Interactive Access to Internet Topology Data

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SDSC/UCSD

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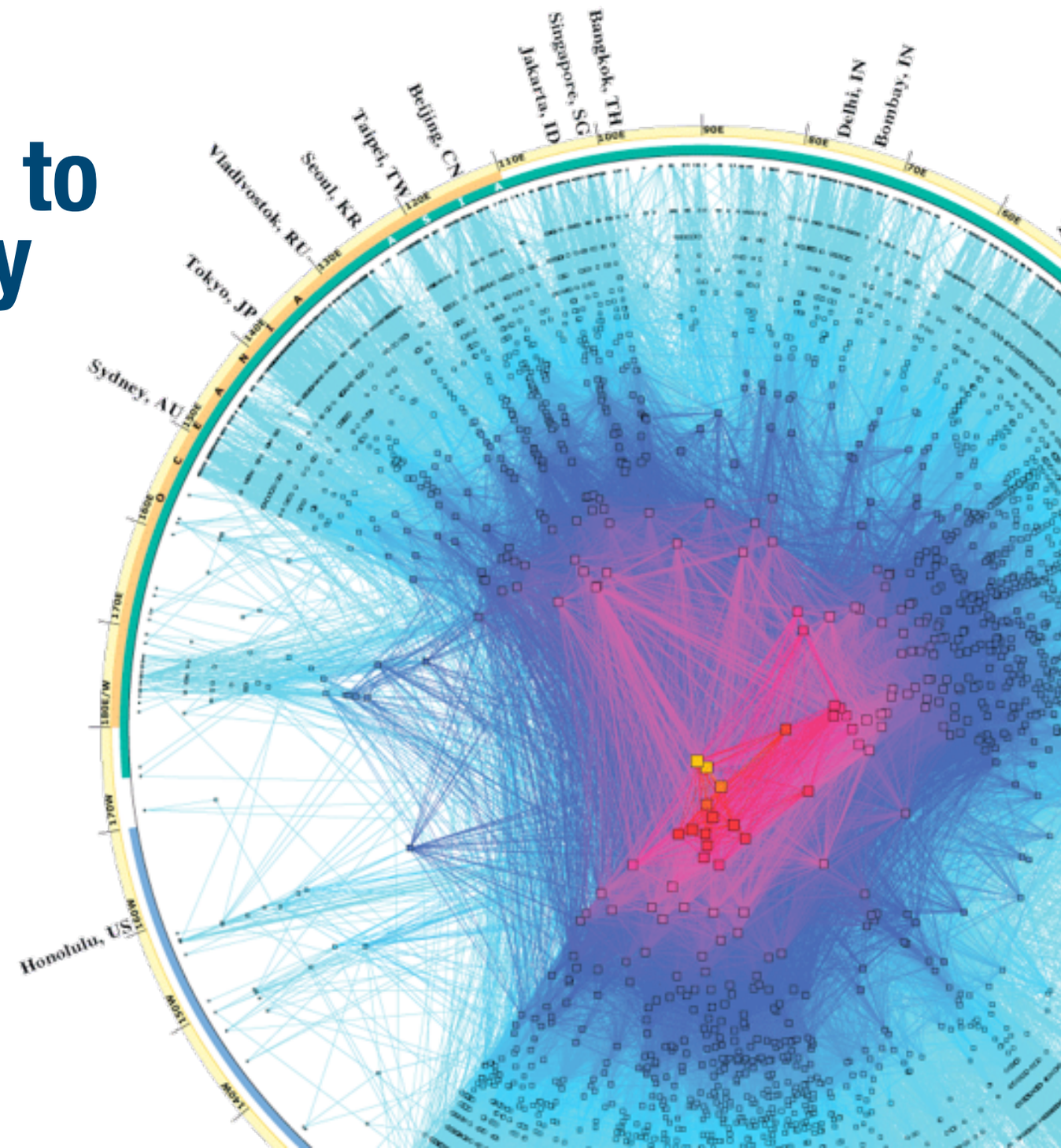
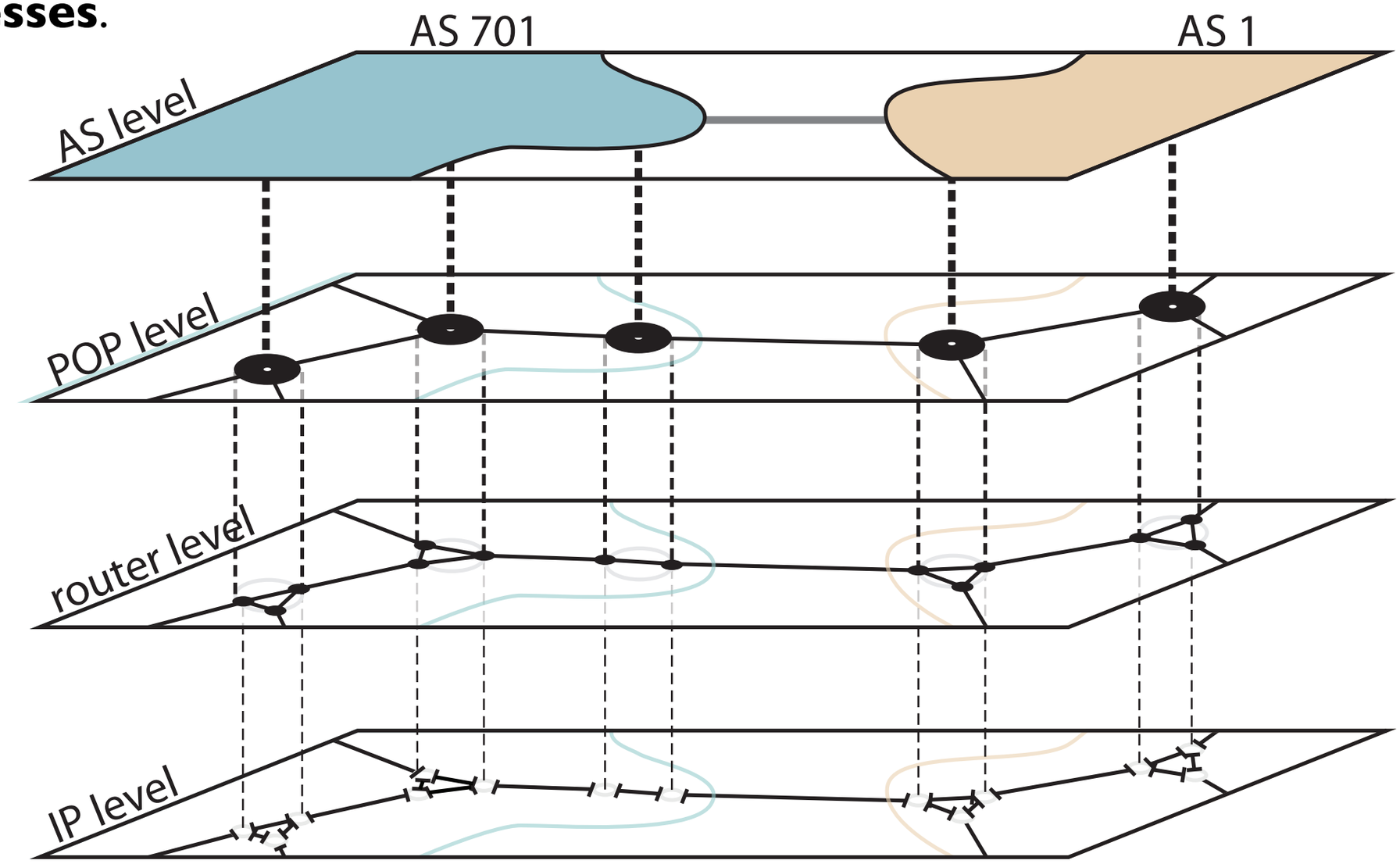


Layered view of the Internet

background

Internet maps can be grouped into three levels.

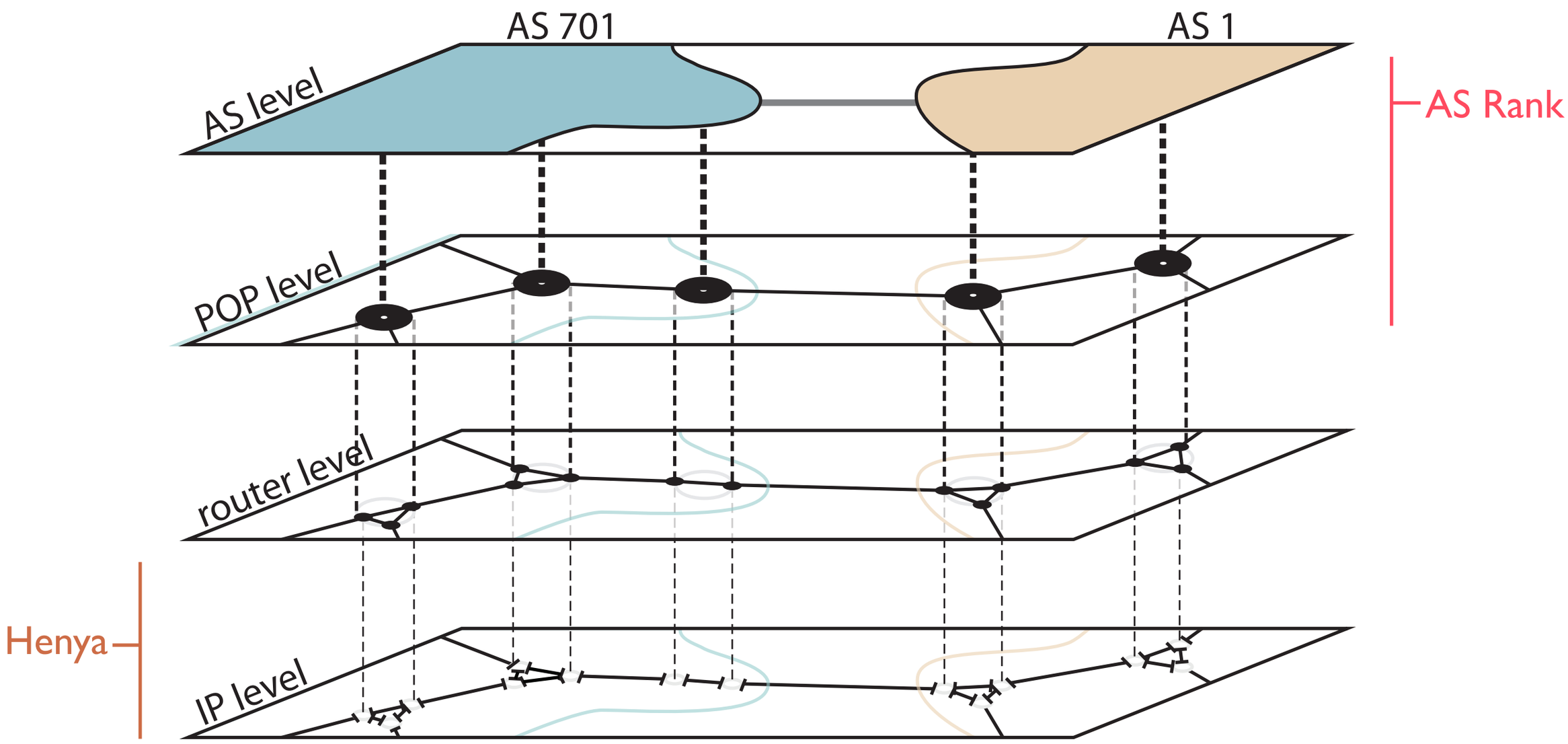
1. **IP addresses** that connect devices on to the Internet.
2. **Routers,** machines that route the traffic, interconnect via **IP addresses.**
3. **Point of Presence (PoP)** geographic location with
4. **Autonomous Systems (AS)** are numbers used to route groups of **IP addresses**.



systems

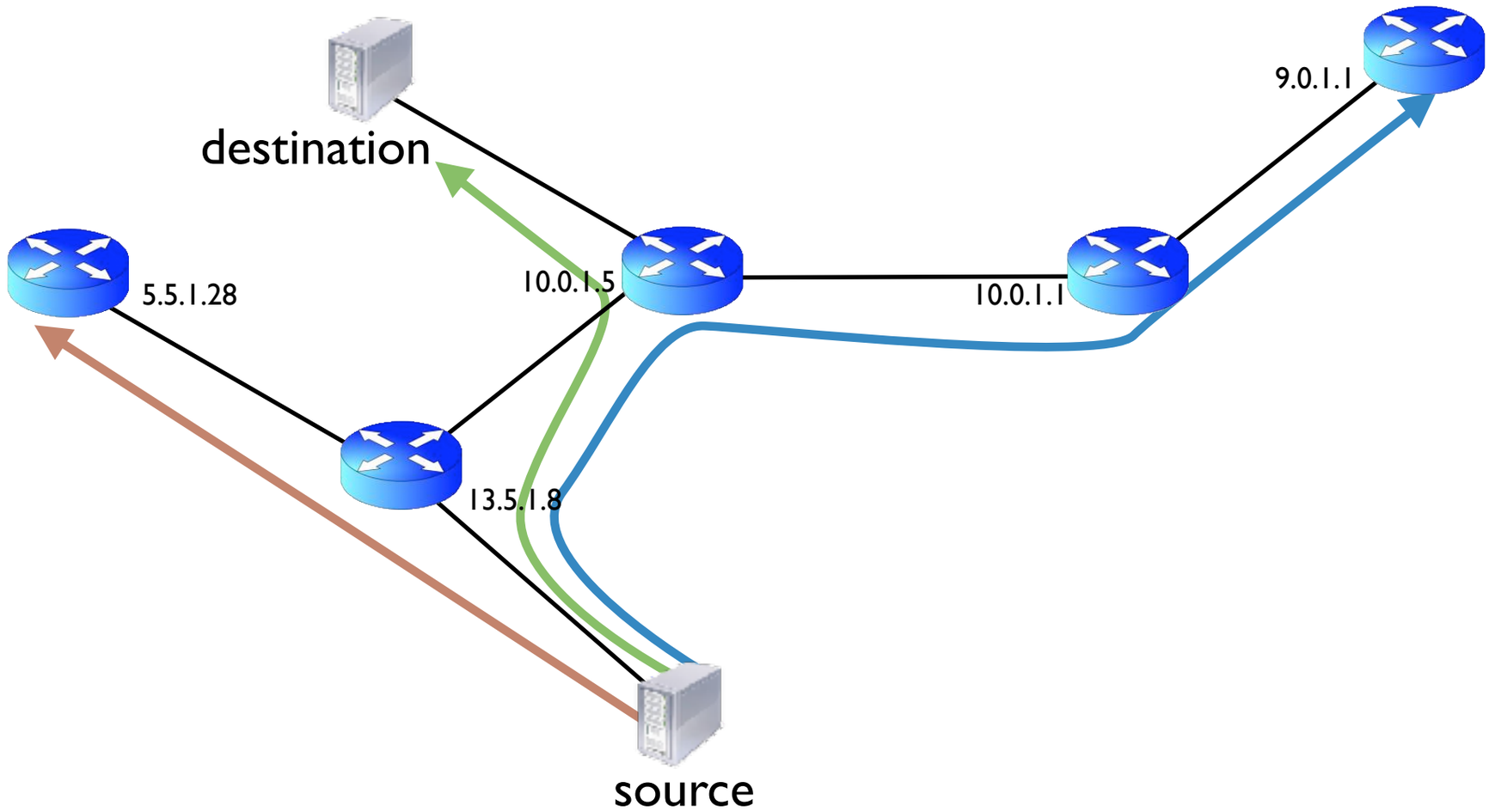
background

- **Henya** primarily concerned with querying **IP paths**
- **AS Rank** primarily concerned with querying **AS topology**



traceroute paths

background



source → 13.5.1.8 → 5.5.1.28

source → 13.5.1.8 → 10.0.1.5 → destination

source → 13.5.1.8 → 10.0.1.5 → 10.0.1.1 → 9.0.1.1

traceroute data

background

- 9+ years of CAIDA traceroute data
  - 47 billion traces in 20.3 TB of files
  - now growing by **20 billions traces/year**
- useful for studying global Internet connectivity, evolution, performance, censorship, ...
- basis for higher-level Internet maps

Henya

overview

- 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

topology queries

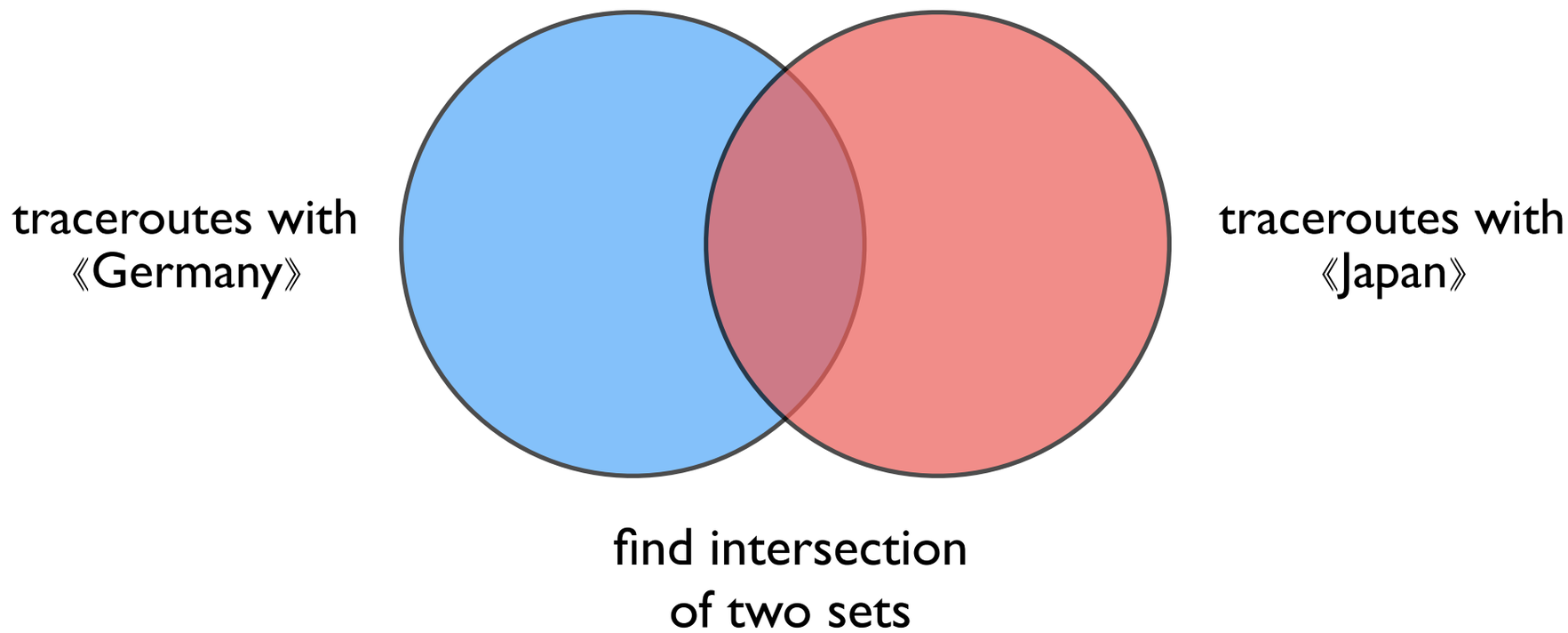
Henya

- find occurrences of traceroute path elements
- 《*targets*》 = IP addreses (and other types)
- queries:
  - traceroutes **toward** 《*targets*》
  - traceroutes **containing** one or more 《*targets*》
- parameters:
  - measurement vantage points
  - data collection time periods
  - position of 《*targets*》 in path
  - hop distance between sets of 《*targets*》

query complexity

Henya

- the most complex case:
  - traceroutes containing **two or more** 《*targets*》
    - precisely: traceroutes containing some hop $h_1 \in$ 《$targets_1$》, $h_2 \in$ 《$targets_2$》, $\cdots$
  - example: traceroutes containing hops in both 《Germany》 and 《Japan》



- harder:
  - traceroutes with hops in 《Germany or UK or France》 and hops in 《ATT or Level3 network》 and hops in 《Amsterdam Internet Exchange》

challenges

Henya

- large target sets
  - 《Germany》 = 92,239,360 target IP addresses
  - 《Japan》 = 154,025,984 target IP addresses
- multiple 《*targets*》 in a single query
  - need the **intersection** of subqueries for 《$targets_1$》 and 《$targets_2$》 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

design

Henya

- 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

web interface

Henya

- 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

Henya

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, 10.0.0.0/8, 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 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.

Submit Reset

ad-hoc queries

Henya

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**

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

pre-made analysis

Henya

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:

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

Start Date: End Date:

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

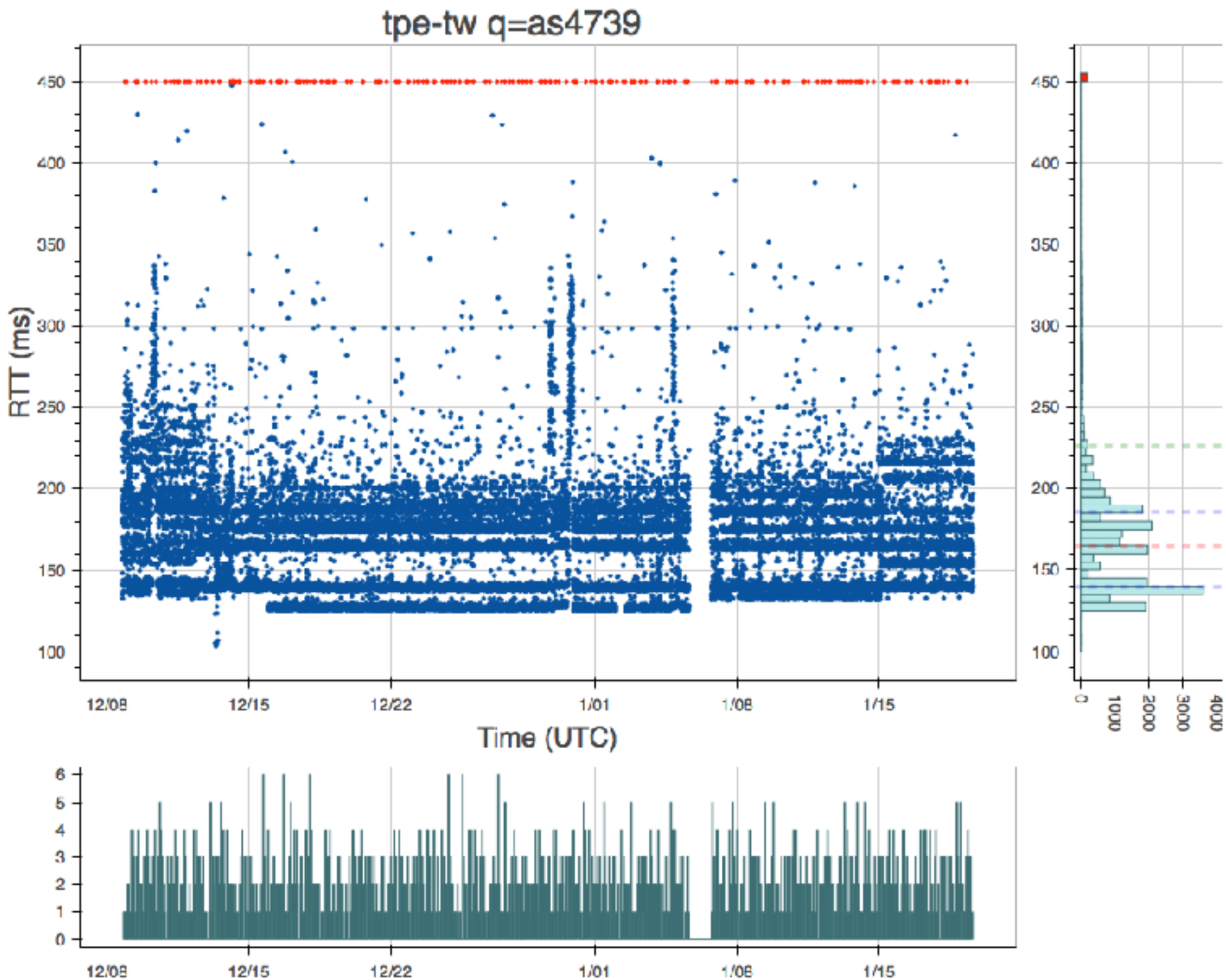
By Name | By Continent | By Country | By Org Type

Monitors with IPv6 have an asterisk next to their name.

Submit Reset

pre-made analysis

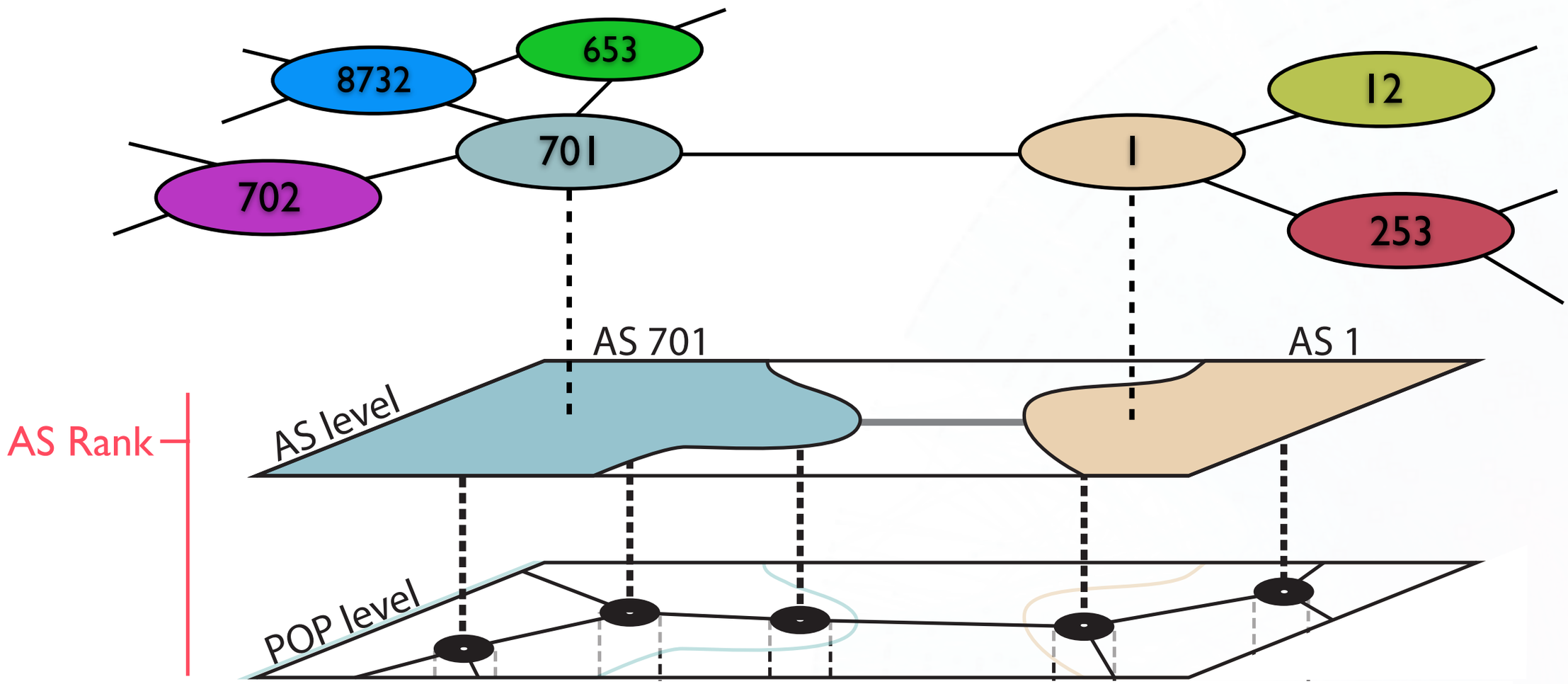
Henya



Internet of layers

as-rank.caida.org

- **AS Rank** primarily concerned with querying **AS topology**



AS Rank goal

as-rank.caida.org

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)

AS Rank highlights

as-rank.caida.org

- 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

primary key — key selected based on AS topology

AS Topology	Organization	AS Geography	Link Geography	AS Classifcation
monthly	quartly (roughly)			yearly (ish)
selected **date**	matched **org_id**	nearest to **date**		

AS Rank tables

as-rank.caida.org

Dataset Tables

Dataset
This holds the set of datasets both AS topology and ITDK

dataset_id	internal ID
type	"ITDK" "ASNGEO" "ASN2ORG" "ASNGEO_LINK" "ASNTOP"
name	string
date	date
description	string
state	string

ASN2ORG Tables

ASN2ORG_Organization
org_id_external from AS2org file

dataset_id	internal ID
org_id	internal ID
org_id_external	external string
name	string
country	string
source	string

ASN2ORG_Asn
source is not related to Sources, but from the algorithm

dataset_id	internal ID
asn	int
org_id	internal ID
name	string
source	string

ASNTOP Tables

ASNTOP_Information

dataset_id	internal ID
address_family	"AF_INET", "AF_IENT6"
asn2org_dataset_id	internal ID
number_asnes	int
number_organizes	int
number_prefixes	int
number_addresses	int

ASNTOP_AsnTopClique
ASN which are in the top Clique

dataset_id	internal ID
asn	int
hostname	string

AsnPath
the as path is stored as "|" separated ASes

asn_path_id	internal ID
asn_path	string

AsnLink

asn_link_id	internal ID
asn	int
sequence_num	int

ASNTOP_AsnRank

dataset_id	internal ID
asn	internal ID
cone_rank	int
degree_rank	int

ASNTOP_OrgRank

dataset_id	internal ID
org_id	internal ID
cone_rank	int
degree_rank	int

ASNTOP_AsnDegree

dataset_id	internal ID
asn	int
asn_transit_degree	int
asn_degree	int

ASNTOP_OrgDegree

dataset_id	internal ID
asn_transit_degree	int
asn_degree	int
org_transit_degree	int
org_degree	int

ASNTOP_AsnCustomerCone

dataset_id	internal ID
asn	int
number_asnes	int
number_prefixes	int
number_addresses	int

ASNTOP_OrgCustomerCone

dataset_id	internal ID
org_id	internal ID
number_asnes	int
number_prefixes	int
number_addresses	int

ASNTOP_AsnLinkPath

dataset_id	internal ID
asn_link_id	internal ID
asn_path_id	internal ID

ASNTOP_AsnLinkRelationship

dataset_id	internal ID
asn_link_id	internal ID
type	"PROVIDER", "CUSTOMER", "PEER", "SILBING", "UNKNOWN"

ASNTOP_AsnType

dataset_id	internal ID
asn	int
type	string

ASNTOP_AsnLinkAttribute
additional information IPv6, etc

dataset_id	internal ID
asn_link_id	internal ID
attribute	string

ASNTYPE Tables

ASNTYPE_AsnType

dataset_id	internal ID
asn_link_id	int
asn	int
type	string

ASNGEO Tables

ASNGEO_AsnGeo

dataset_id	internal ID
asn	int
latitude	float
longitude	float

ASNLinkGeo Tables

ASNLINKGEO_AsnLinkGeo

dataset_id	internal ID
asn_link_id	internal ID
loc_id	internal ID

AS Rank architecture

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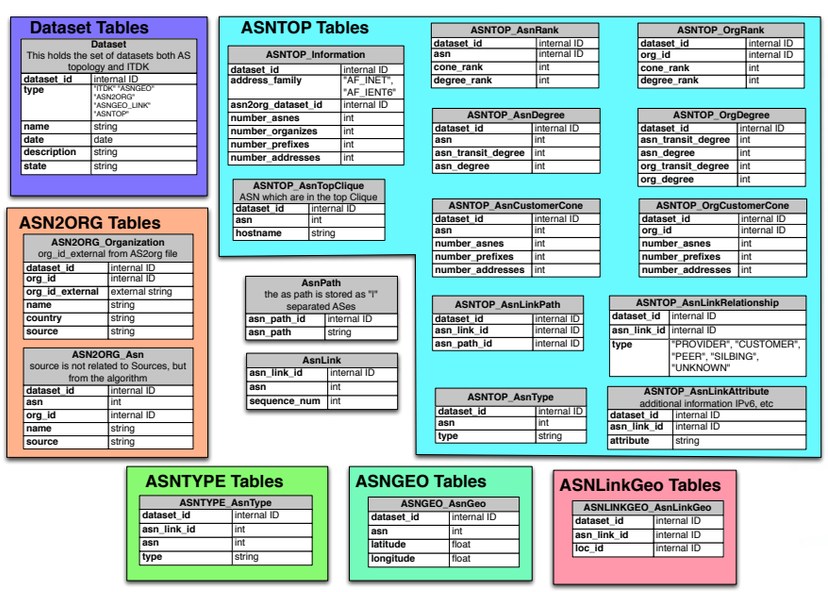
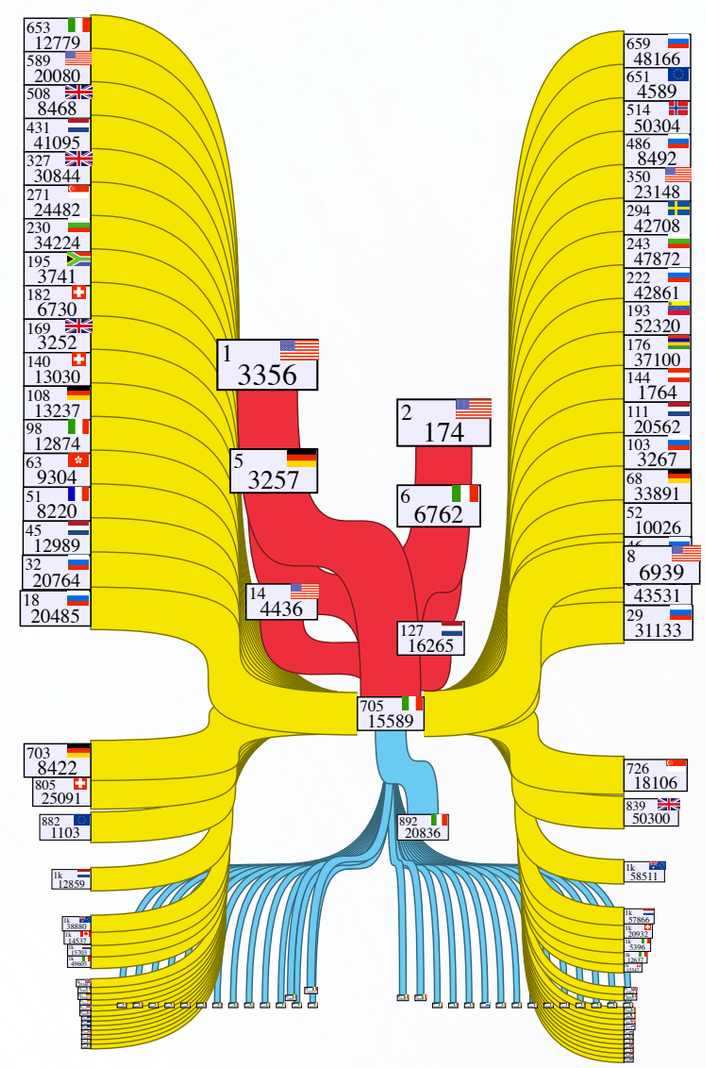
- CGI (Perl) front end
  - cache based on CGI parameters
- visualizations
  - Perl and C scripts
  - generates SVG files
- MySQL server back end





global AS ranking

as-rank.caida.org

organization dataset (04/01/2016)

topology dataset (06/16/2016)

AS rank	AS number	AS name	Org name	AS Type(s)	customer cone						AS transit degree
					Number of			Percentages of all			
					ASes	IPv4 Prefixes	IPv4 Addresses	ASes	IPv4 Prefixes	IPv4 Addresses	
1	3356	LEVEL3	Level 3 Communications, Inc.	Tr/Ac	29,494	224,970	783,401,728	53%	34%	36%	4138
2	174	COGENT-174	Cogent Communications	Tr/Ac	23,299	172,963	616,423,936	42%	26%	28%	4567
3	1299	TELIANET	TeliaSonera AB	Tr/Ac	21,954	191,391	667,346,176	40%	29%	31%	1272
4	2914	NTT-COMMUN...	NTT America, Inc.	Tr/Ac	18,991	174,304	642,432,768	34%	26%	29%	1352
5	3257	GTT-BACKBONE	Tinet Spa	Tr/Ac	18,140	161,377	565,089,024	33%	24%	26%	1282
6	6762	SEABONE-NET	TELECOM ITALIA SPARKLE S.p.A.	Tr/Ac	14,394	123,771	329,530,624	26%	18%	15%	534
7	6453	AS6453	TATA COMMUNICATIONS (AMERICA) INC	Tr/Ac	12,300	135,127	533,133,824	22%	20%	24%	685
8	6939	HURRICANE	Hurricane Electric, Inc.	Tr/Ac	8,088	79,800	278,942,720	14%	12%	12%	4809
9	2828	XO-AS15	XO Communications	Tr/Ac	6,251	60,271	250,568,448	11%	9.2%	11%	1089
10	1273	CW	Cable and Wireless Worldwide plc	Tr/Ac	5,878	42,258	173,223,936	10%	6.4%	8.1%	296

type dataset (08/02/2015)

local AS view

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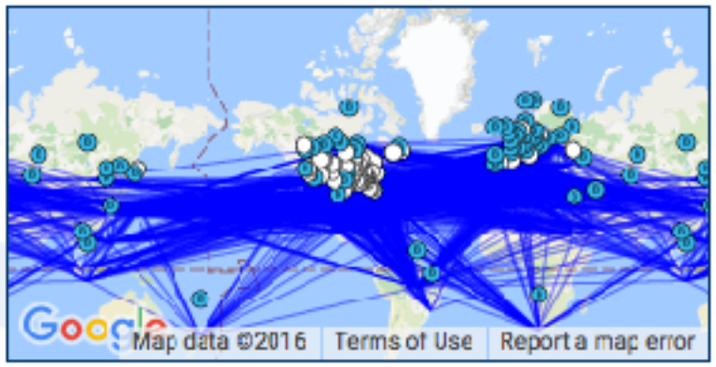
geographic



AS number:	3356
AS name:	LEVEL3
Org name:	Level 3 Communications, Inc.
AS rank:	1
Country:	US
Customer cone size:	29,494
AS transit degree:	4,138 (0 Provider, 75 Peer, 4,361 Customer, 8 Sibling)
Type:	TrAc

organization

topology

type

Position in Ranking | **AS Relationship Table** | AS Relationship (Geo) Graph | AS Relationship Graph | Corrections

The relationship table below displays the neighbors of AS 3356, and each neighbor's inferred relationship type with AS 3356.

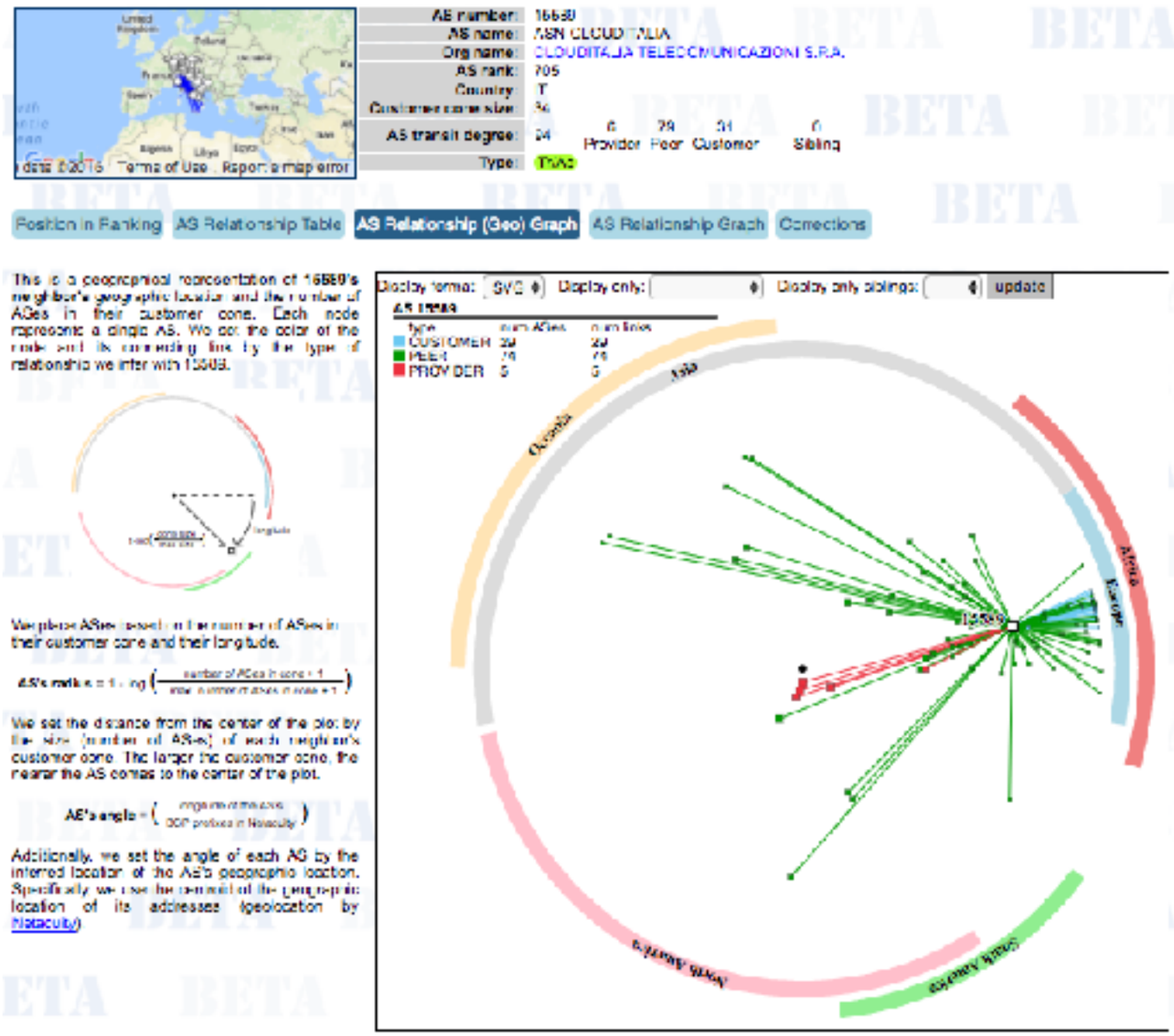
Table **shows** 100 of 4436 neighbor ASes, **sorted by** relationship type and AS rank, with simple **details.** update view

neighbor					type
AS rank	AS	AS name	AS type(s)	Org name	
2	174	COGENT-174	TrAc	Cogent Communications	↔ peer
3	1299	TELIANET	TrAc	TeliaSonera AB	↔ peer
4	2914	NTT COMMUN...	TrAc	NTT America, Inc.	↔ peer
5	3257	GTT-BACKBONE	TrAc	Tinet Spa	↔ peer
6	6762	SEABONE NET	TrAc	TELECOM ITALIA SPARKLE S.p.A.	↔ peer
7	6453	AS6453	TrAc	TATA COMMUNICATIONS (AMERICA) INC	↔ peer
8	6939	HURRICANE	TrAc	Hurricane Electric, Inc.	↔ peer
9	2828	XO-AS15	TrAc	XO Communications	↔ peer
12	701	UUNET	TrAc	MCI Communications Services, Inc. d/b/a Verizon Business	↔ peer
13	6461	ABOVENET	TrAc	Abovenet Communications, Inc	↔ peer

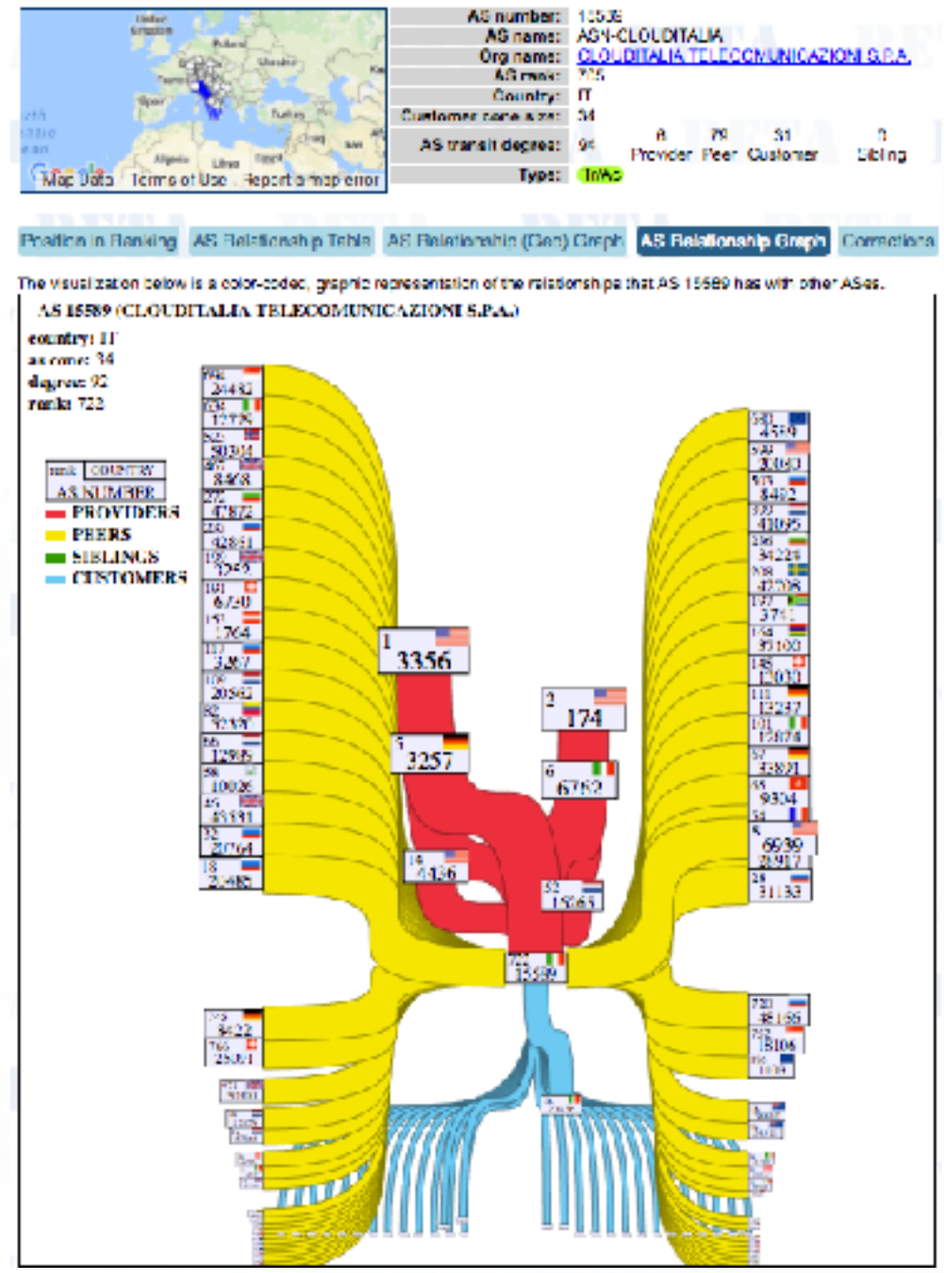
top. org. type org. top.

local AS visualizations

as-rank.caida.org



topology & geography



topology & organization

conclusion

- AS rank and Hyena represent only a beginning at bring 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