



Internet measurement: state of DeUnion

*scientific apparatus offers a window to knowledge,
but as they grow more elaborate,
scientists spend ever more time washing the windows.*
-- Isaac Asimov

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abysmal but unsurprising

- little capacity to predict, depict, or even measure traffic behavior on current and advanced networks
- few tools to engineer/operate networks or identify traffic anomalies in real time
- doesn't stop researchers from building junk
- doesn't stop random users from doing random junk (no dearth of activity)
- increasing risk to infrastructure

payoffs

- insights for **vendors** re next generation hw/sw requirement
- calibration for **users**, e.g., monitoring service level agreements
- diagnostic and planning tools for **ISPs**
- windows into the infrastructure for **researchers**

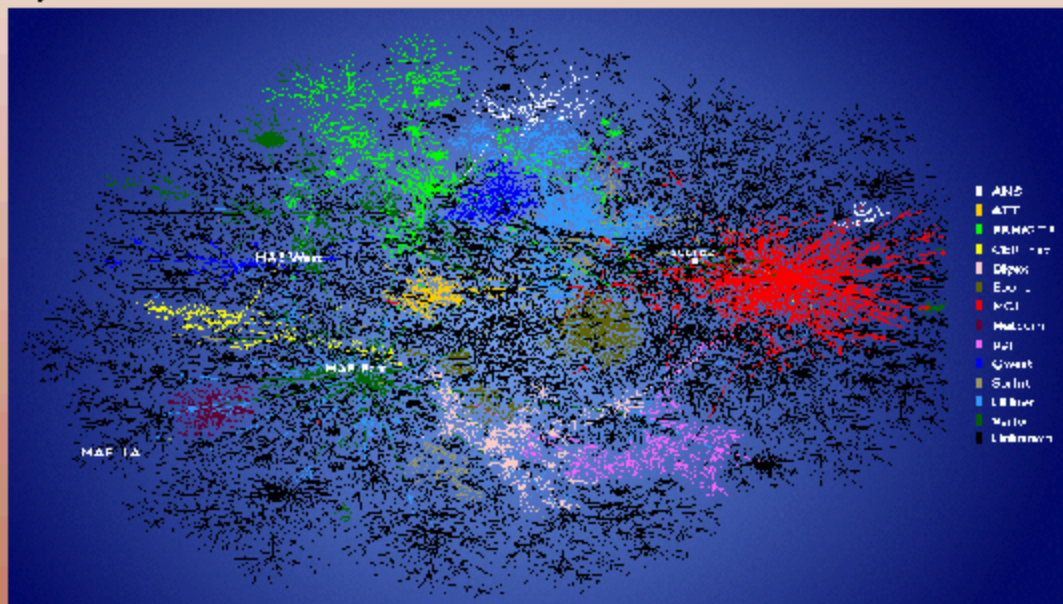
four areas of measurement

- topology (mapping)
- workload characterization (passive)
- performance evaluation (active)
- routing (dynamics)

will show examples, priorities, obstacles

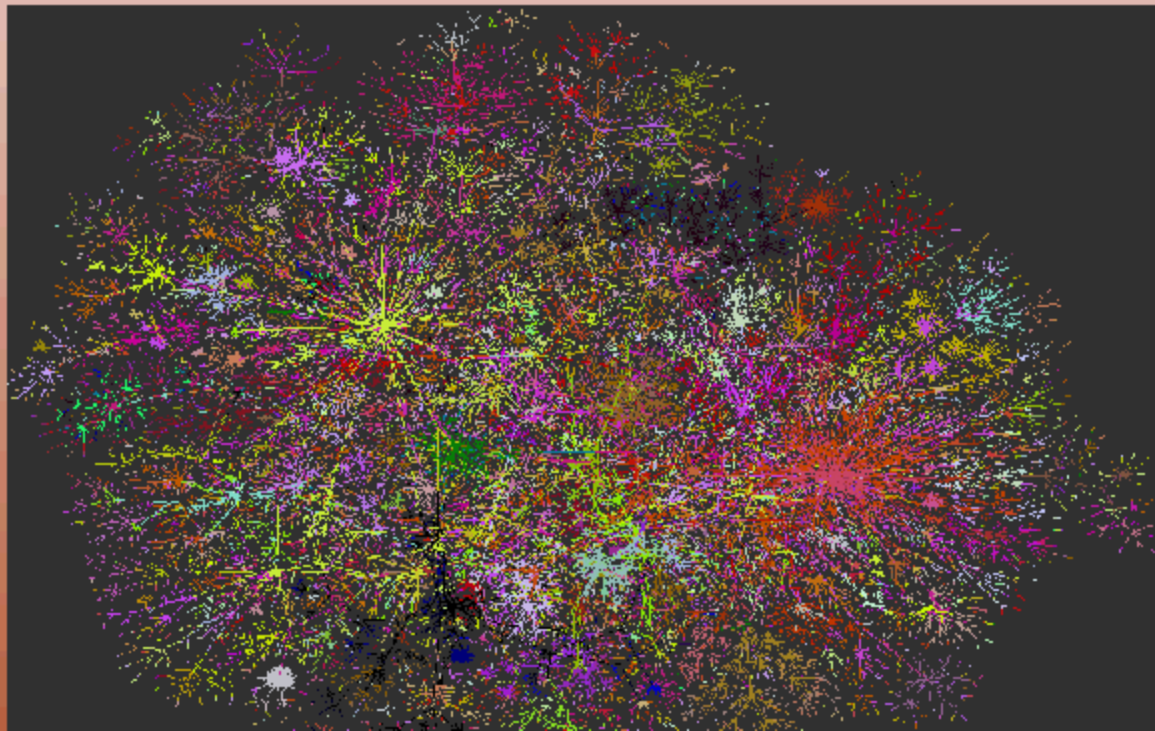
infrastructure-wide priorities

- dynamically discover/depict topology (& b/w)
- correlate effects with BGP routing changes
- correlate path performance with specific events
- identify critical infrastructure within the Internet

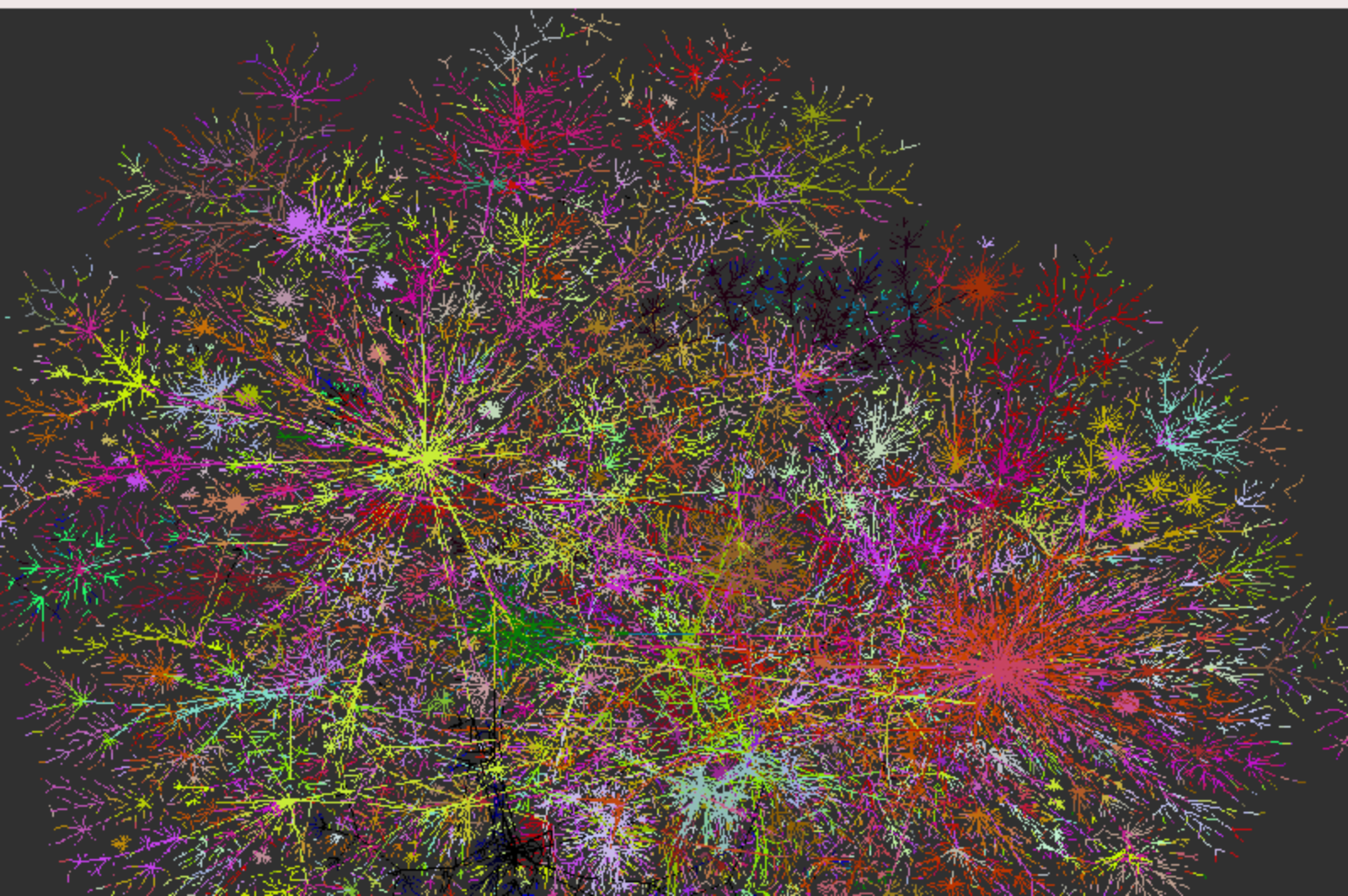


skitter: infrastructure-wide measurements

- 17 monitors (inc. 1 root name server)
- multiple lists 29k servers / 36k 2nd root server destinations
- architecture:
 - parallel ICMP probes
 - 52-byte packets
 - kernel time stamping
 - ssh / Kerberos



skitter: colored by IP address



skitter: colored by country

Country Code: from mask

DE

IT

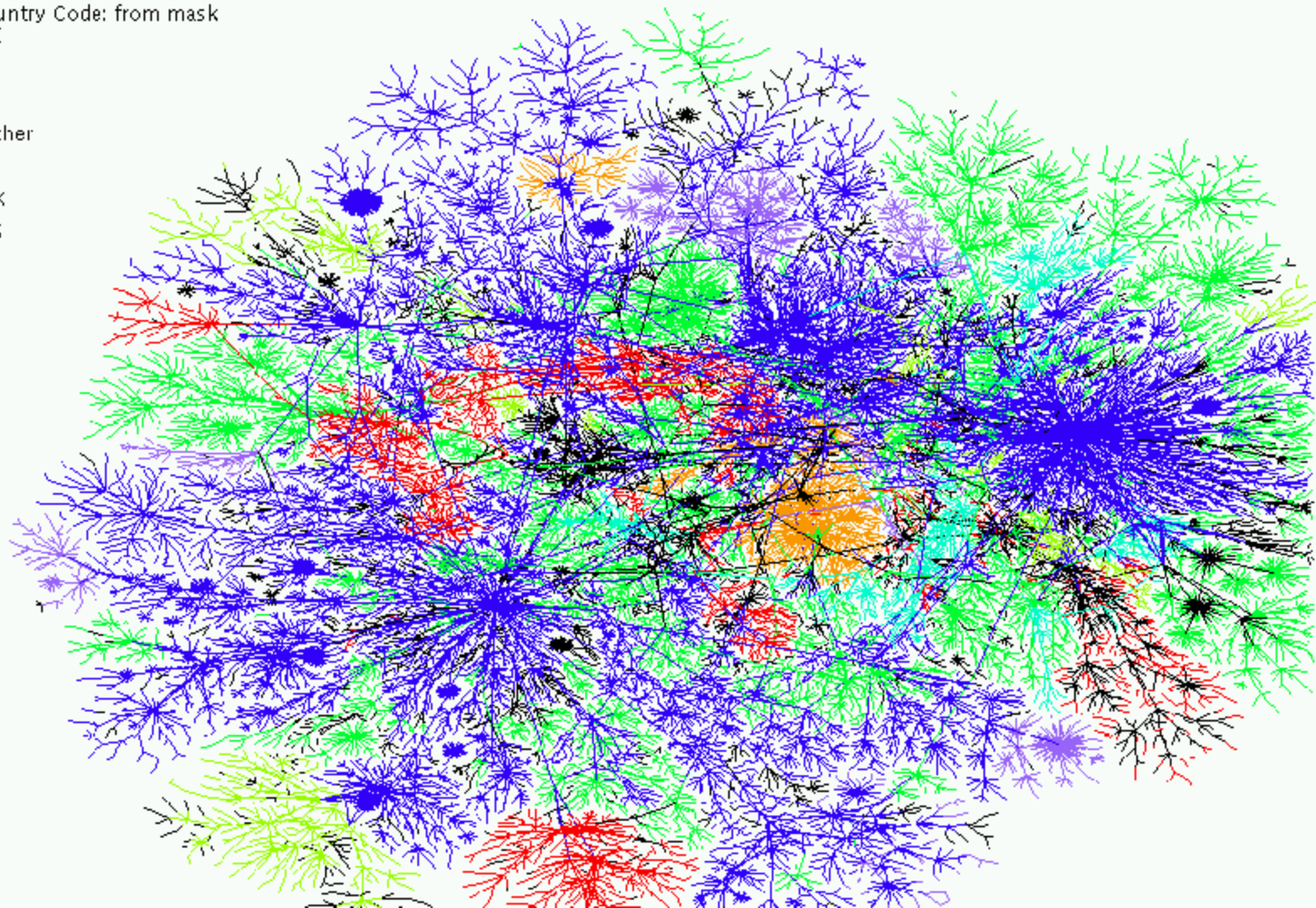
JP

Other

SE

UK

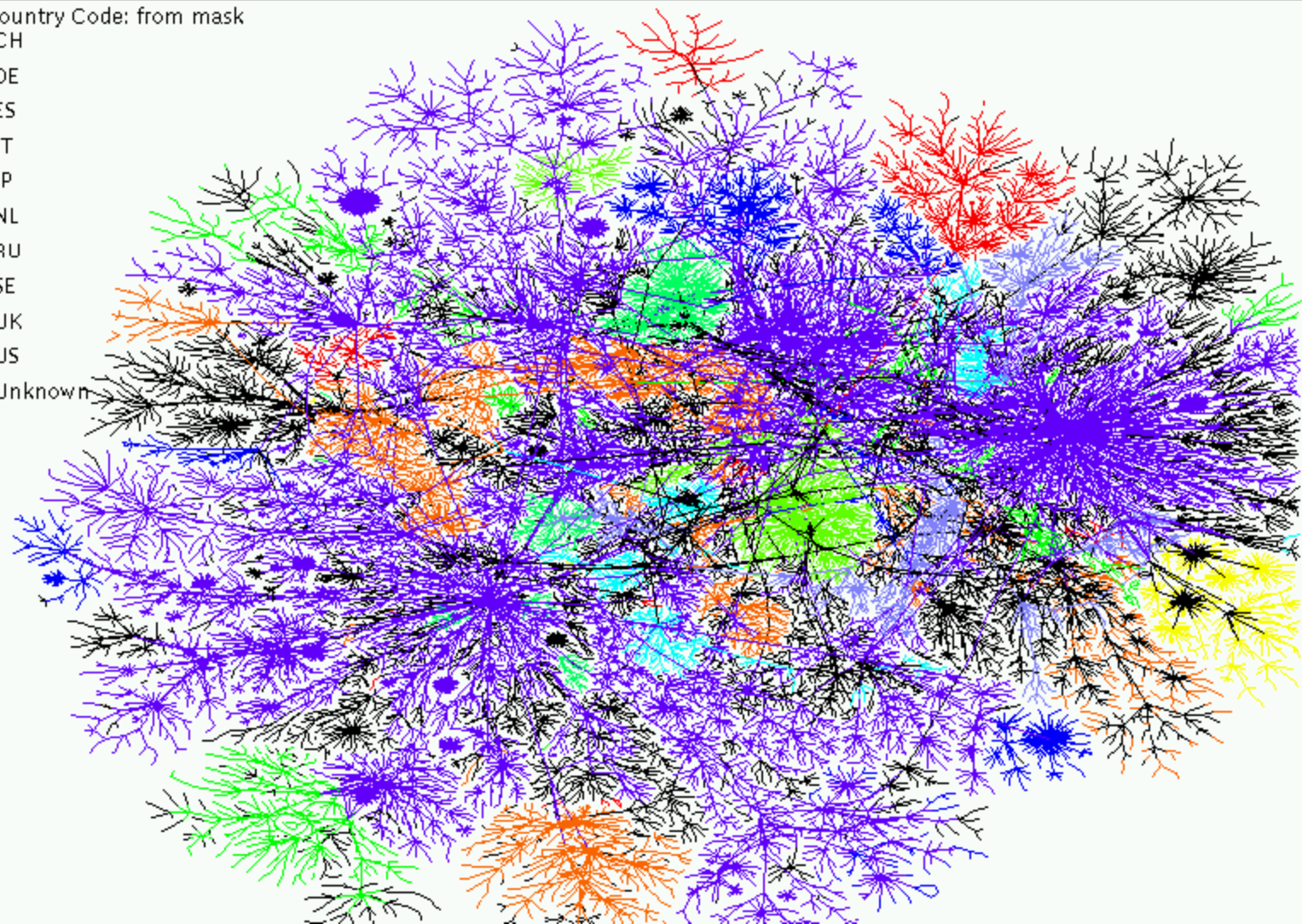
US



skitter: colored by more countries

Country Code: from mask

CH
DE
ES
IT
JP
NL
RU
SE
UK
US
Unknown



skitter: AS interconnectivity

Netname:

(1717)

as-ebone(3215)

as-telianetse(3301)

bbn/gte(1)

digex(2548)

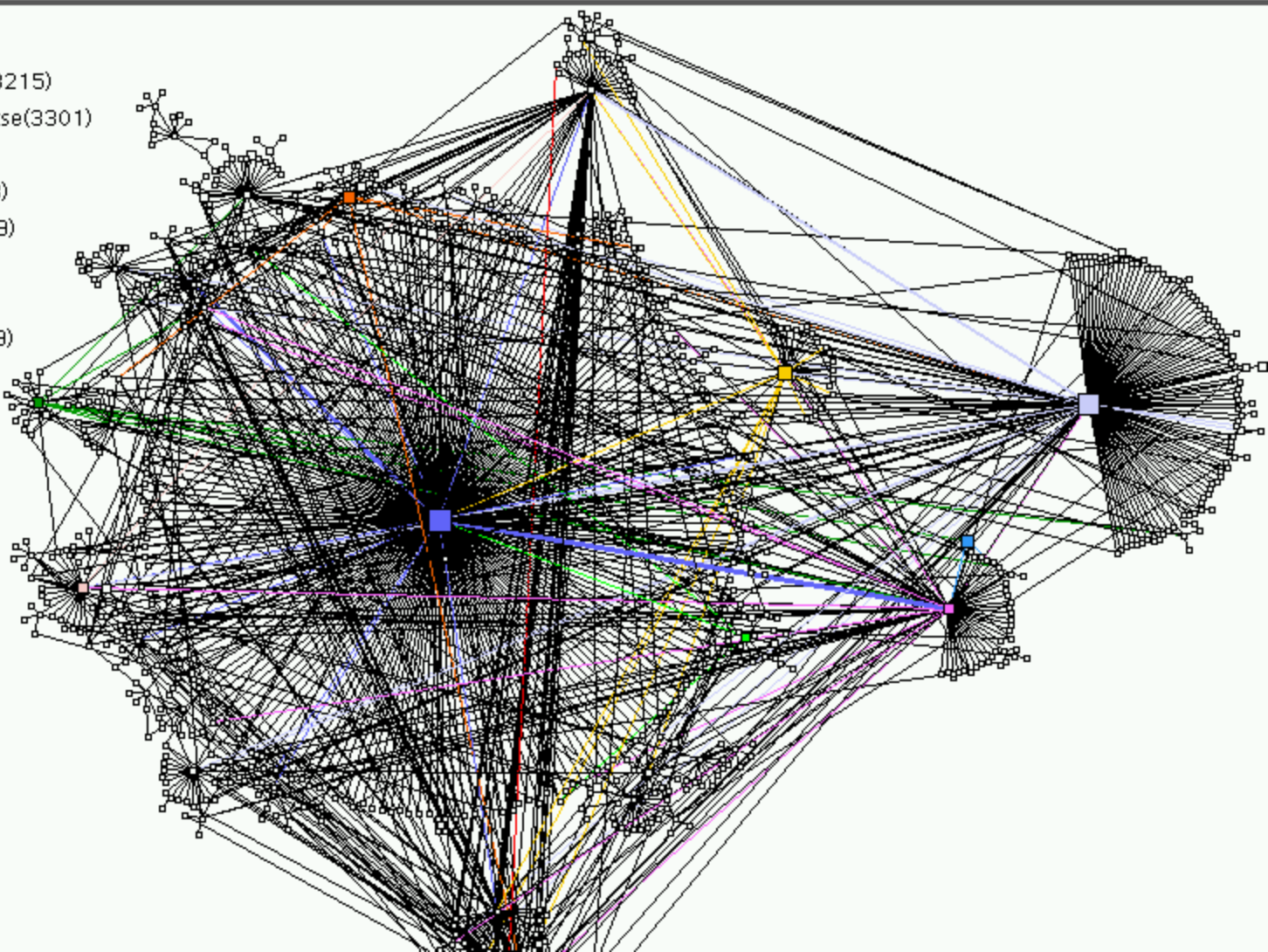
ebone(3269)

janet(786)

mci(3561)

sprint(1239)

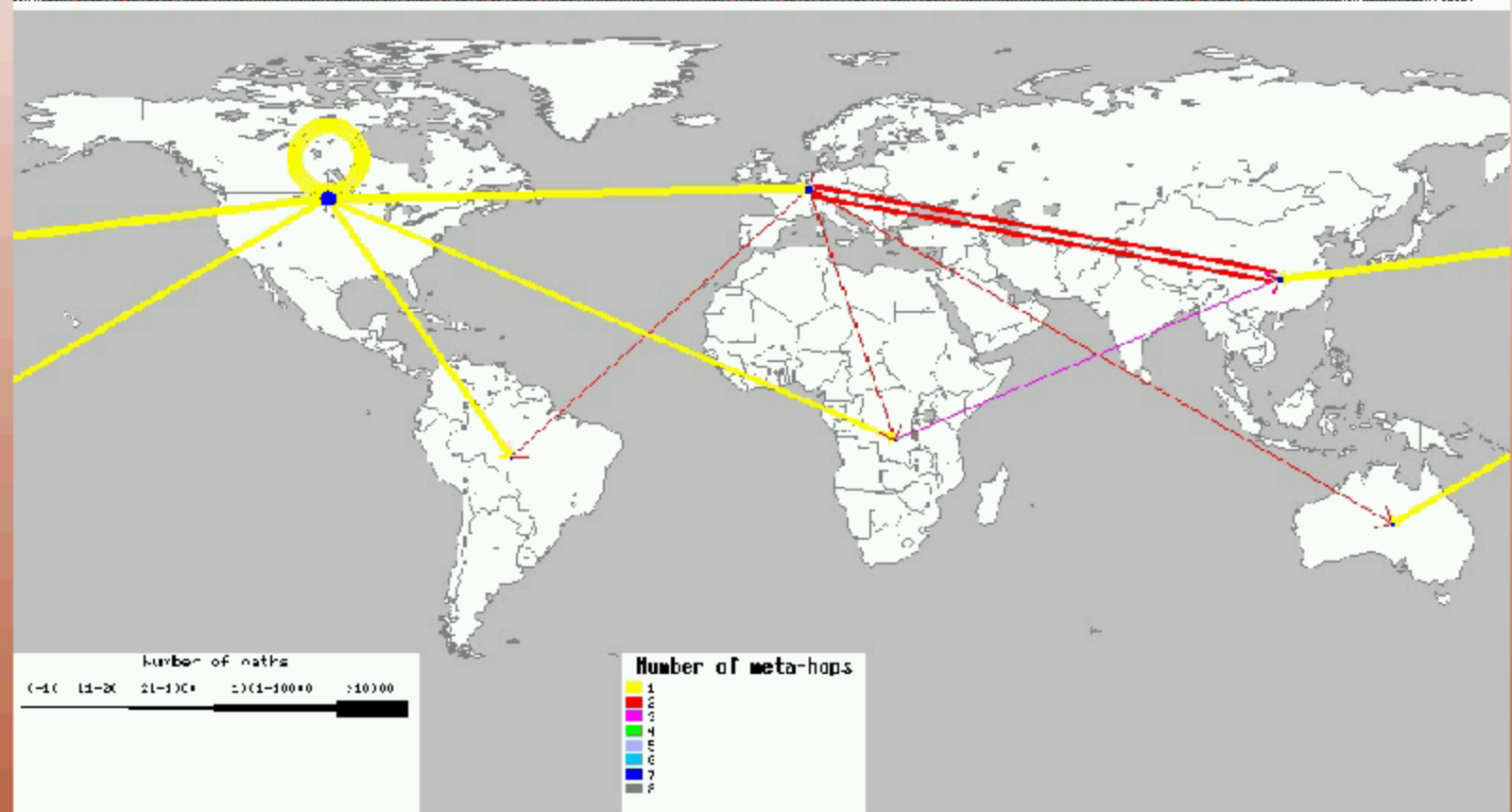
uunet(701)



skitter: cont'l connectivity

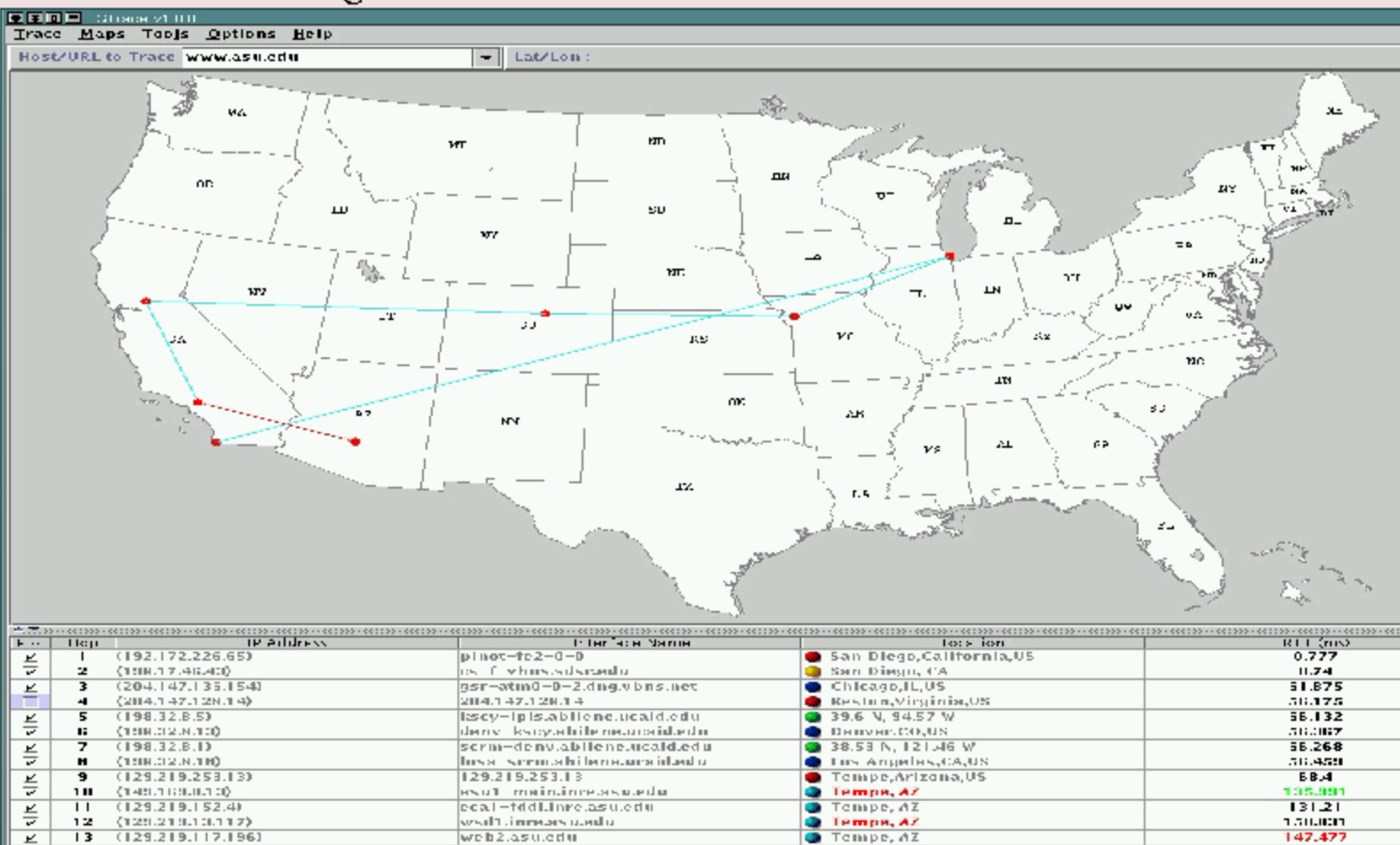
www.caida.org/Tools/GeoPlot/
[www.caida.org/Tools/NetGeo/]

GeoPlot

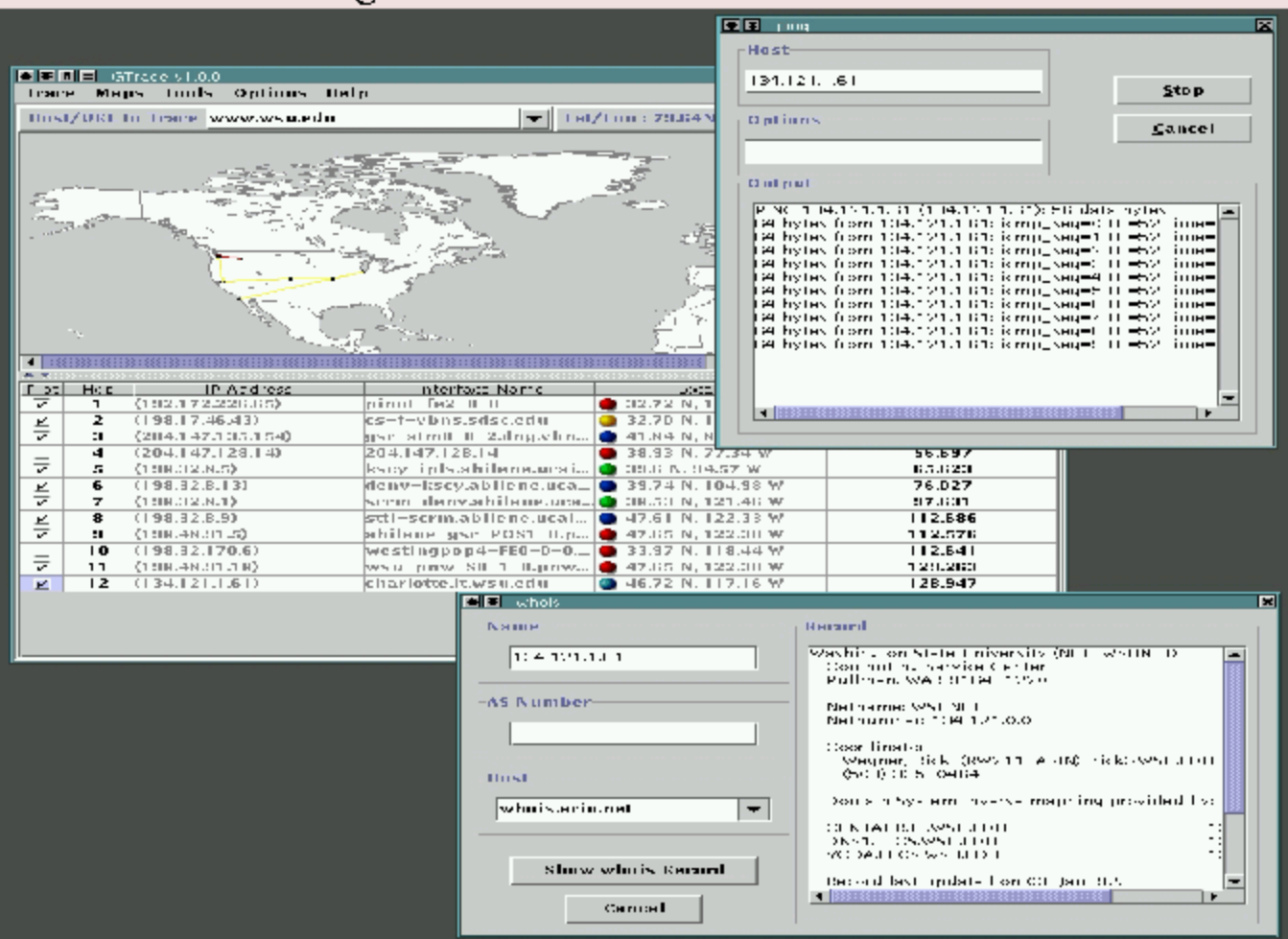


GTrace: geographic traceroute

www.caida.org/Tools/GTrace/

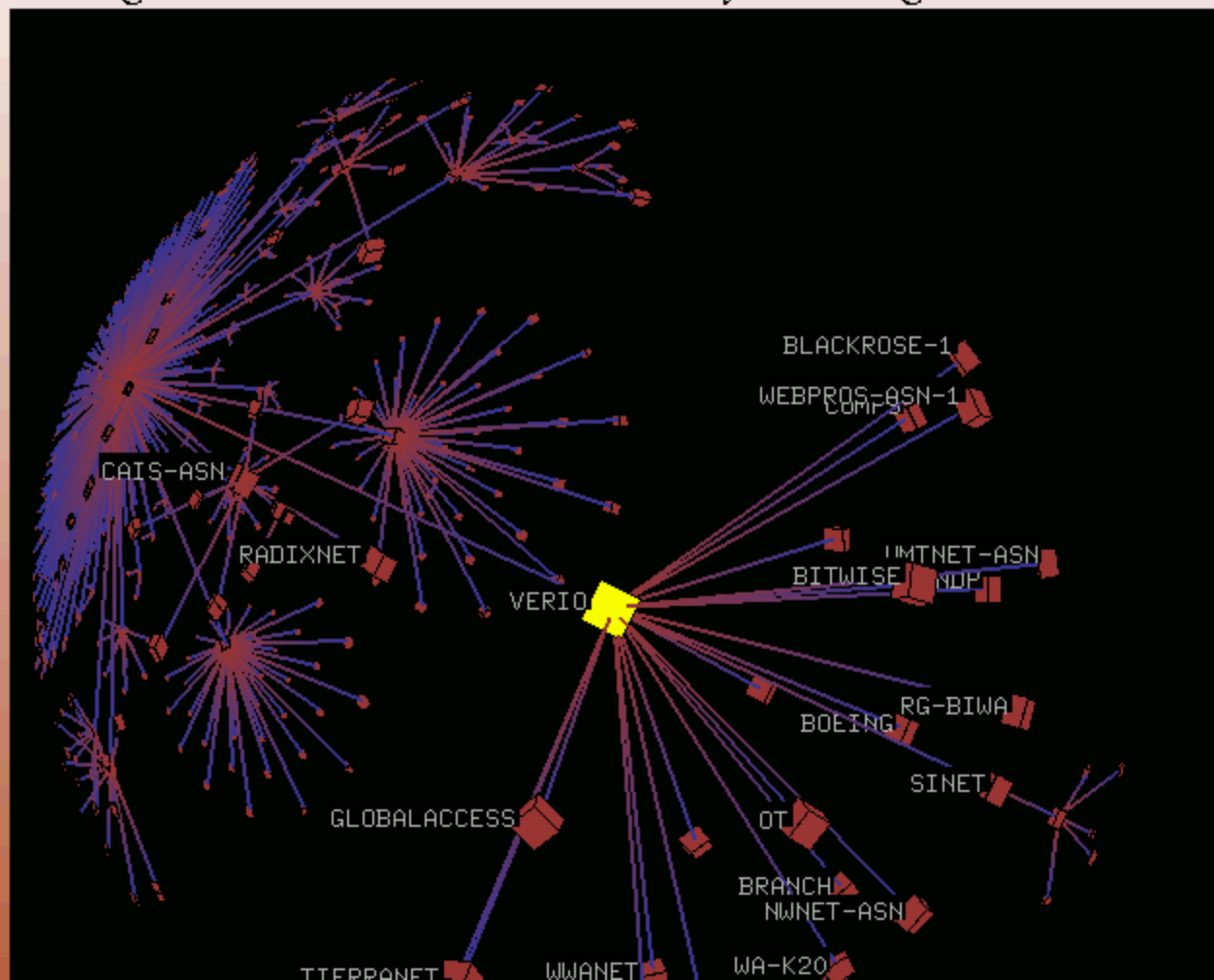


www.caida.org/Tools/GTrace/



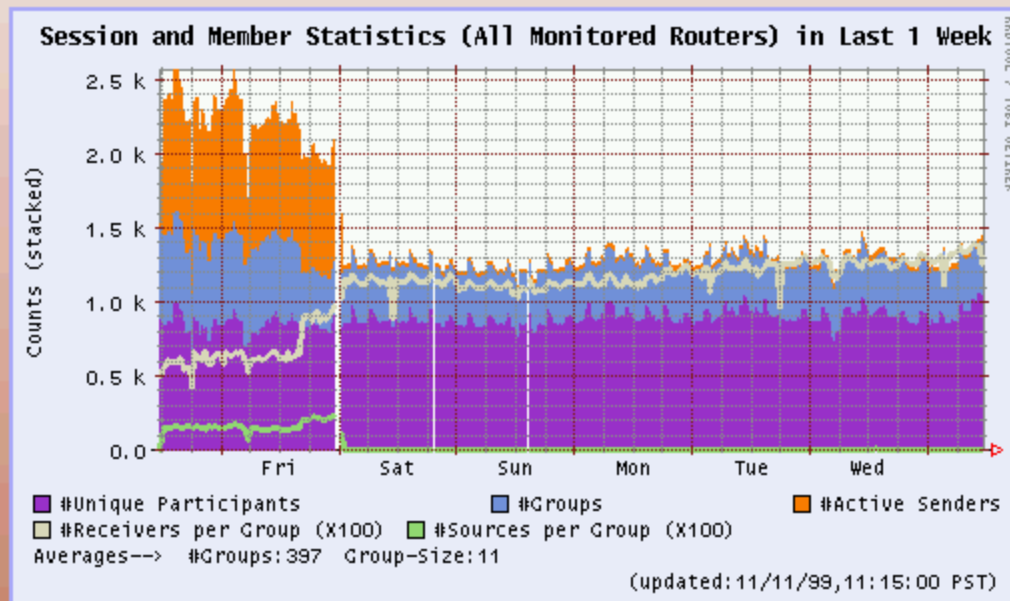
skitter: 3D hyperbolic

BGP routing table data (connectivity among ASes)



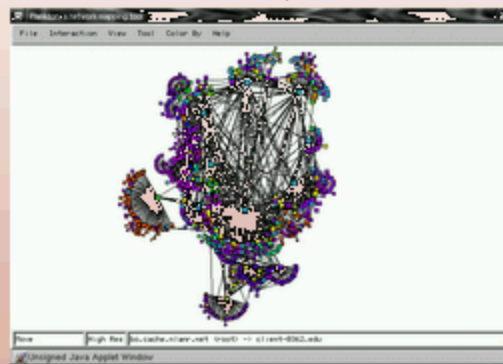
mantra: analyzing multicast

www.caida.org/Tools/Mantra



logical vs geographic topology

2-dimensional, hierarchical

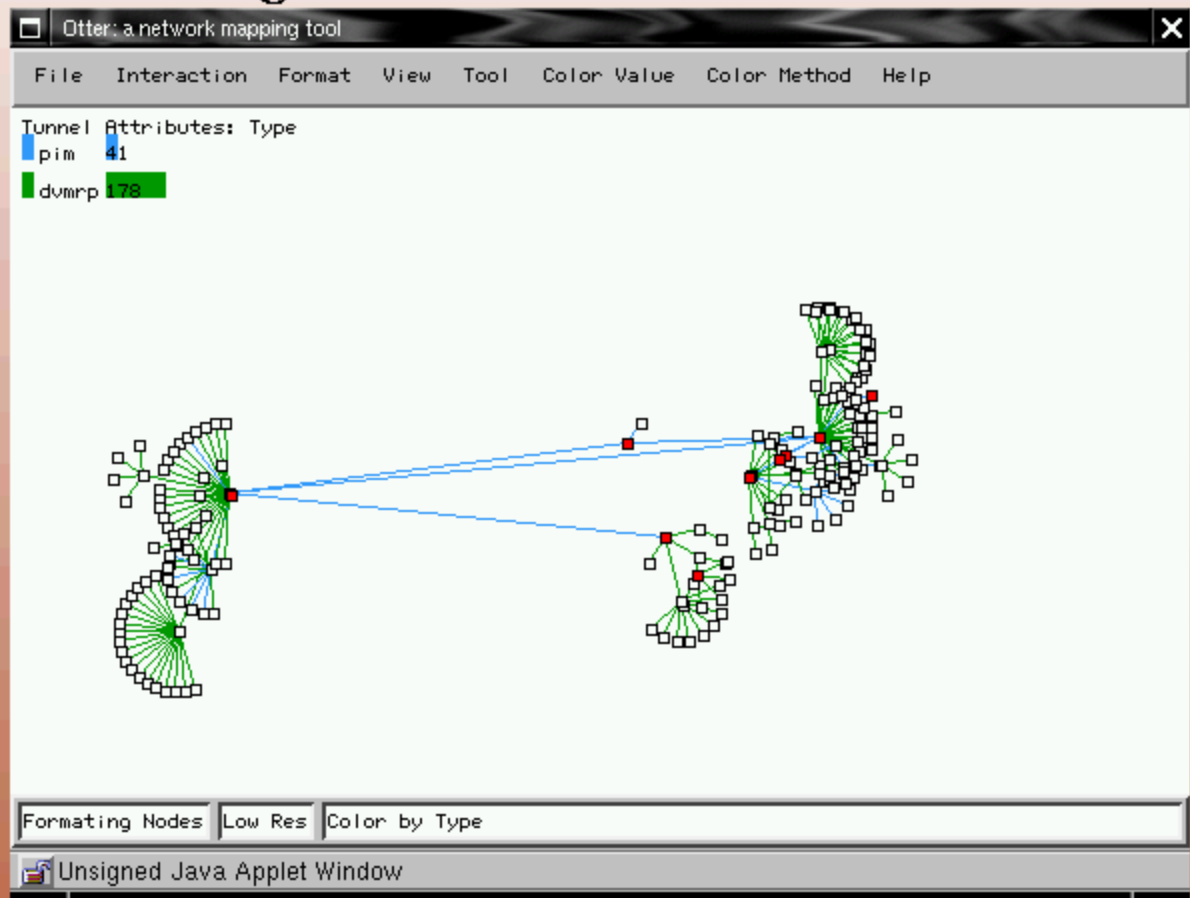


geographic



semi-geographical (otter)

www.caida.org/Tools/Otter



topology: research priorities

■ visualization

- latency
- key routers/networks
- AS granularity
- geographic
- integration w mgt tools

■ obstacles:

mapping IP addresses to

- router
- geography
- AS
- service provider
- country
- anything...

route changes faster than can measure

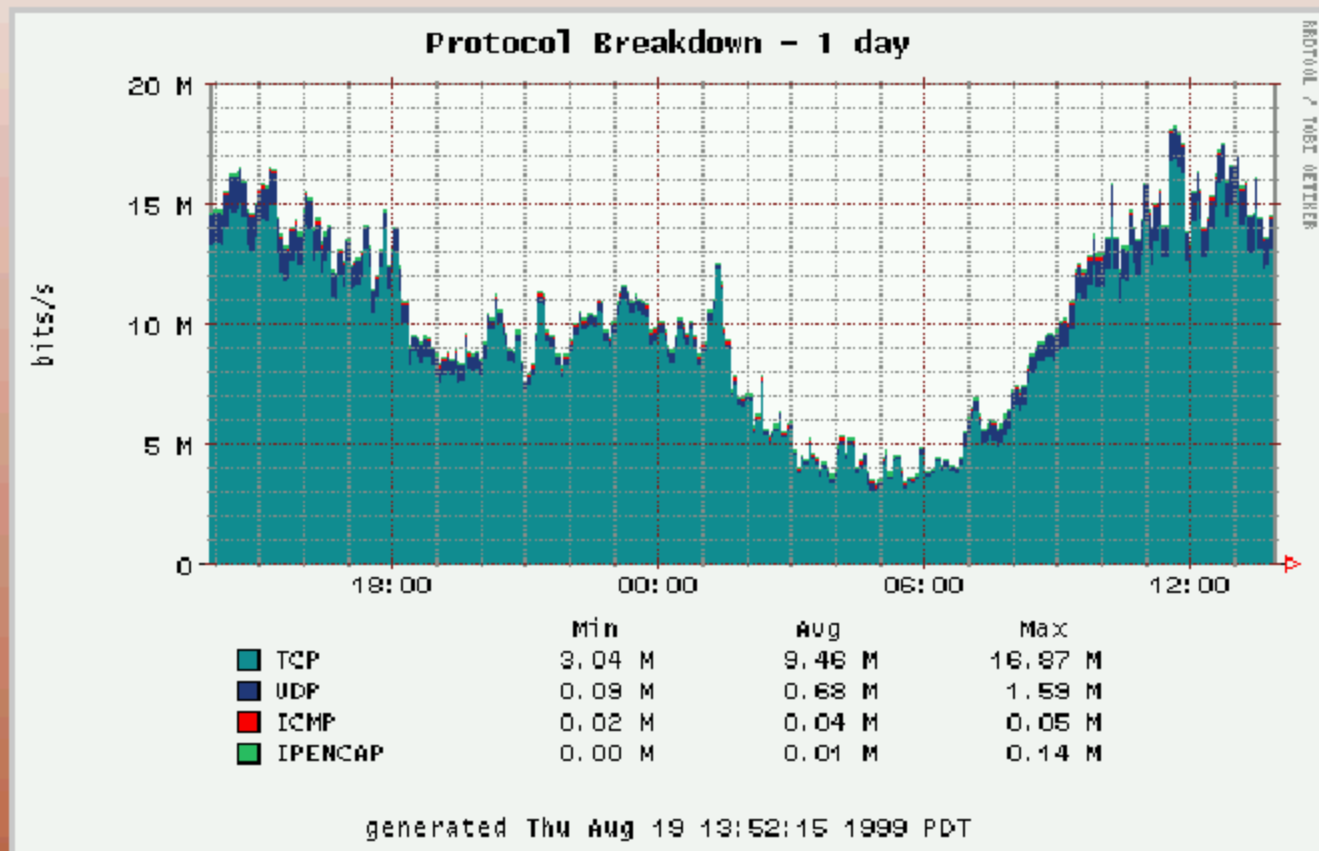
workload characterization

- workload profiling (s/w & h/w design, architecture optimizing, capacity planning)
- security
- performance analysis
 - delay, loss, jitter?
- QOS assurance across ISPs
- accounting/billing

- tools: netramet, netflow, cflowd, coral
 - some suck less? ...evolution requires use

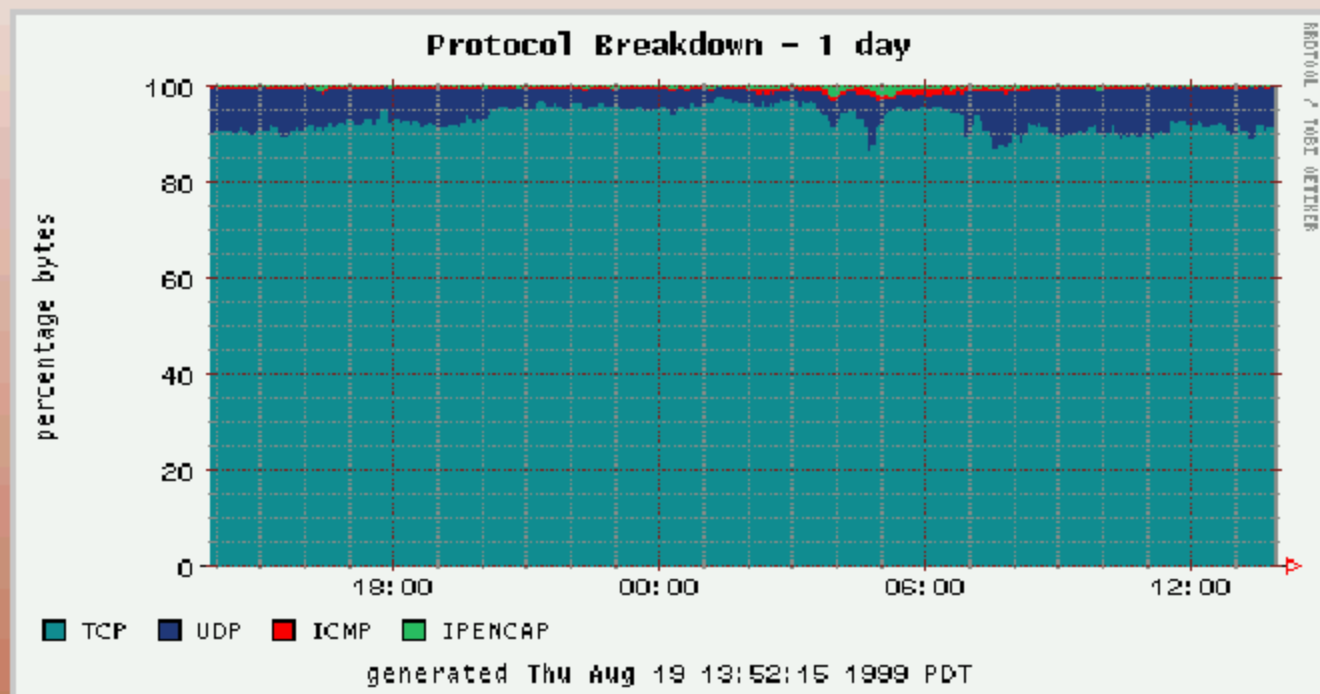
workload char.: protocol

19 aug 99, ucsd-cerfnet

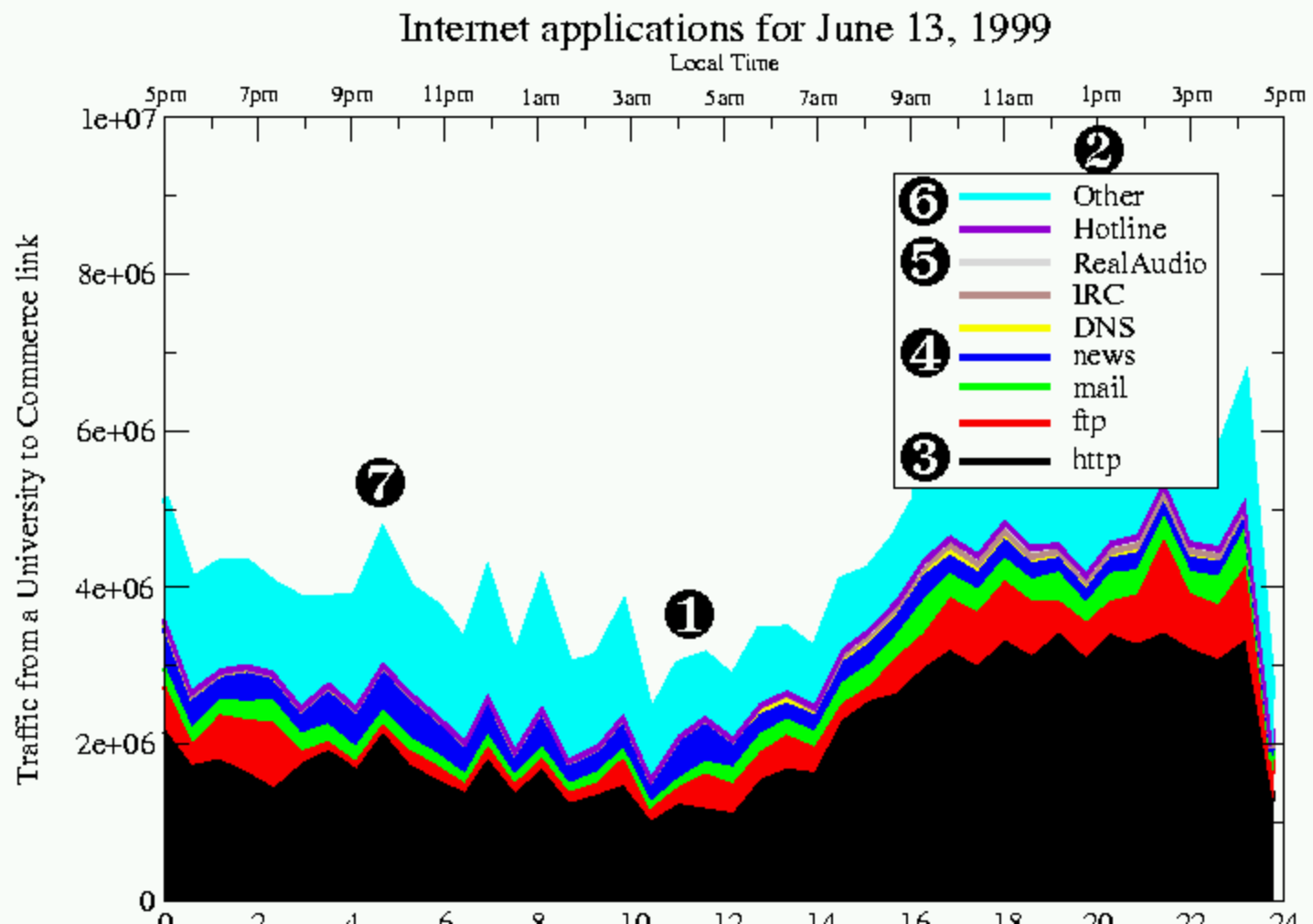


workload char.: protocol (proportion)

19 aug 99, ucsd-cerfnet

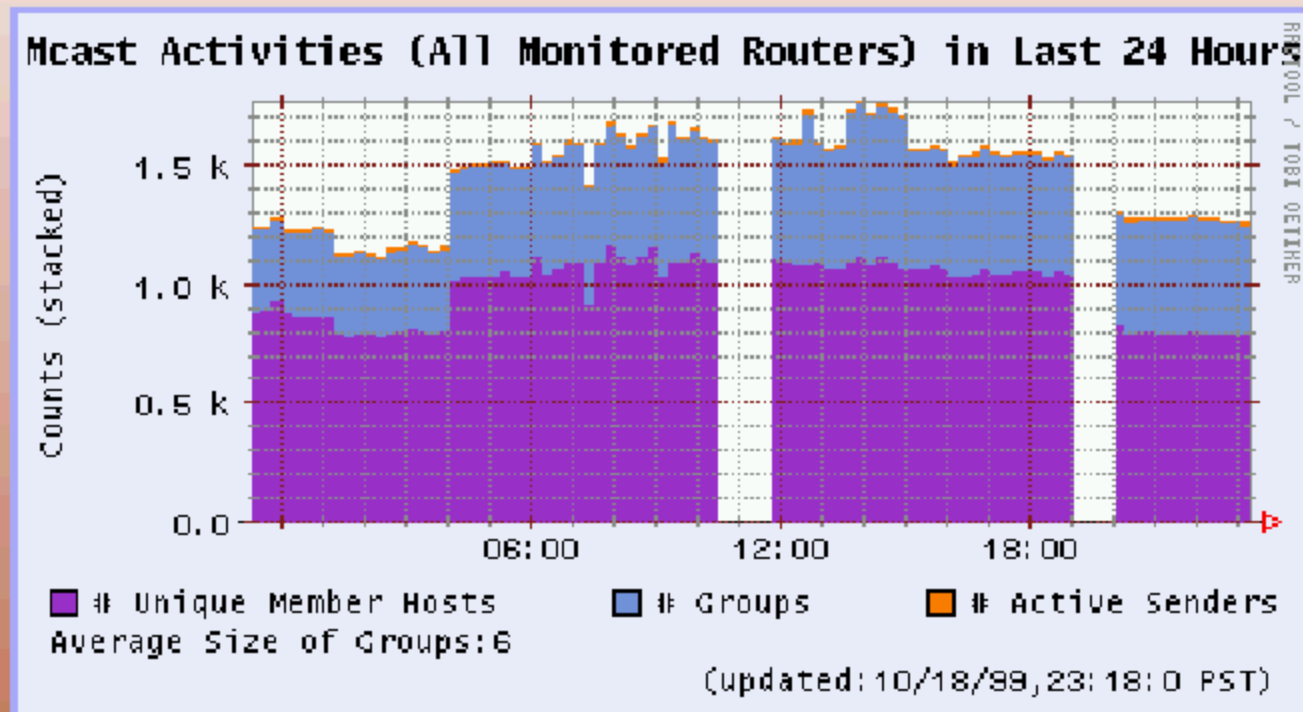


workload char: applications (ucsd-cerfnet)



workload char.: mantra

18 oct 99, fix-west.mbone.nasa.gov

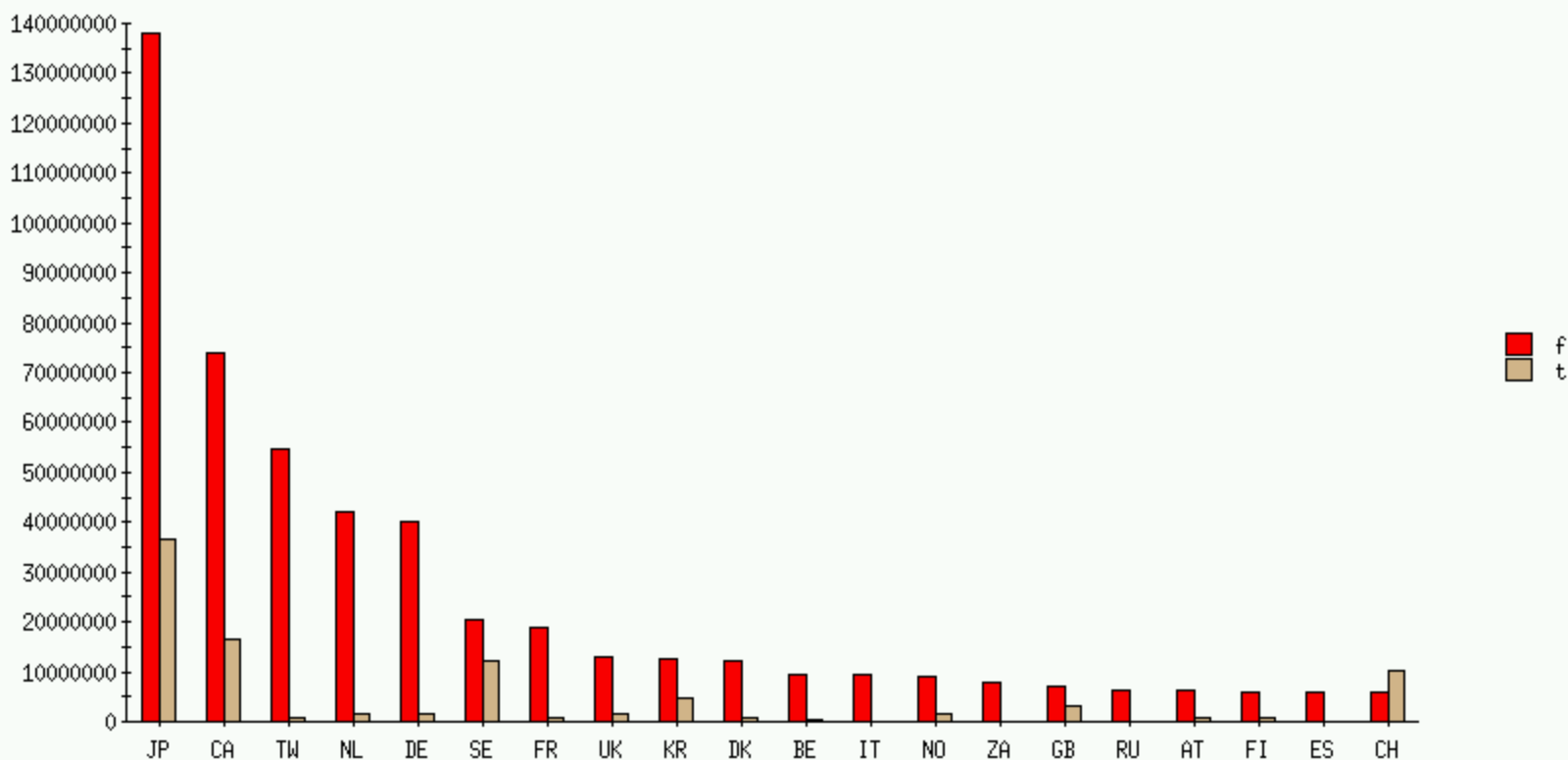


workload: IP trade balance (pkts)

12 march 98, 2 min sample, fixwest

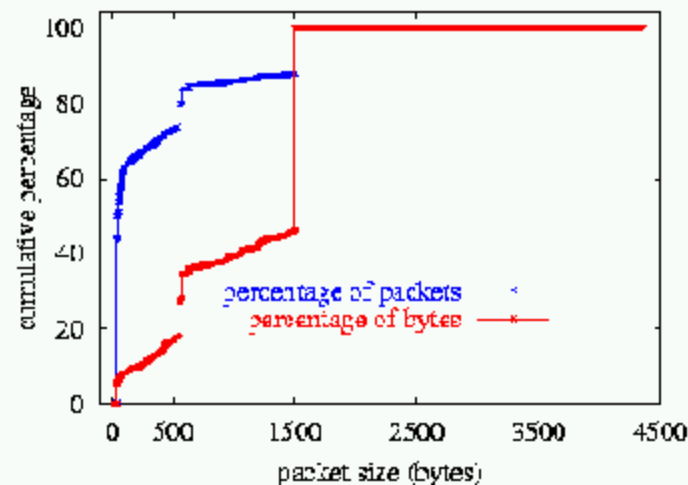
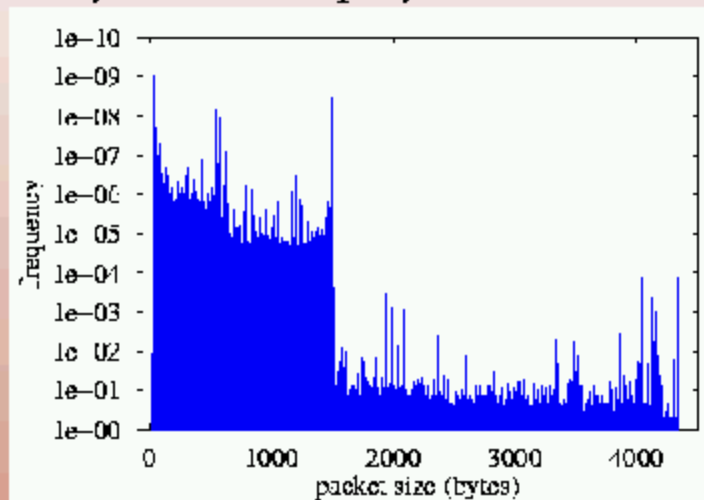
US still net exporter of IP pkts (w/2 exceptions)

980312.1532UT.bytes_bycountry



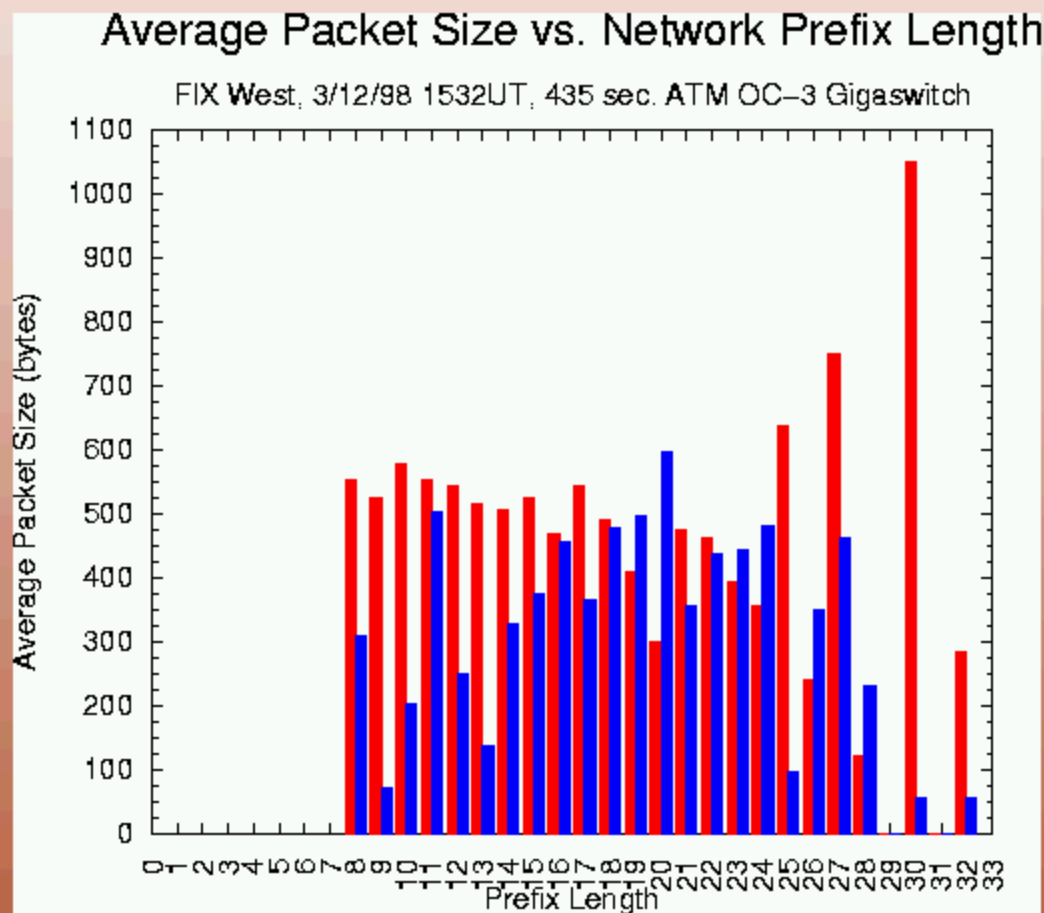
packet sizes, 4/13/98 mci backbone

half pkts 40 bytes, half payload in 1500 byte pkts



packet sizes by prefix length

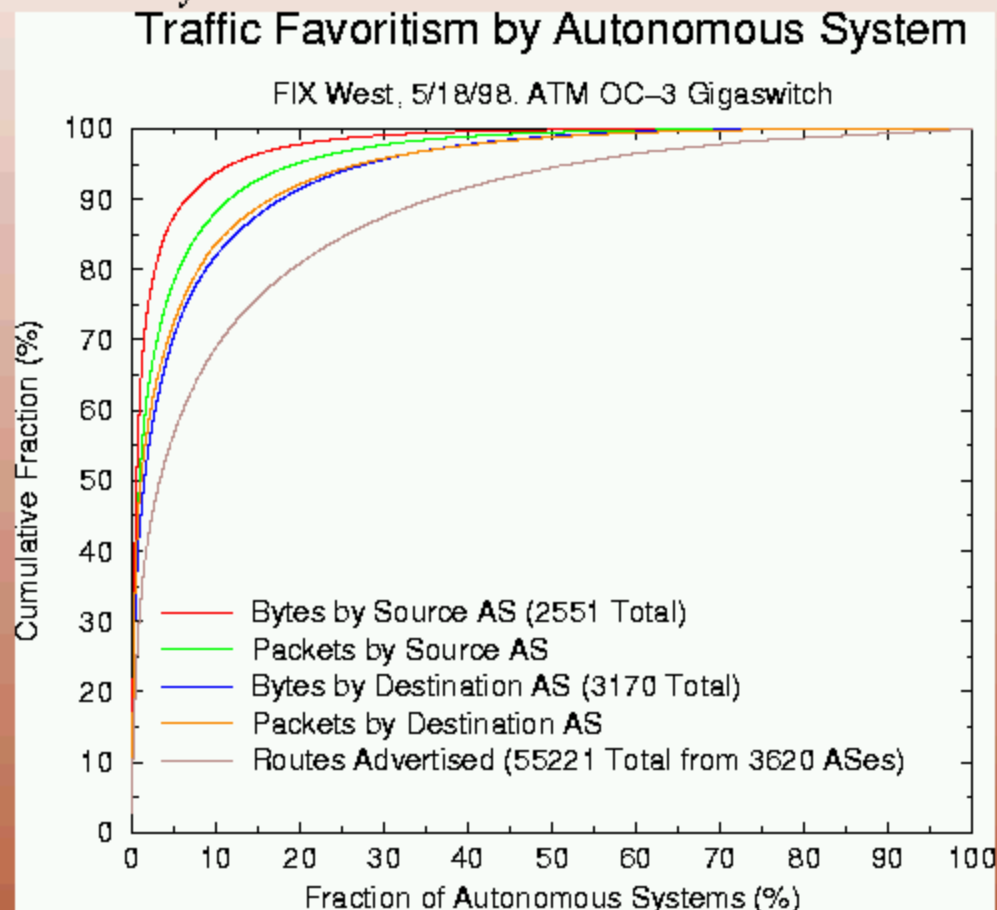
larger packets from shorter prefixes (why?)



favoritism/locality by AS

80% of traffic from < 5% of ASes

60% of reachability from < 7% of ASes

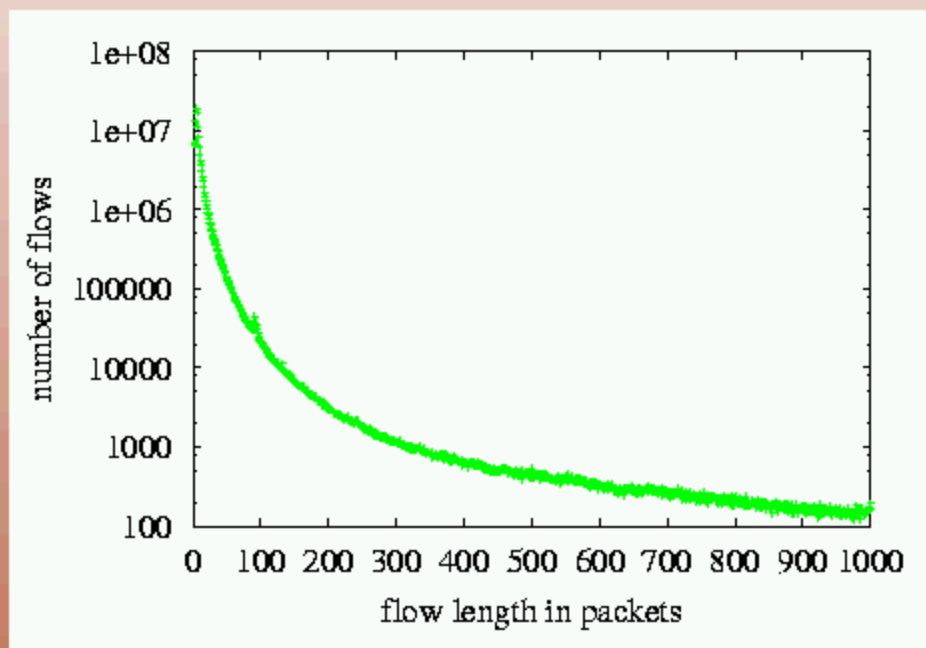


flow length distribution, 4/13/98 mci backbone

heavy tail (quite truncated)

if you only learn about one distribution this quarter...

flow defn creates artifacts (100 bytes)



workload characterization: priorities

- coral/ocXmons (OC3,12,48, gigE)
- persistent, real-time, full-frame collection
- dynamic packet filtering triggered by attack precursors
- security policy
 - compliance auditing (passive)
 - enforcement (active)

obstacles

- hardware expensive
- privacy issues
- IPsec

workload char: working w/vendors

cflowd

- www.caida.org/Tools/Cflowd
- primarily for capacity planning and trend analysis
- Cisco's netflow export

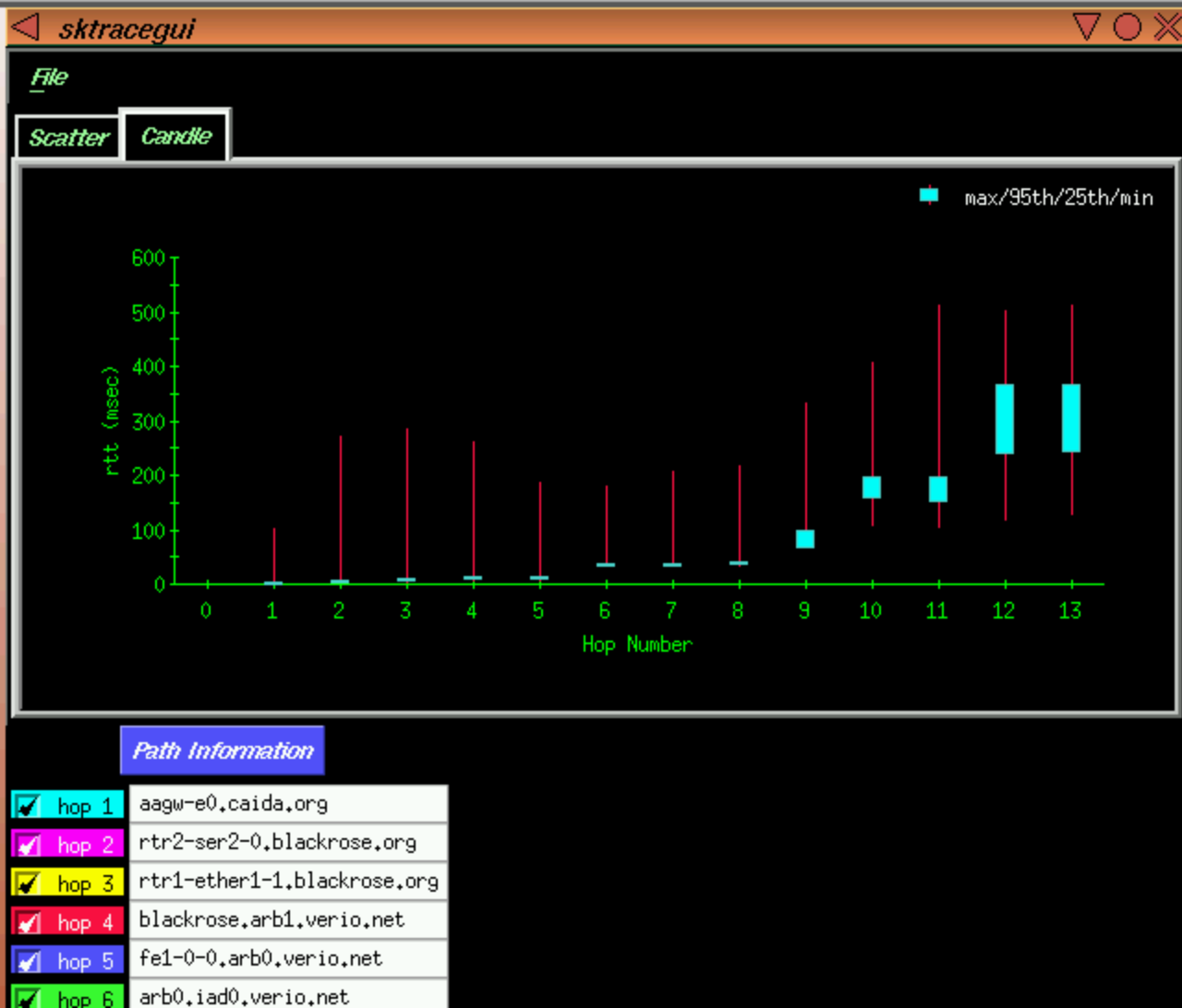
- AS-to-AS matrices
- net-to-net matrices
- port and protocol tables
- forward IP path

measurement specifications to vendors

performance evaluation (active)

- network engineers to diagnose problems
- ISPs & users to verify SLAs
- designers of real-time apps to predict software HCI
- Internet weather reports

perf. eval: skping (www.freebsd.org)

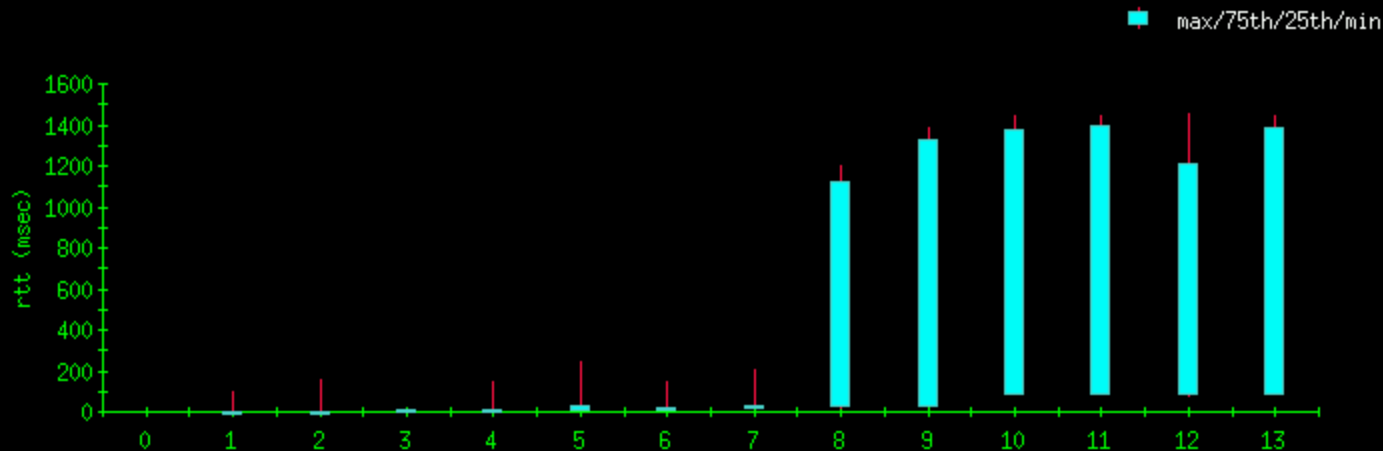
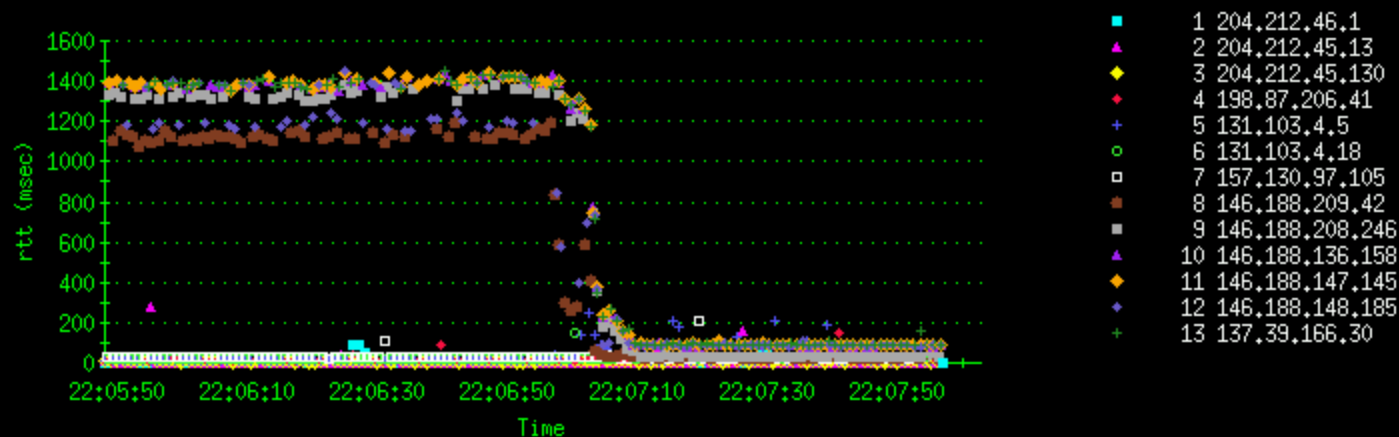


perf.eval: routing (path change)



perf.eval: sktrace (www.cnet.com)

sktracegui



performance eval.: priorities

- definitions & metrics
- bandwidth assessment techniques
- correlation
 - across sources
 - with workload, routing data
- large scale deployment
- user interface to measurements

obstacles

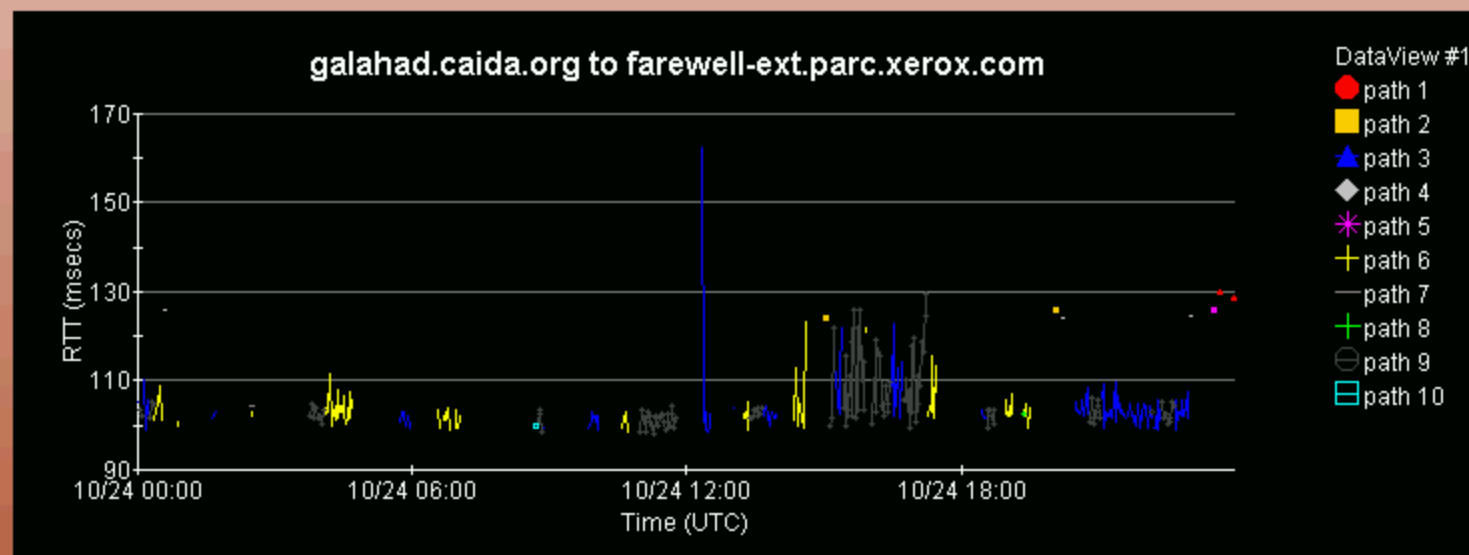
- core infrastructural access
- mathematicians needed
- statisticians needed

routing dynamics

- 15-year-old technology
- admittedly seems like pretty good stuff
- sausage/laws....
- incredibly inefficient, incantation-driven

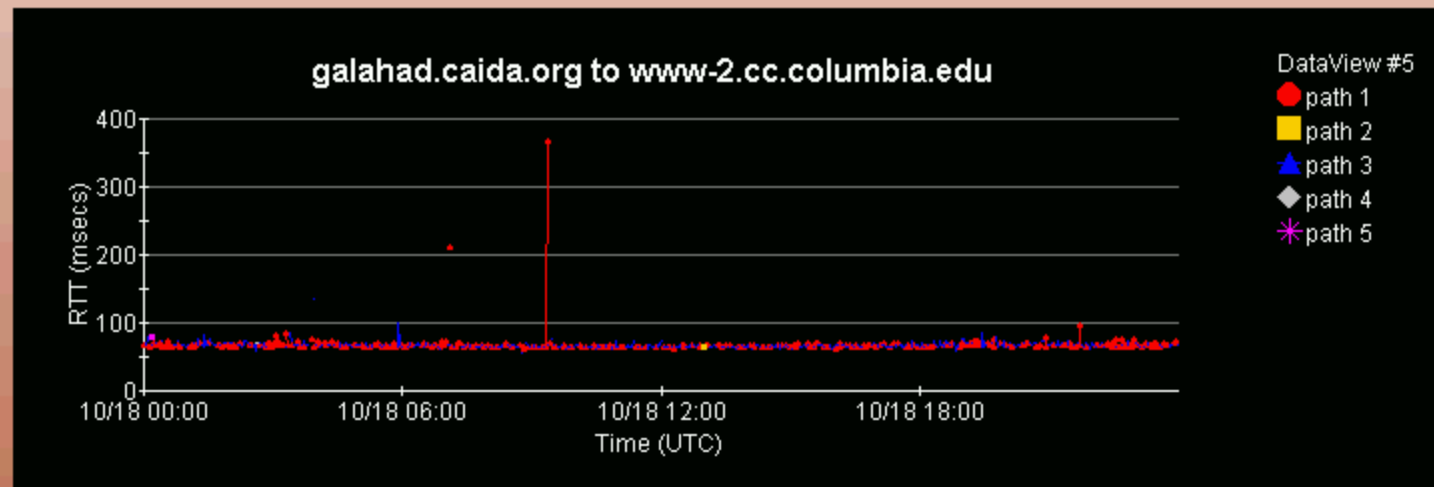
routing: example (instability)

- RTT data changes color if path changes
- 10 unique paths over 24 hour period
- lots of jitter in data
 - unlikely to be intentional
- heavy tails predominate

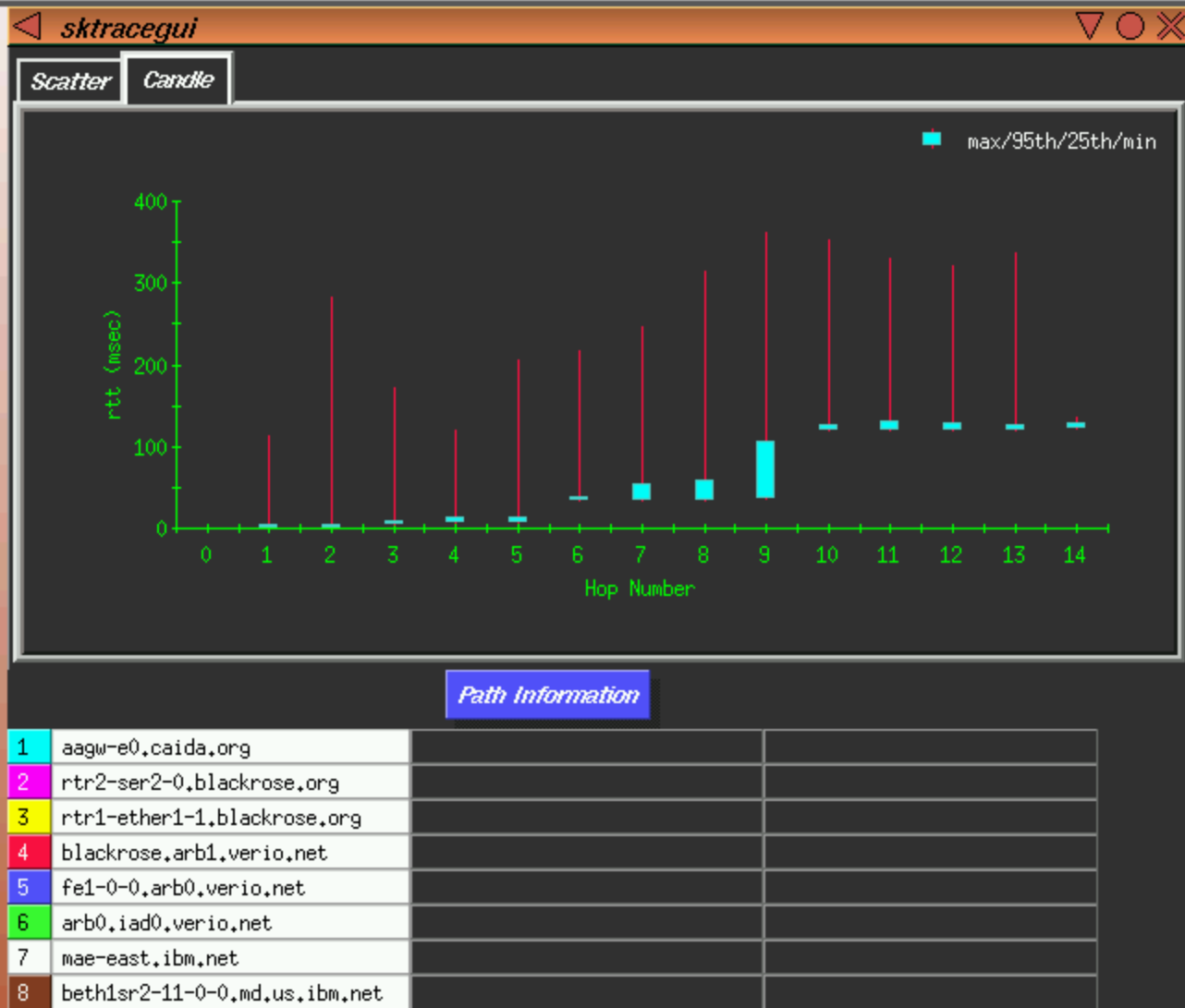


routing: example (load balancing)

- RTT similar over predominantly two paths
- likely intentional load balancing



routing: sktrace (parc.xerox.com)



routing: research priorities

- effects of outages on surrounding ISPs
- effects of topology changes on Internet performance
- unintended consequences of new policies
 - MPLS
 - traffic engineering
- dynamic detection/response to congestion & topology changes
- identifying vulnerabilities created by dependencies on critical paths
- utilization of address space
- efficiency of routing table
- asymmetric, instabilities in routing across providers
- effects of unicast/multicast incongruity

routing: research obstacles

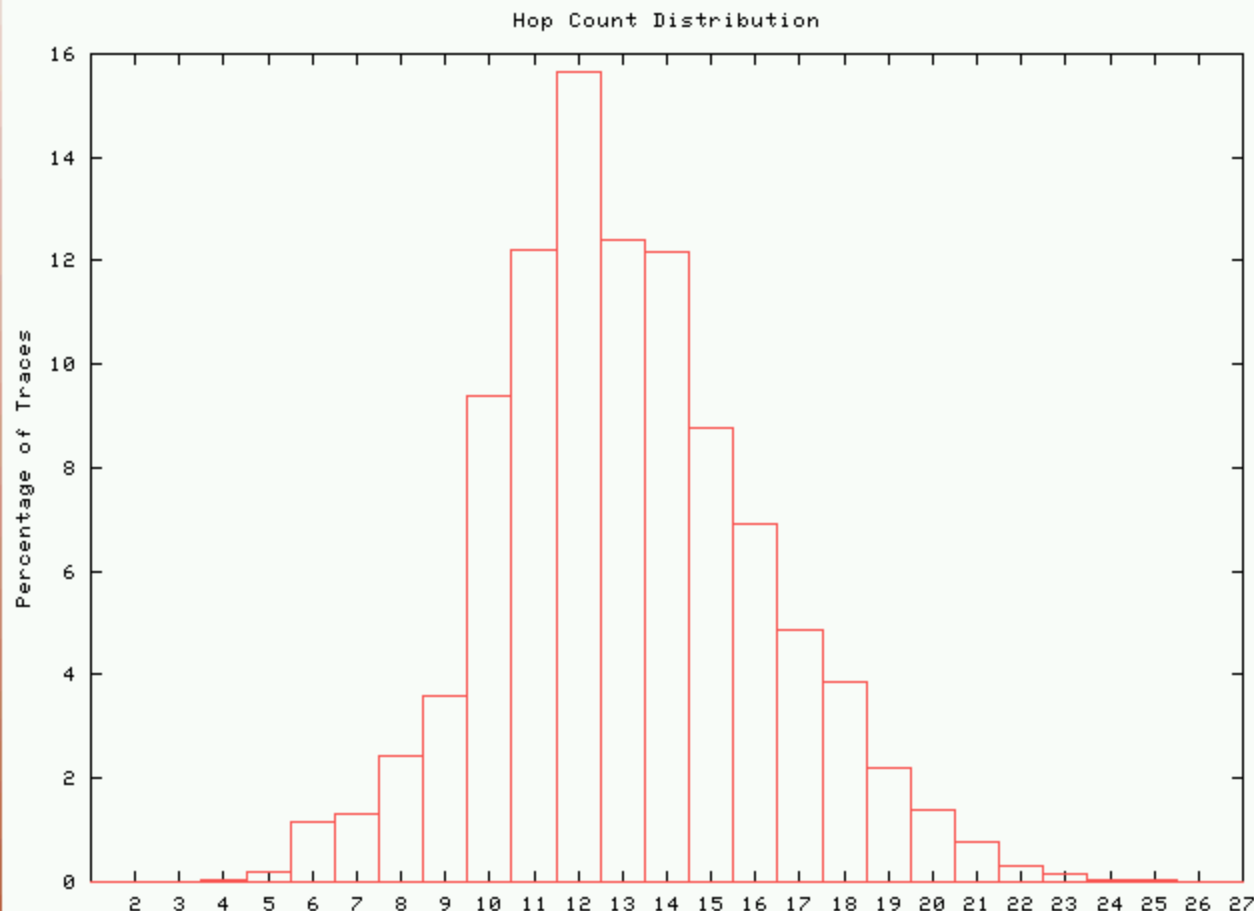
- canonical BGP (route table) data
(not so much anymore)
- mapping IP address to anything
(we've been here before)
- prudent security dictates making research difficult

now what?

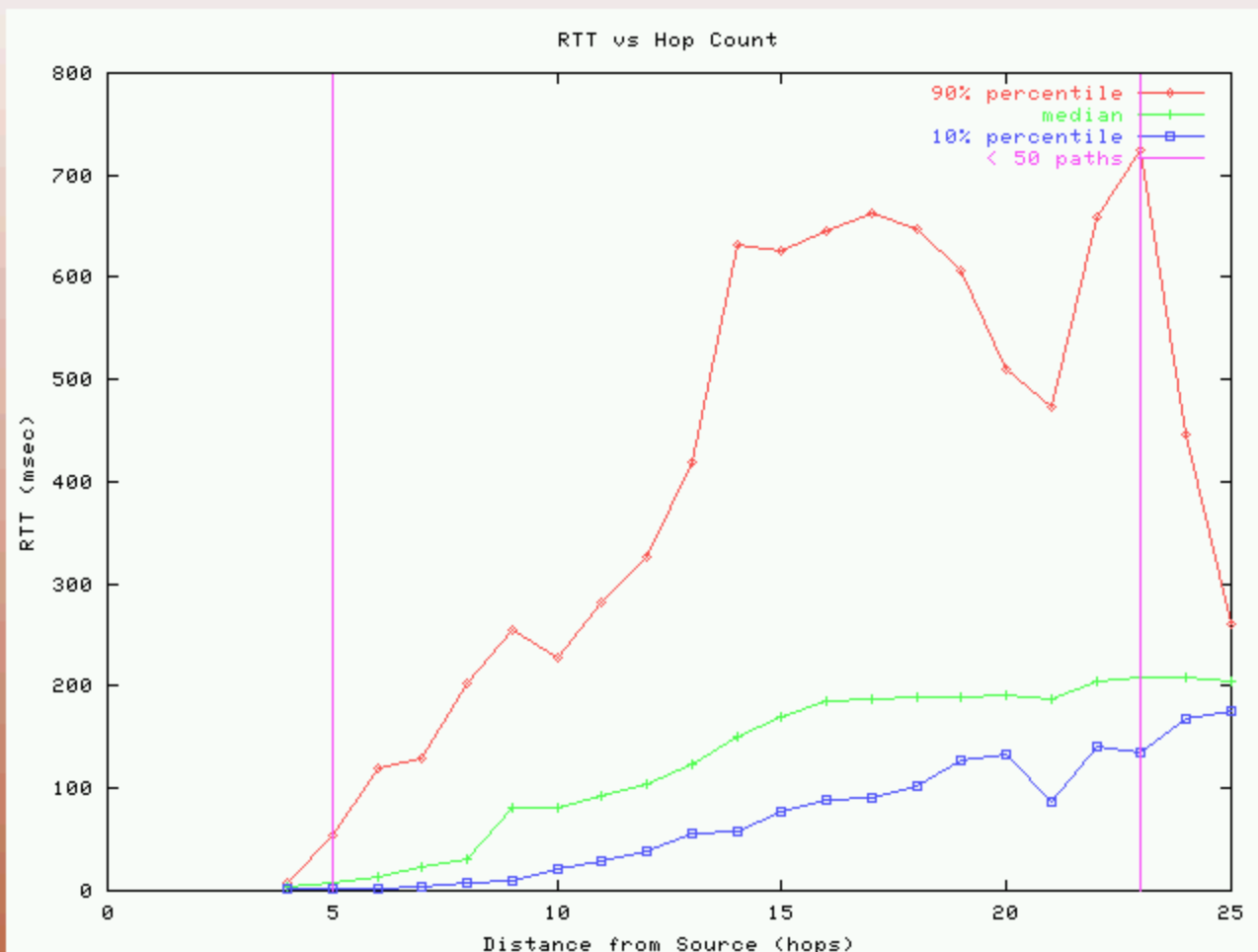
- ‘seamless’: no such thing
- measurement tools/infrastructure
 - well-considered
 - strategically deployed
 - collaboratively maintained
- more infrastructure-relevant research on resulting data
 - feedback into tool design
- correlation among data sources/types, simulation, visualization
- proactive participation
 - top-down (app devel’s scope constr.)
 - bottom-up (ISP cooperation)

skitter: macroscopic study

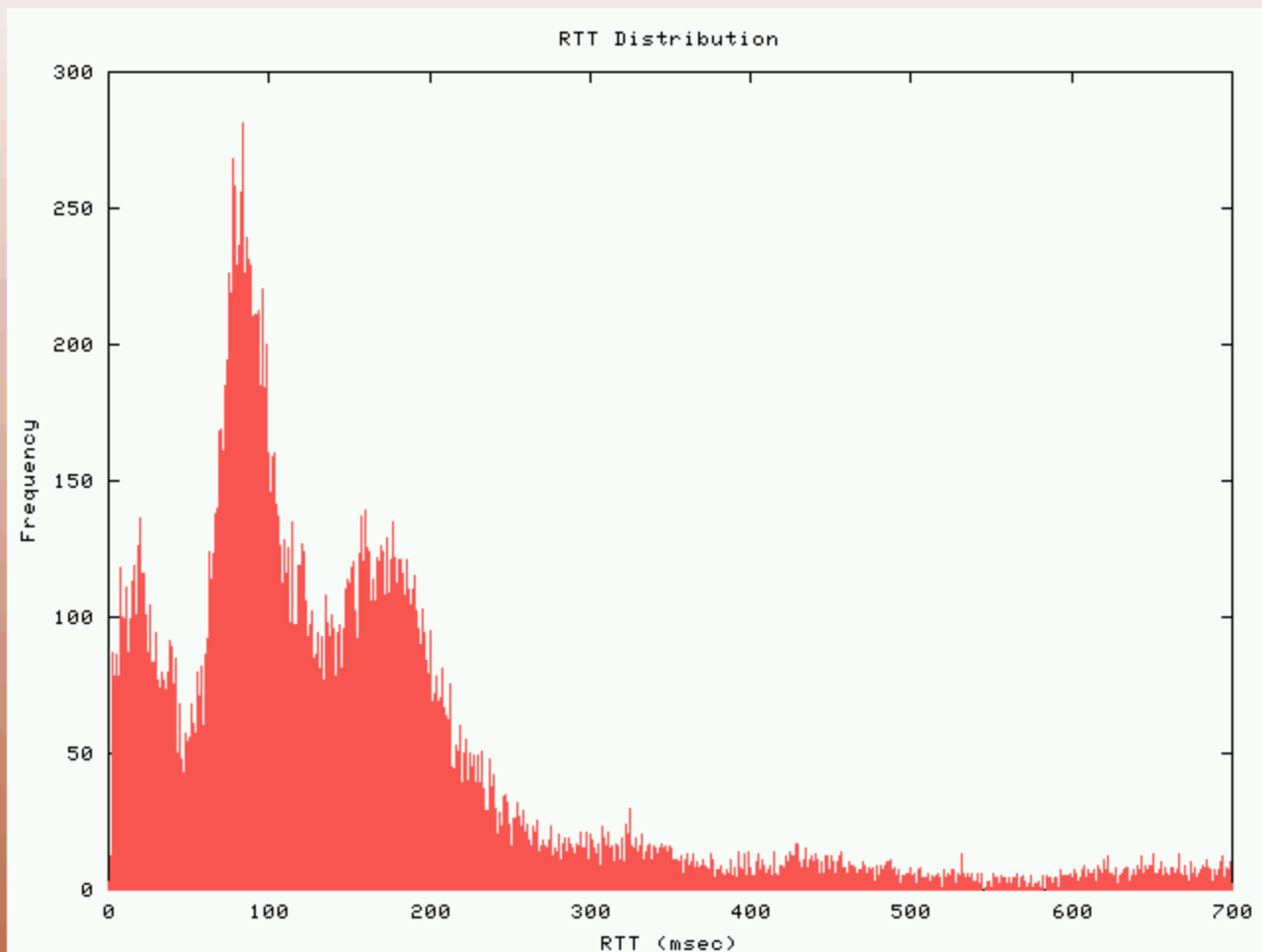
DNS f root server (pv's): path wingspans
www.caida.org/Tools/Skitter/



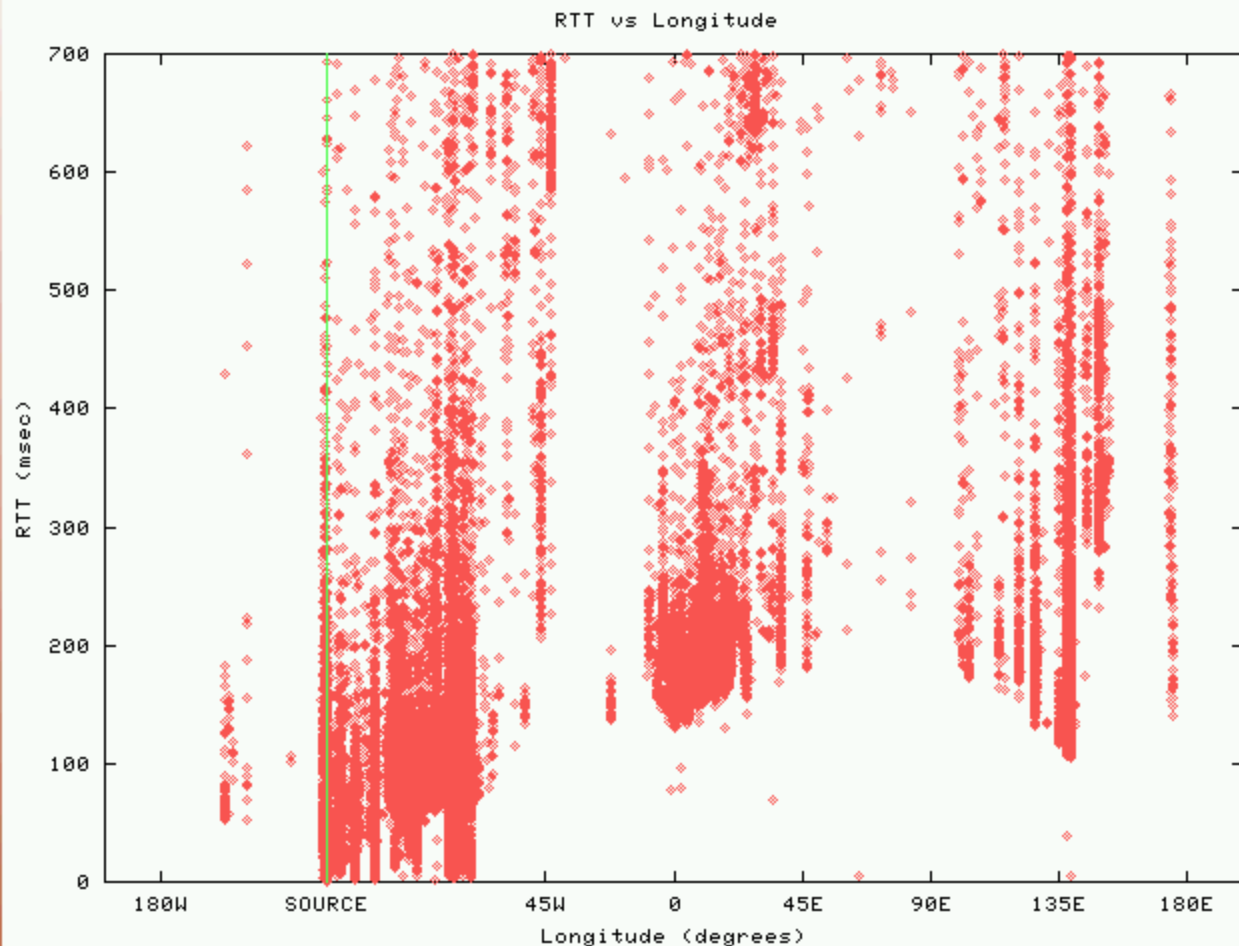
skitter: rtt vs hopcount (correlation?)



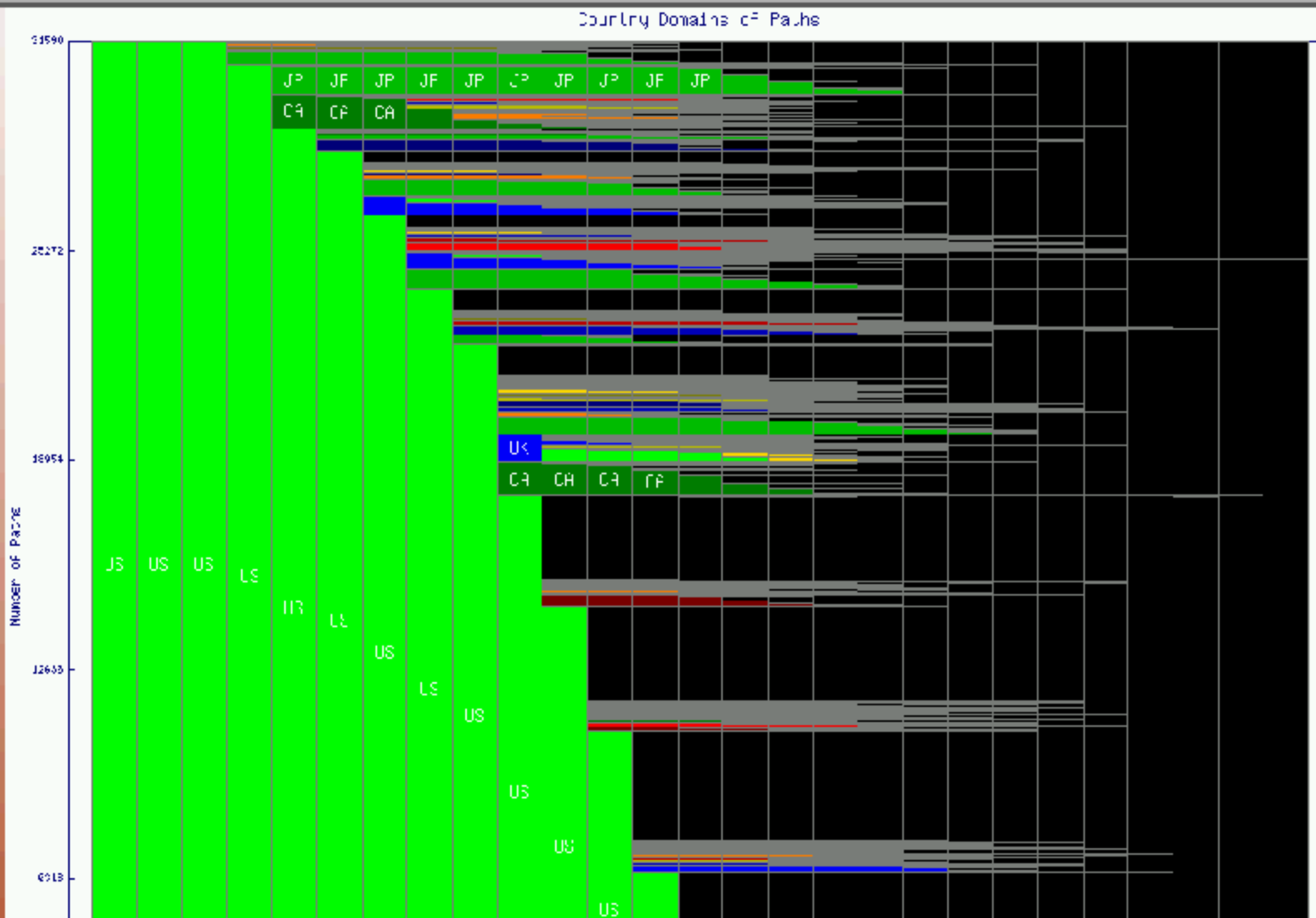
skitter: rtt distribution: tri-modal

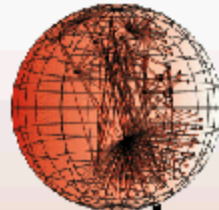


skitter: rtt vs longitude (light cone)



dispersion among countries across paths





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