

Internet measurement: topology, workload, performance and routing

16 dec 1998

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caida's focus

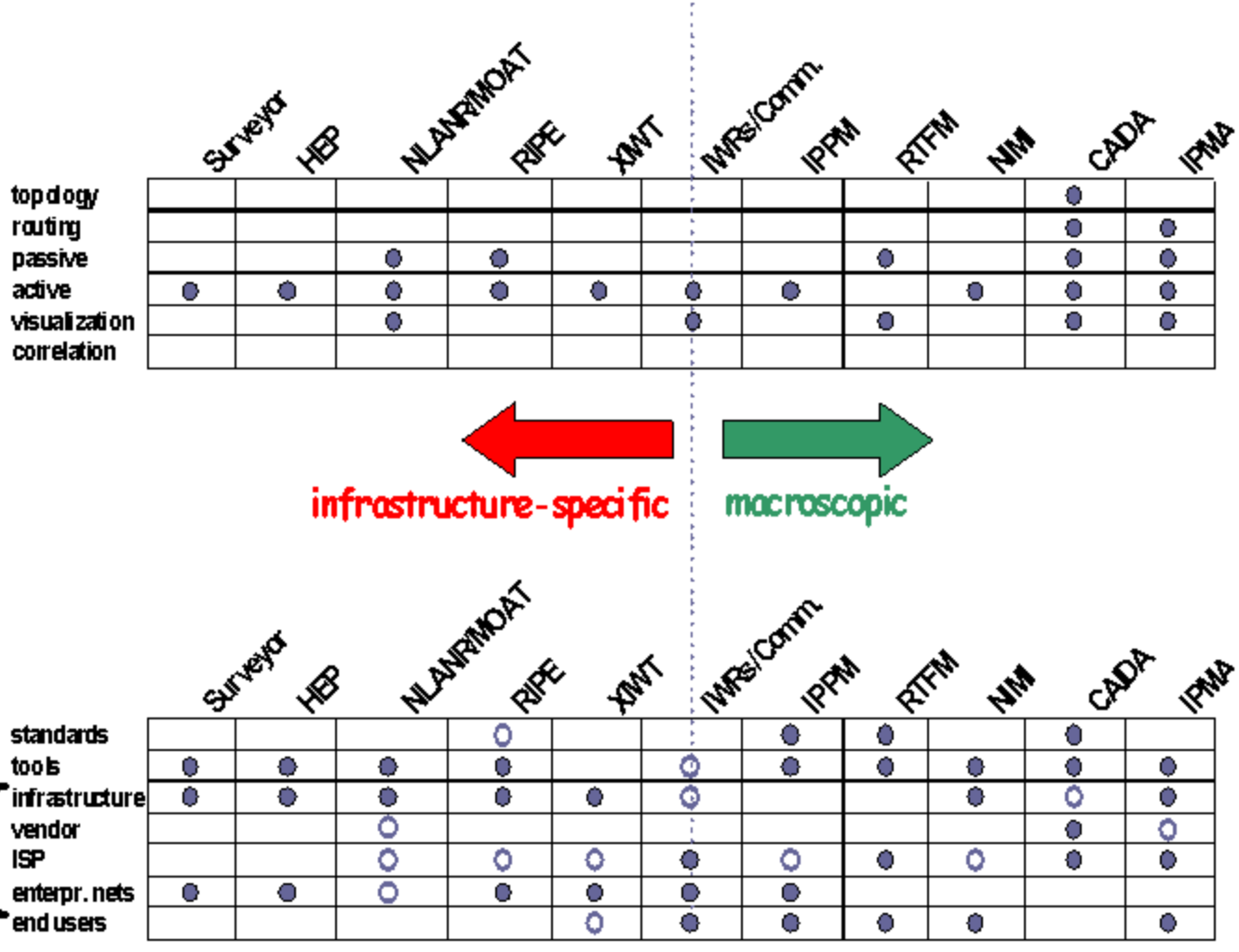
- advancing the capacity to monitor, depict, and predict traffic behavior on current and advanced networks
- developing and deploying tools to better engineer and operate networks and to identify traffic anomalies in real time



payoffs

- insights for vendors re next generation hw/sw requirements
- calibration for users, e.g., monitoring sla's
- diagnostic and planning tools for ISPs
- windows into the infrastructure for researchers

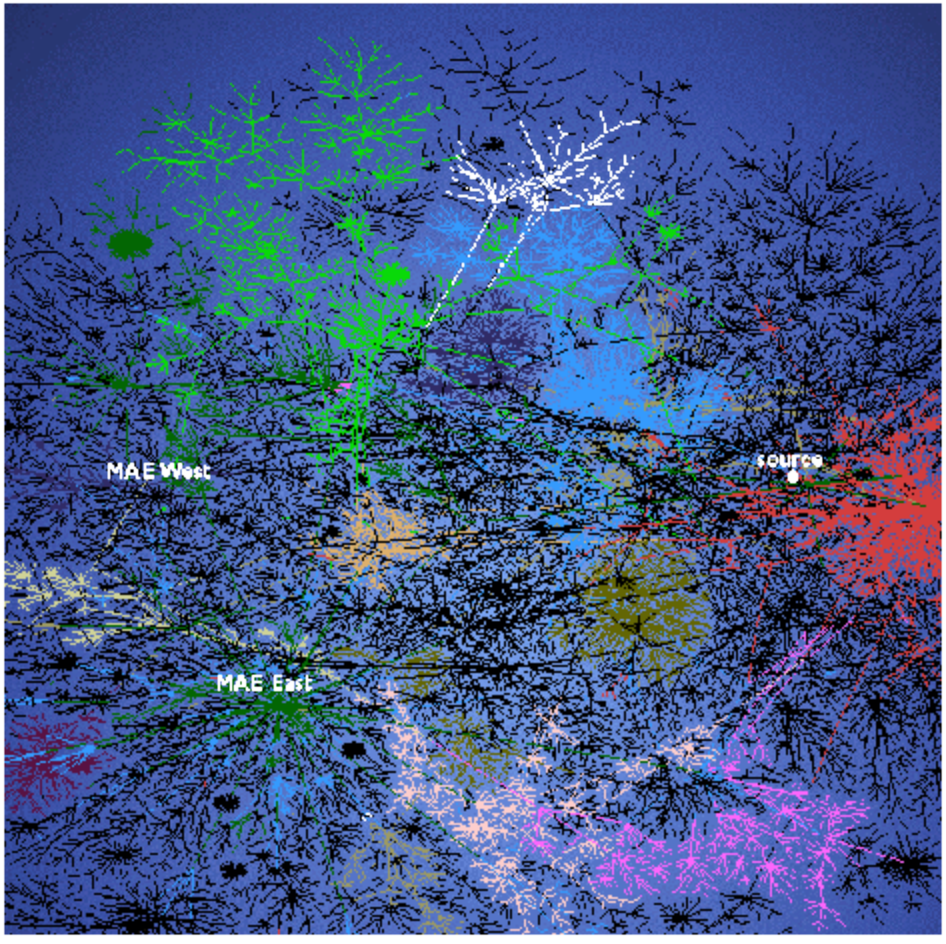
no dearth of activity





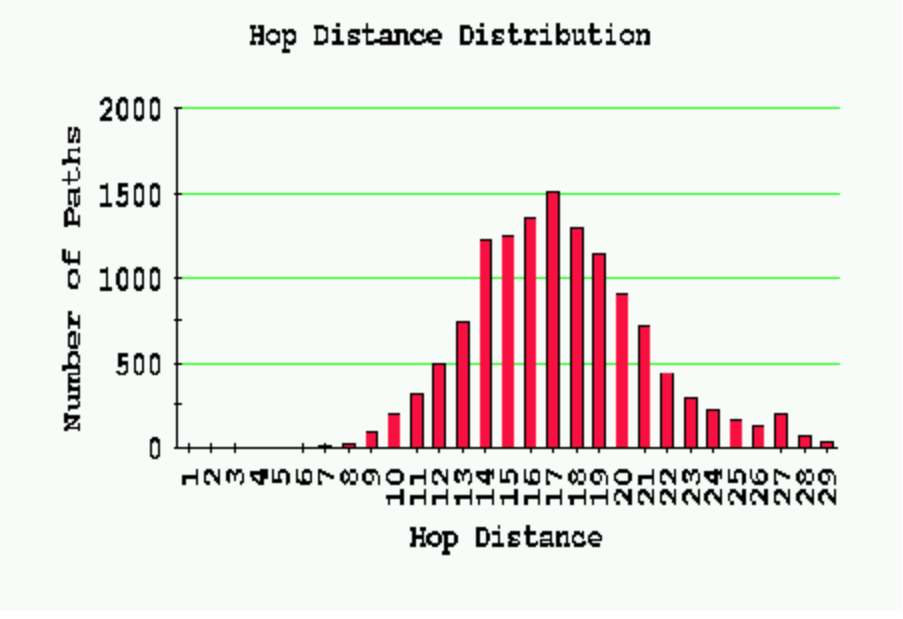
active measurement: skitter

- goals:
  - dynamically discover/ depict network topology (directed graphs rooted at sources)
  - correlate effects of BGP routing changes
  - correlate path performance with specific events
- Daniel McRobb (UCSD/CAIDA) developer



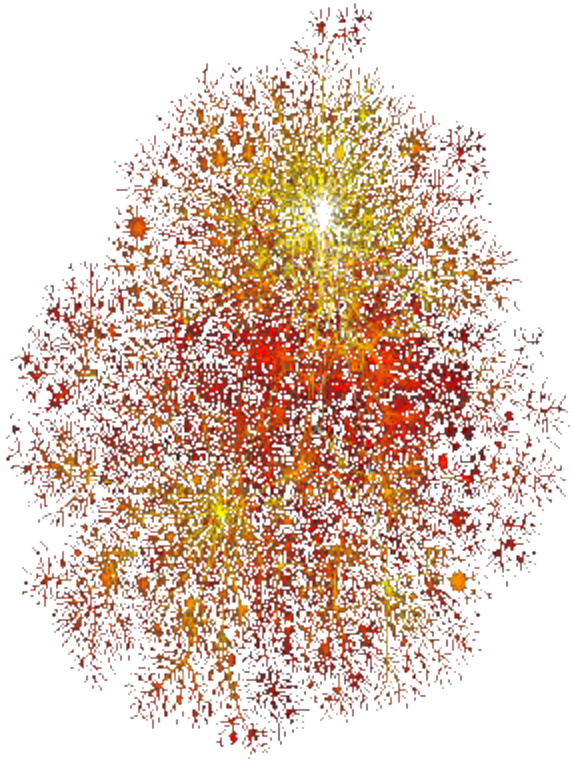
skitter: infrastructure-wide measurements

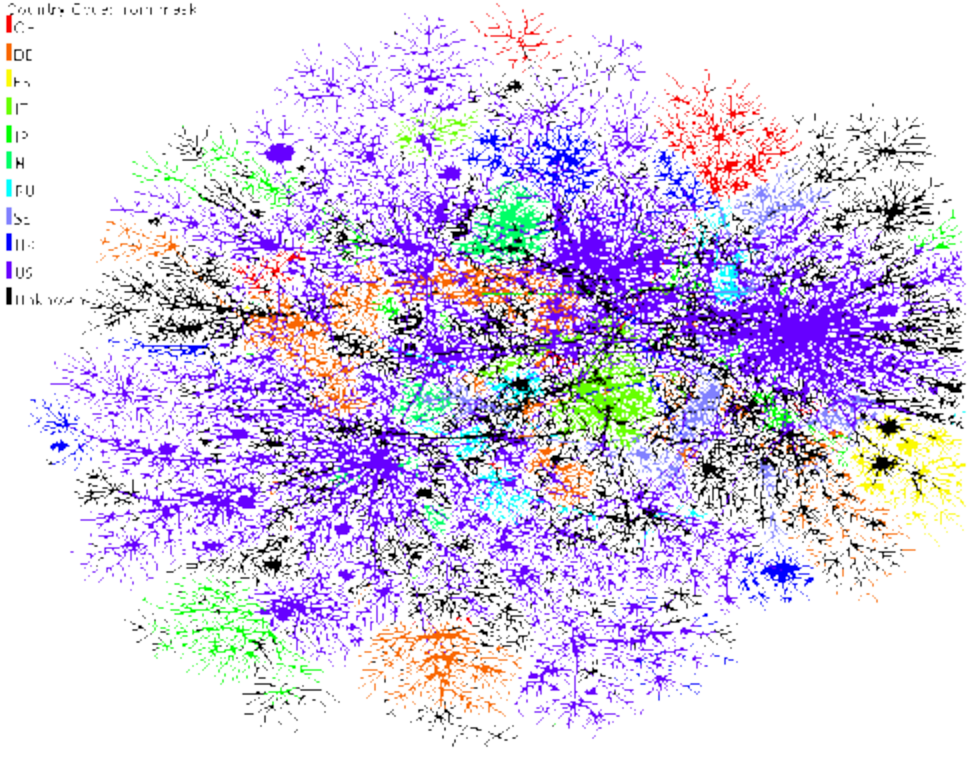
- 6 monitors
- 23K (eventually 60K) destinations
- architecture
  - parallel ICMP probes
  - 52-byte packets
  - kernel time stamping
  - *ssh* / Kerberos



www.caida.org/ISMA/isma9808/slides/isma98-skitter/

visualizations of connectivity / topology





colored by distance from source
www.caida.org/Tools/Skitter/viz/hal.html

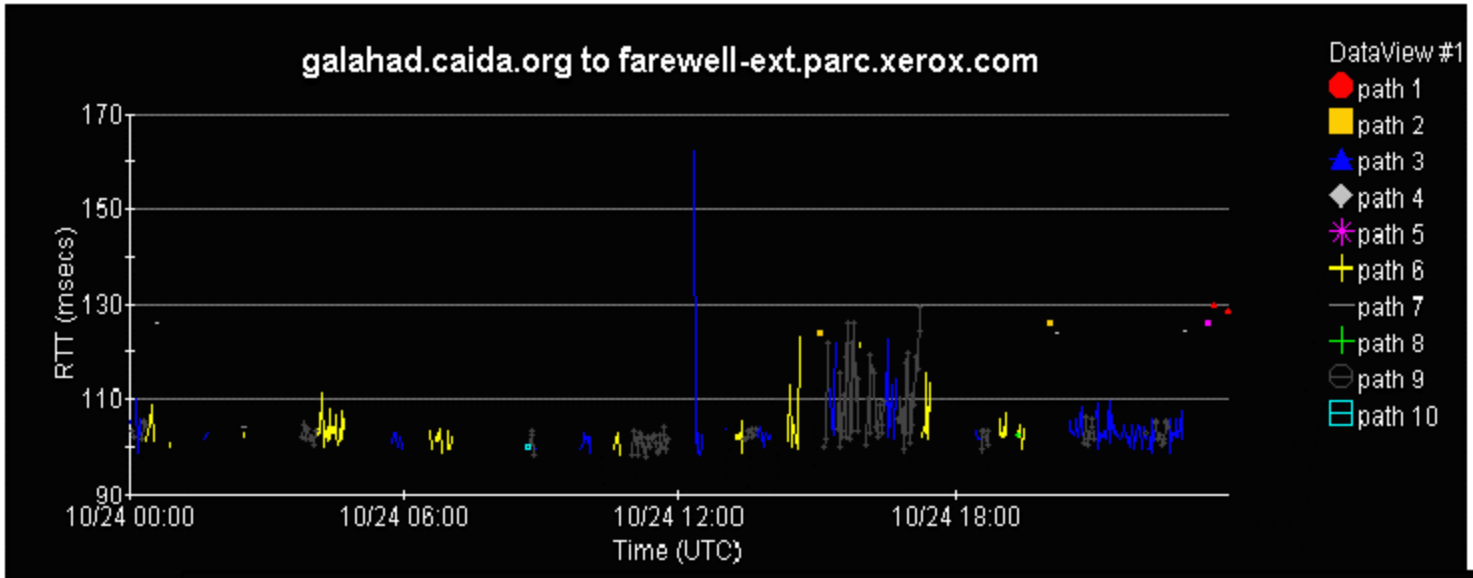
colored by country-level domain
www.caida.org/Tools/Otter/Skitter/Images/



skitter as rtt analysis tool

- path connectivity & performance: used in assessing route stability and ISP performance (~5 minute)
- end2end performance: rtt between source and destination sites (10-20 pps)
- h/w performance: depicts nuances of specific h/w & OS (ms granularity)



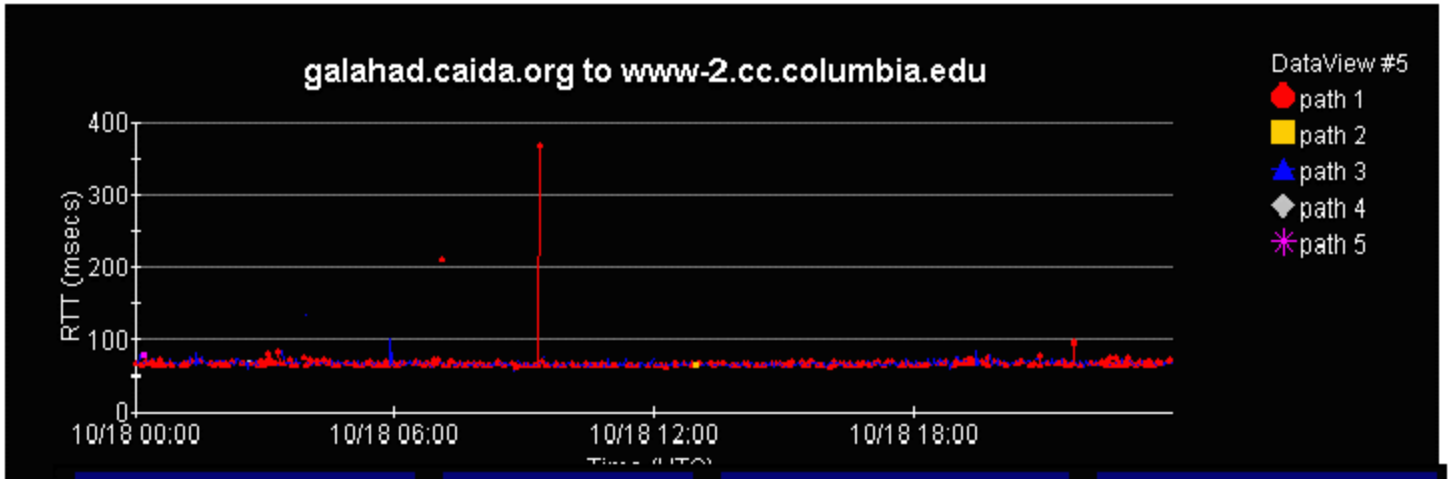


RTT Statistics

Path #	Min	25th	Median	75th
1	128.646	128.646	129.898	129.898
2	124.205	124.205	125.795	125.795
3	98.561	101.782	102.519	104.873
4	124.077	124.077	124.557	125.93
5	126.147	126.147	126.147	126.147
6	99.111	101.826	102.768	104.557
7	104.312	104.312	104.312	104.312
8	102.657	102.657	102.657	102.657
9	98.049	101.763	102.935	105.17
10	99.958	99.958	99.958	99.958

	path 1	path 2	path 3	path 4	
1	aagw-e0.caida.org	aagw-e0.caida.org	aagw-e0.caida.org	aagw-e0.caida.org	1
2	rtr2-ser2-0.blackrose.org	rtr2-ser2-0.blackrose.org	rtr2-ser2-0.blackrose.org	rtr2-ser2-0.blackrose.org	2
3	rtr1-ether1-1.blackrose.org	rtr1-ether1-1.blackrose.org	rtr1-ether1-1.blackrose.org	rtr1-ether1-1.blackrose.org	3
4	blackrose.arb1.verio.net	blackrose.arb1.verio.net	blackrose.arb1.verio.net	blackrose.arb1.verio.net	4
5	fe1-0-0.arb0.verio.net	fe1-0-0.arb0.verio.net	fe1-0-0.arb0.verio.net	fe1-0-0.arb0.verio.net	5
6	arb0.iad0.verio.net	arb0.iad0.verio.net	arb0.iad0.verio.net	arb0.iad0.verio.net	6
7	mae-east.ibm.net	mae-east.ibm.net	mae-east.ibm.net	mae-east.ibm.net	7
8	beth1sr2-11-0-0.md.us.ibm.net	beth1sr2-11-0-0.md.us.ibm.net	beth1sr2-11-0-0.md.us.ibm.net	beth1sr2-11-0-0.md.us.ibm.net	8
9	beth1br2-3-0.md.us.ibm.net	beth1br2-1-1-0.md.us.ibm.net	beth1br1-0-0-0.md.us.ibm.net	beth1br2-1-1-0.md.us.ibm.net	9
10	165.87.230.102	165.87.230.102	165.87.230.98	165.87.230.102	10
11	165.87.33.115	165.87.33.115	165.87.33.131	165.87.33.115	11
12	165.87.161.5	165.87.161.5	165.87.161.5	165.87.161.5	12
13	ign2-f00.snfc21.pbi.net	ign2-f00.snfc21.pbi.net	ign2-fe12-0-0.snfc21.pbi.net	ign2-fe12-0-0.snfc21.pbi.net	13
14	209.232.138.114	209.232.138.114	209.232.138.114	209.232.138.114	14
dst	farewell-ext.parc.xerox.com	farewell-ext.parc.xerox.com	farewell-ext.parc.xerox.com	farewell-ext.parc.xerox.com	dst





RTT Statistics

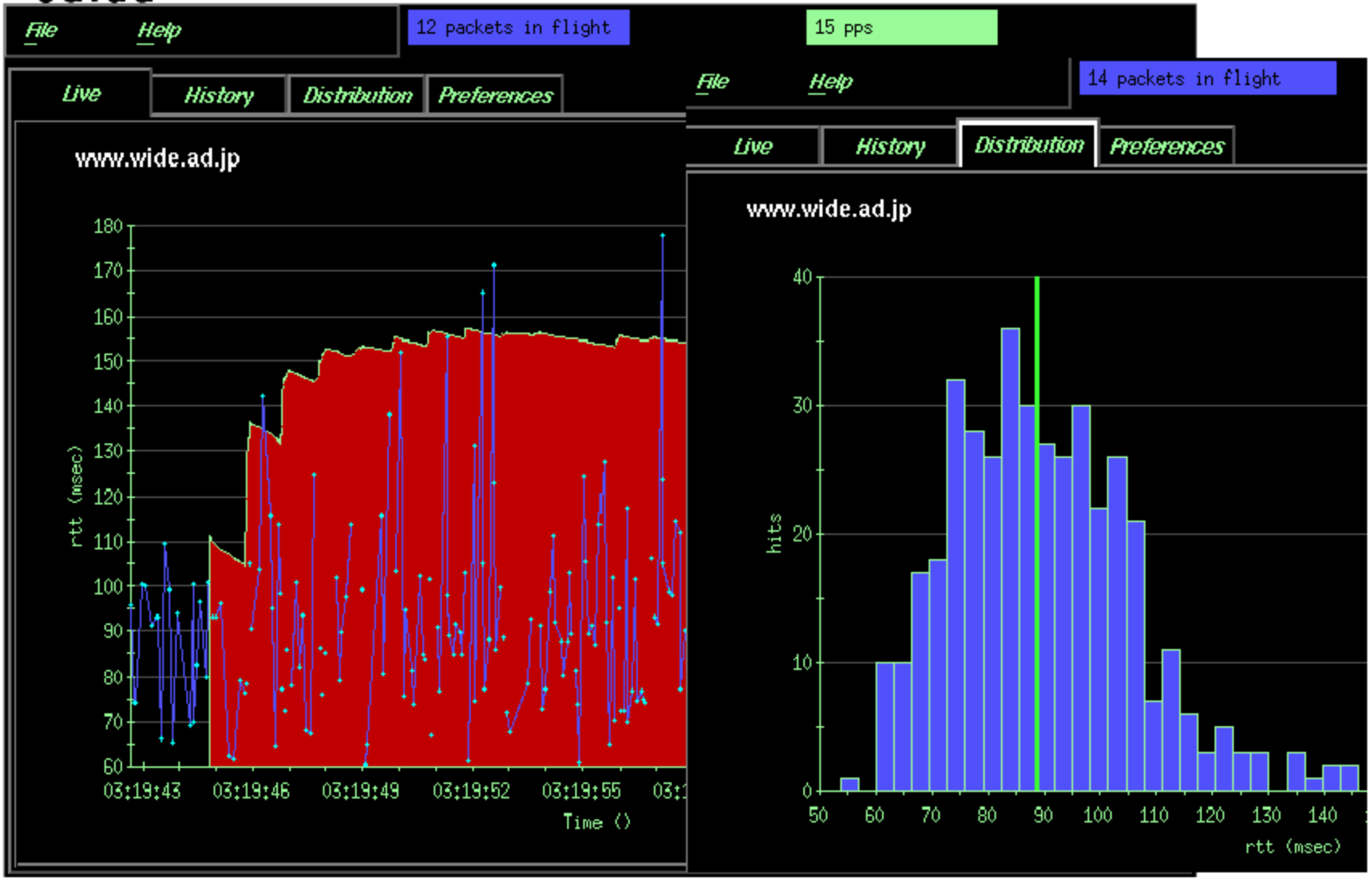
Path #	Min	25th	Median	75th	Max
1	62.879	65.385	66.611	68.646	367.931
2	64.465	64.465	64.465	64.465	64.465
3	55.282	65.038	66.422	68.312	135.117
4	69.467	69.467	69.467	69.467	69.467
5	79.299	79.299	79.299	79.299	79.299

	path 1	path 2	path 3	path 4
1		aagw-e0.caida.org	aagw-e0.caida.org	aagw-e0.caida.org
2	:e.org	rtr2-ser2-0.blackrose.org	rtr2-ser2-0.blackrose.org	rtr2-ser2-0.blackrose.org
3	se.org	rtr1-ether1-1.blackrose.org	seed-ether0.blackrose.org	arb0.pit1.verio.net
4		blackrose.arb1.verio.net	198.87.206.41	fe5-1-0.pit0.verio.net
5	w.qual.net	fe1-0-0.arb0.verio.net	border1-ser1-0-1.dtw.qual.net	pit0.mdt1.verio.net
6	l-0.cle.qual.net	arb0.pit1.verio.net	bordercore1-ser12-1-0.cle.qual.net	fe0-0-0.mdt0.verio.net
7	0.mdw.qual.net	fe5-1-0.pit0.verio.net	bordercore1-ser1-0-0.mdw.qual.net	mdt0.phl0.verio.net
8	bordercore2-hssi1-0-0.ord.qual.net	pit0.mdt1.verio.net	bordercore2-hssi1-0-0.ord.qual.net	phl0-1.pne0-1.verio.net
9	sl-gw12-chi-9-0.sprintlink.net	fe0-0-0.mdt0.verio.net	sl-gw12-chi-9-0.sprintlink.net	192.157.69.10
10	sl-bb11-chi-1-2.sprintlink.net	mdt0.phl0.verio.net	sl-bb11-chi-1-2.sprintlink.net	sl-bb12-pen-3-3.sprintlink.net
11	sl-bb10-nyc-0-0.sprintlink.net	phl0-0.pne0-0.verio.net	sl-bb10-nyc-0-0.sprintlink.net	sl-bb10-pen-10-0.sprintlink.net
12	sl-bb11-nyc-9-0.sprintlink.net	dst www-2.cc.columbia.edu	sl-bb11-nyc-9-0.sprintlink.net	at-bb1-pen-0-0-0.appliedtheory.net
13	sl-bb10-pen-5-0.sprintlink.net		sl-bb10-pen-5-0.sprintlink.net	at-bb3-nyc-0-1-0.appliedtheory.net
14	sl-bb10-pen-10-0.sprintlink.net		sl-bb10-pen-10-0.sprintlink.net	at-gw1-nyc-0-0.appliedtheory.net
15	at-bb1-pen-0-0-0.appliedtheory.net		at-bb1-pen-0-0-0.appliedtheory.net	at-columbia-1-0-T3.appliedtheory.net
16	at-bb3-nyc-0-1-0.appliedtheory.net		at-bb3-nyc-1-0-0-T3.appliedtheory.net	vortex-gw.net.columbia.edu
17	at-gw1-nyc-0-0.appliedtheory.net		at-gw1-nyc-0-0.appliedtheory.net	dst www-2.cc.columbia.edu

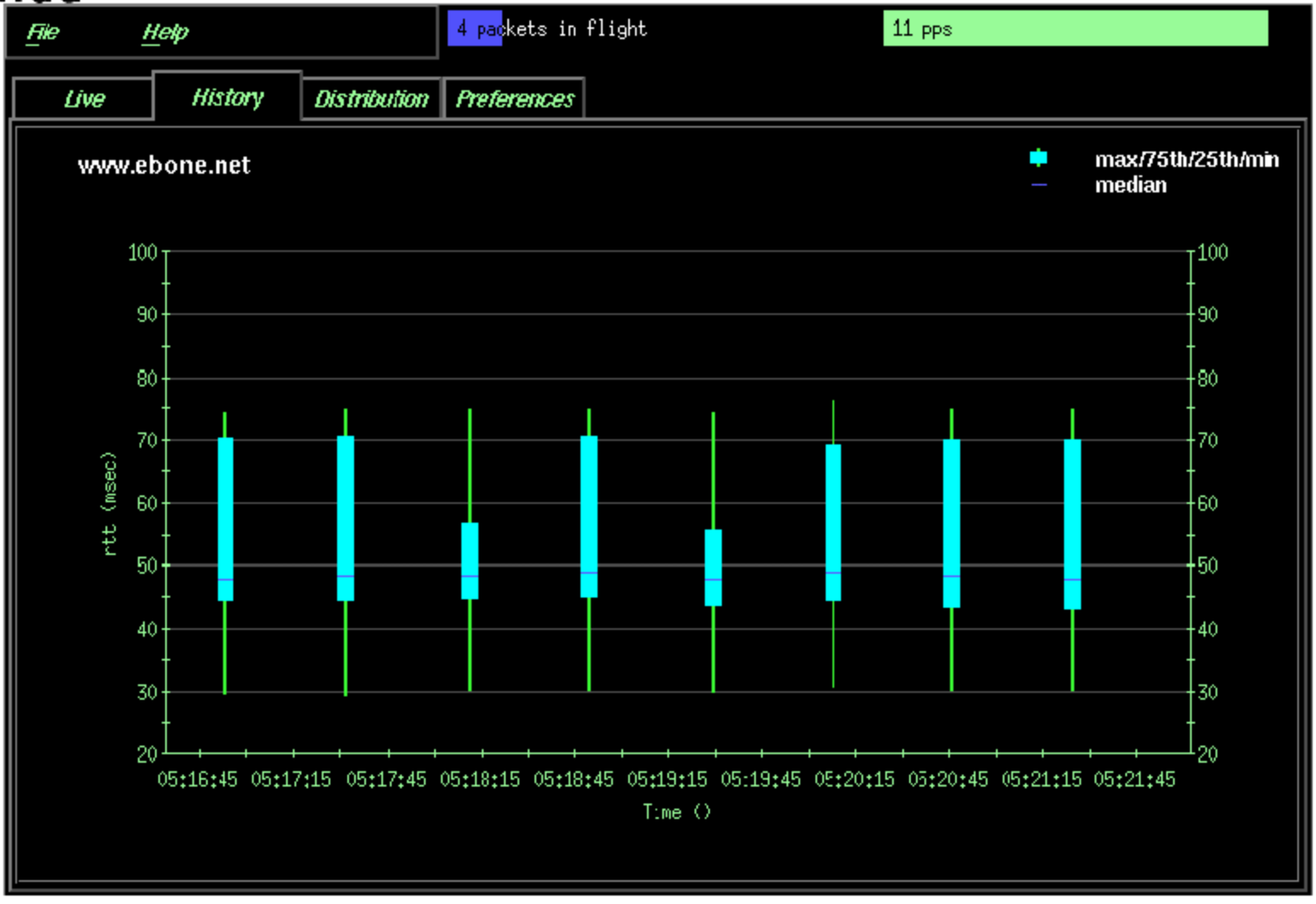
skitter: rtt/loss & distribution (.se)



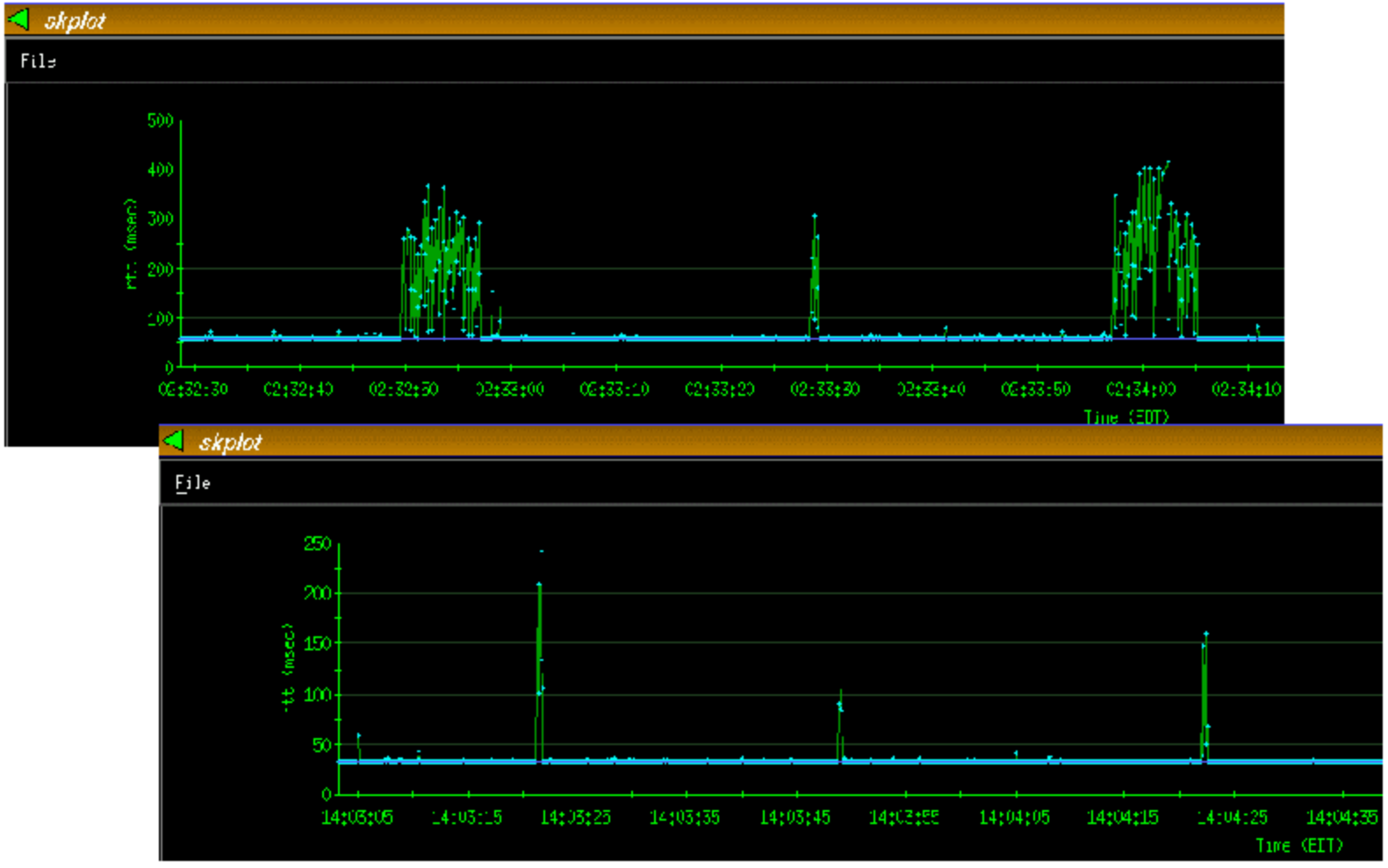
skitter: rtt/loss & distribution (.jp)



skitter: rtt history (.se)

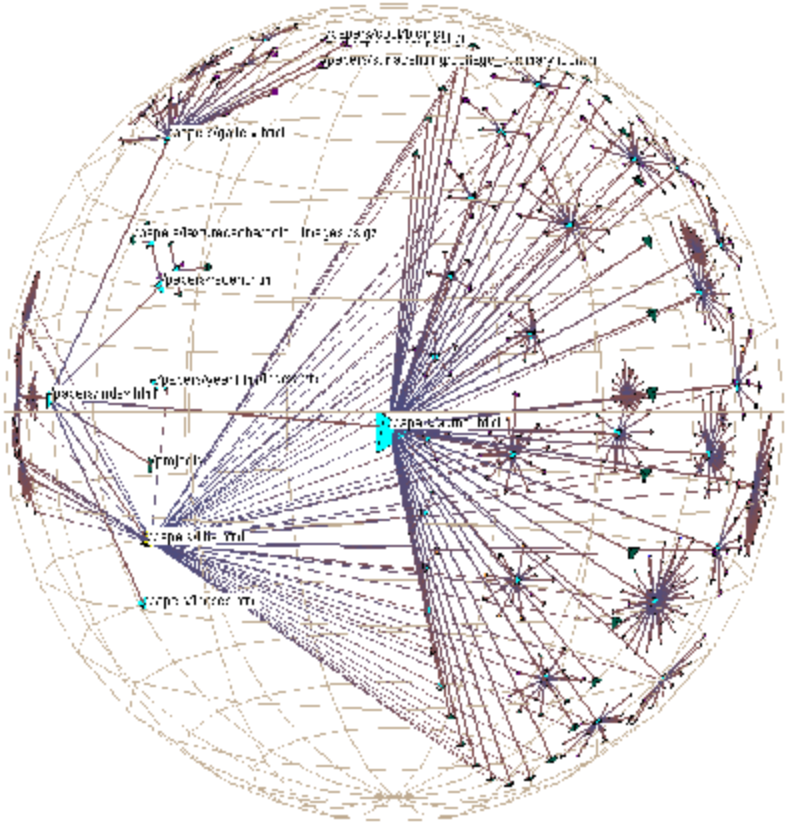


rtt performance: h/w



research priorities...

- visualizations - RTT performance; top routers; hyperbolic space; collapse nodes into ASes
- routing - time series analysis; compare routing policy w/ reality; path optimization; correlate w/ BGP announcements
- analysis - average number of hops (`wingspan') and ASes



graphics.stanford.edu/papers/h3/



passive measurement

- workload profiling (s/w & h/w design, architecture optimizing, capacity planning)
- security
- performance analysis
- QOS assurance across ISPs
- accounting/billing
- many tools: netramet, netflow, cflowd, coral
  - "some suck less" ...evolution requires use



coral ocXmon monitors up to OC12 (OC48?)

- persistent, real-time, full-frame traffic collection
- dynamic packet filtering triggered by attack precursors
- security policy
  - compliance auditing (passive)
  - enforcement (active)
- must address privacy issues
- *http://www.caida.org/Tools/Coral*



cflowd flow-export analysis software

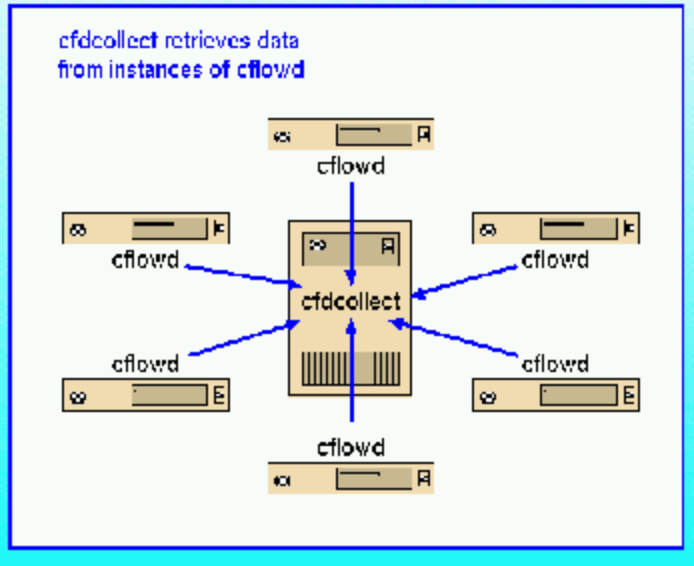
- Cisco routers (***cflowd***) - up to OC3 speeds
  http://www.caida.org/Tools/Cflowd
- used primarily for capacity planning and trend analysis
  - AS-to-AS matrices
  - net-to-net matrices
  - port and protocol tables
  - forward IP path
- measurement specification
  http://www.caida.org/Docs/meas_spec.html

cflowd flow format & collector

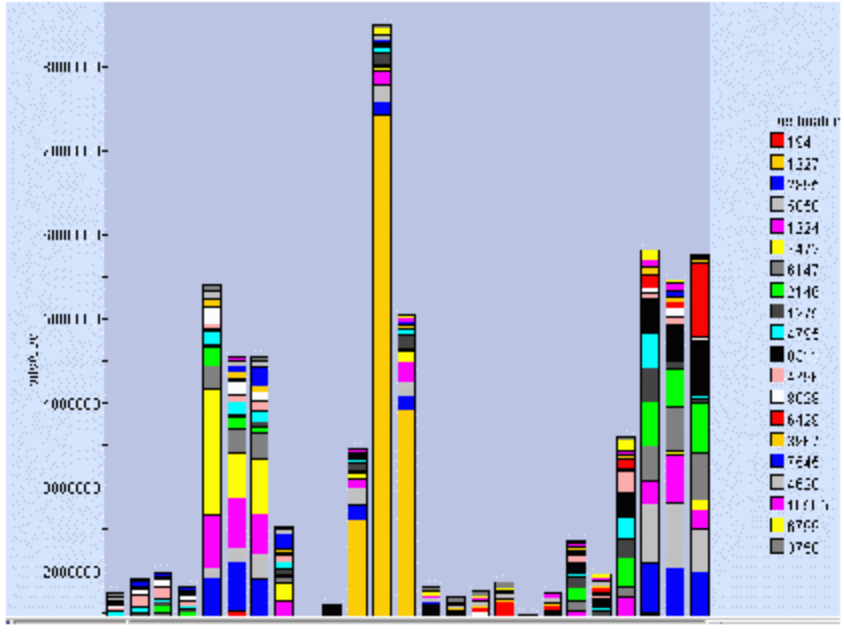
flow entry

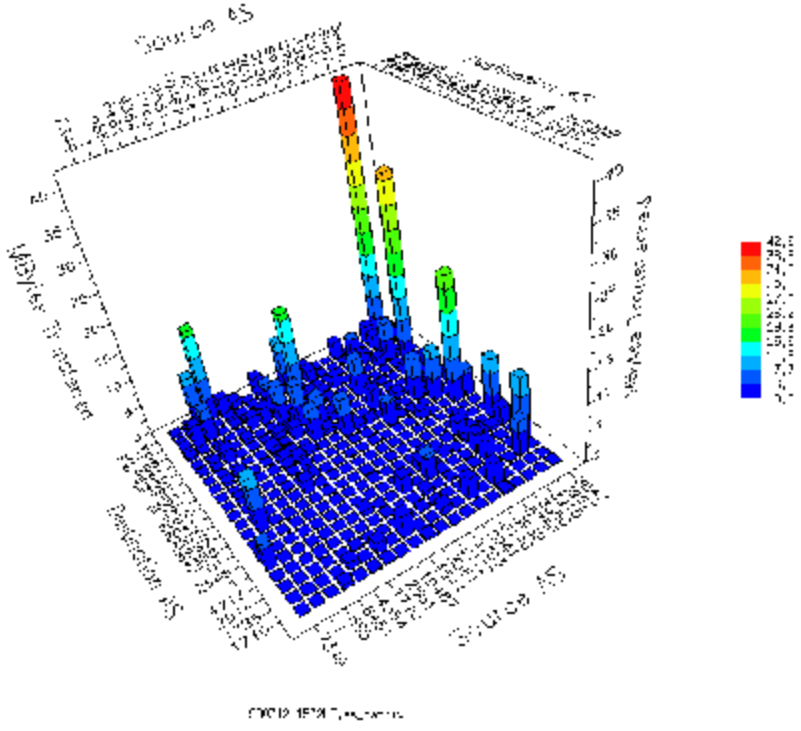
byte 0	*byte 1*	*byte 2*	*byte 3*
Flow Entry			
source IP address			
destination IP address			
next hop IP address			
input intf index		output intf index	
packets			
bytes			
start time of flow			
end time of flow			
source port		destination port	
pad	TCP flags	IP protocol	TOS
source AS		destination AS	
src netmask	dst netmask	padding	

centralized collection



analysis for peering & capacity planning



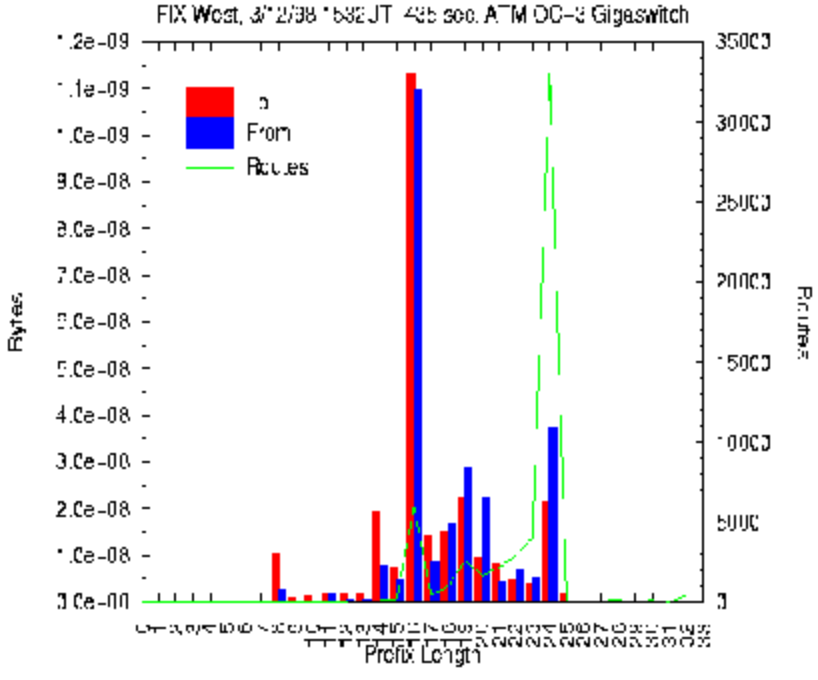


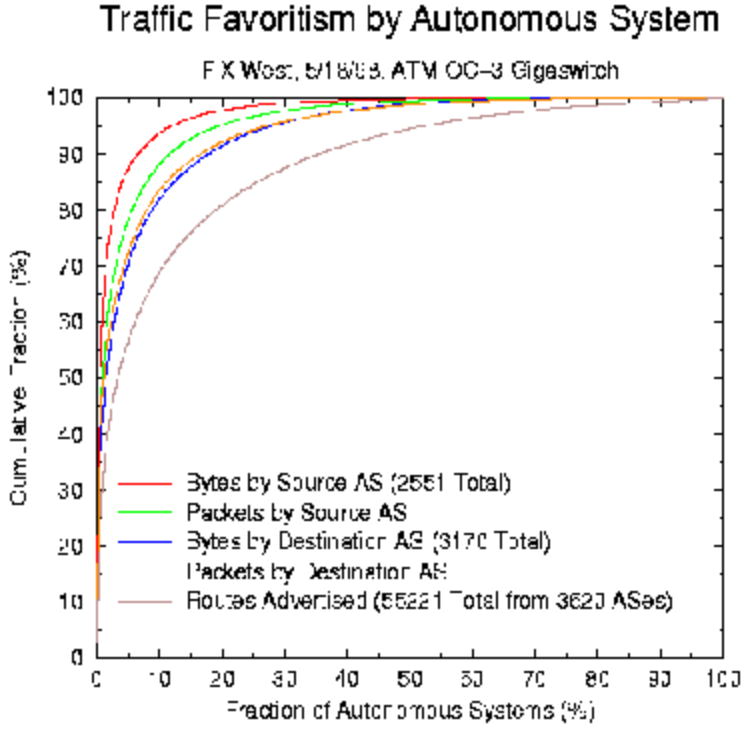
www.caida.org/Tools/Cflowd

www.caida.org/Tools/Coral



traffic analysis: current & future networks



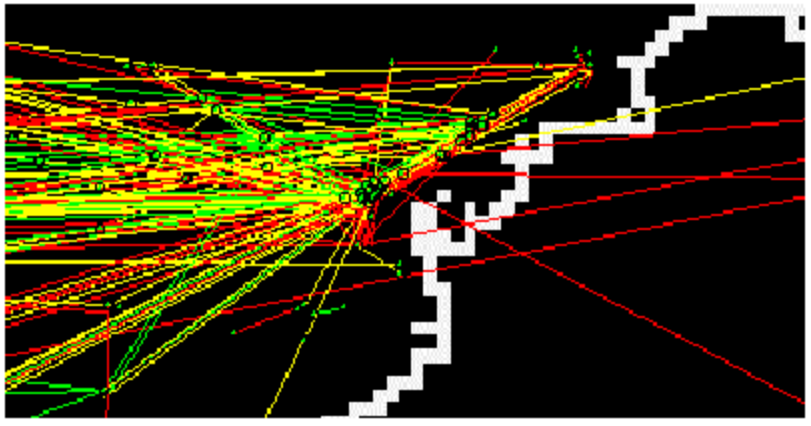


http://www.caida.org/Learn/PrefixLength

http://www.caida.org/Learn/Favoritism/

visualizing metrics: multicast

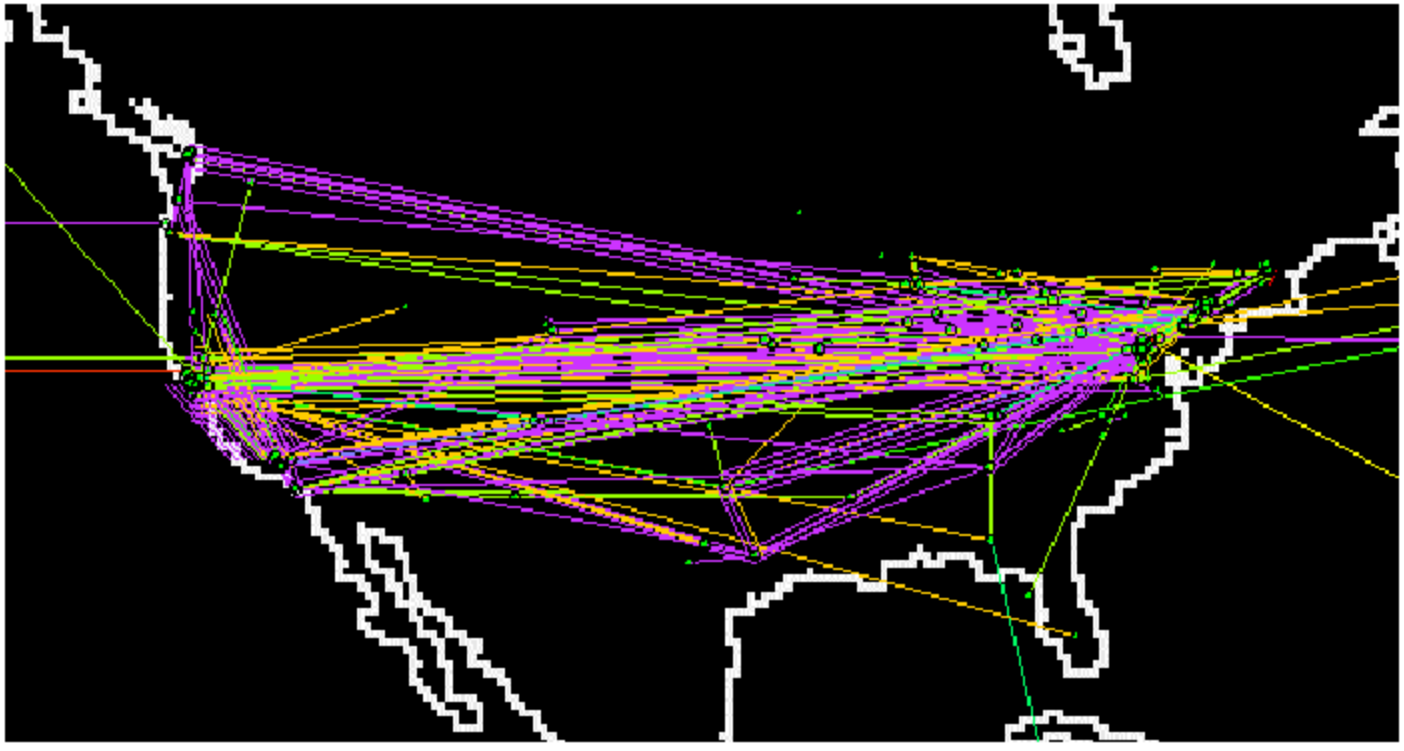
- *manta* displays the geographical placement of Mbone infrastructure using data from the *mwatch* *mrinfo* utilities
- *otter* displays topological views of the multicast infrastructure



http://www.caida.org/Tools/Manta

caida

mbone colored by metrics

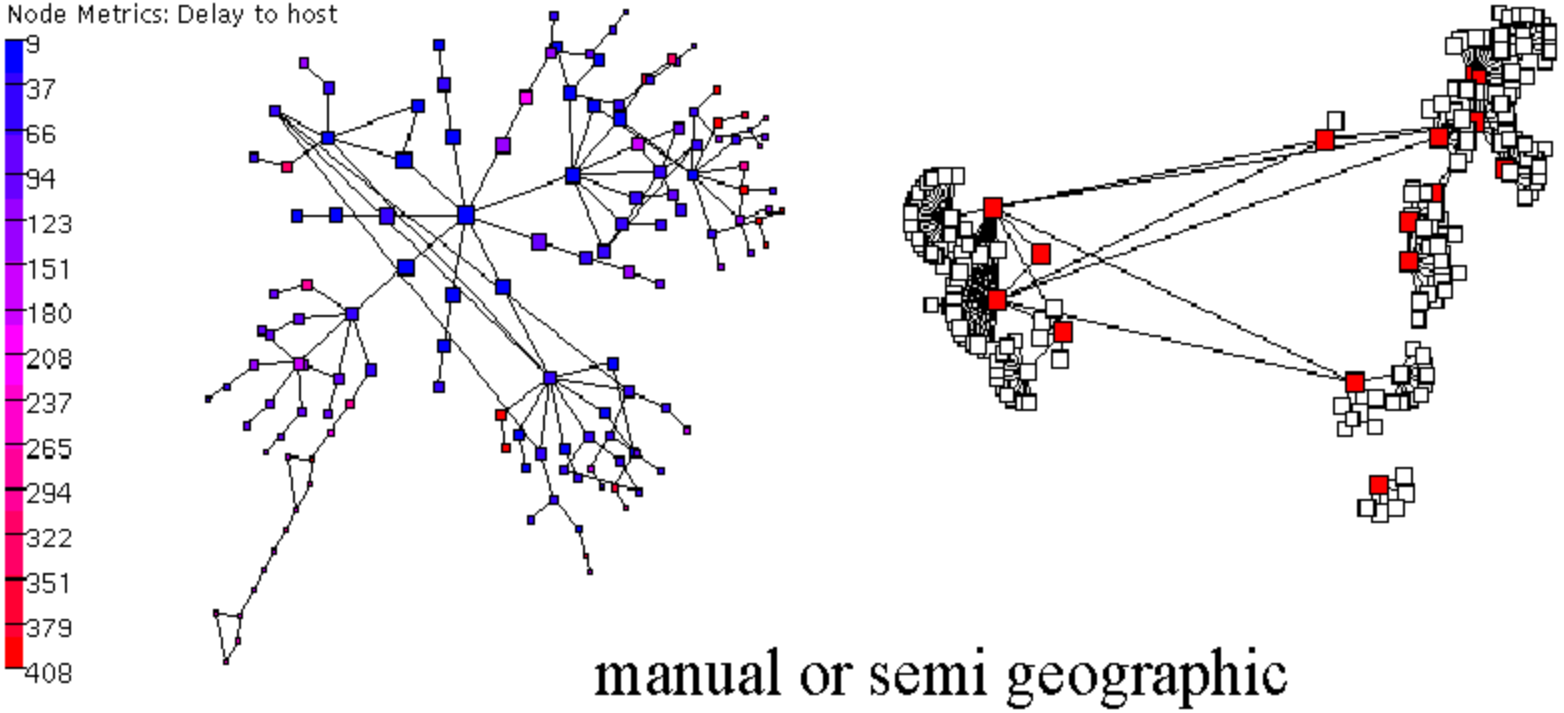


1:3062 2:17 3:4 4:4

5:35 7:2 10:19 20:1



otter visualizations: multipurpose tool



manual or semi geographic placement algorithms

http://www.caida.org/Tools/Otter/



now what?

- 'seamless': no such thing
- measurement tools/infrastr must be well-considered, strategically deployed, collaboratively maintained
- **much** more infrastructure-relevant research on resulting data, feedback into tool design
- correlation among data sources/types, simulation, visualization
- proactive top-down (app devel's scoping constraints) and bottom-up (ISP cooperation) participation



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http://www.caida.org