum_i \text{block}_i.\text{size}}$$

geolocation blocks

origin AS	prefix	IP block	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



AS Information

as-rank.caida.org/api/v1

[as-rank.caida.org/api/v1/asns/\(\d+\)/links](https://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
  }
]
```

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

[as-rank.caida.org/api/v1/orgs/\(\[^/\]+\)](https://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/{id}

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/\(\d+\)](https://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/\(\d+\)](https://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 than with, IX



Direct Download

www.caida.org/data/as-rank

www.caida.org/data/as-rank

All of this data is also available for direct download
as flat files in JSONL format.