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Traffic Source Analysis of the J Root Anycast Instances

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Where it all comes together.™

History

- No analysis of root server anycast service had been done
  - Some questioned the deployment of anycast without testing
- "Life and Times of J-Root", NANOG 32 (October 2004)
  - Analyzed query data collected at some of the J root sites
  - Sliced and diced data in various ways; most results unsurprising
  - Two surprising findings:
    - Lots of non-priming queries to former (pre-11/2002) J root address coming from newer BIND versions
      - Interesting and still unexplained, but not this presentation's focus
    - 3.69% of all source IP addresses seen at two or more sites, **sometimes simultaneously or in quick succession**
      - We had no definitive explanation
- More presentations from others followed …

NANOG 34 (May 05)

- “Anycast Measurements Used to Highlight Routing Instabilities” (Peter Boothe, Randy Bush)
  - Had volunteers run TCP and UDP probes
  - Conclusions:
    - Routing weirdness seems to affect anycast disproportionally
    - TCP and UDP probes had different failure rates
  - Most of the volunteers read NANOG and are presumed more clueful so the sample probes might not be representative
- “DNS Anycast Stability” (Daniel Karrenberg)
  - Looked at DNSMON data from 77 probes to various root server instances
  - Conclusions:
    - DNS availability higher with anycast
    - Saw inter-instance “switches” and linked them to routing instability
    - More research could be done on multiple paths with the same AS path length
  - Again, probes located at more clueful operators so might not be representative

NANOG 37 (June 2006)

- “Effects of Anycast on K-root Performance” (Lorenzo Coletti)
  - Analysis included stability and its effect on performance
  - Findings:
    - April 2005, 24 hours from two global nodes: 1.1% of unique source IPs switched sites
    - April 2006, 5 hours from five global nodes: 0.33% of unique source IPs switched sites
  - Is five hours enough data?
- “Operational Experience with TCP and Anycast” (Matt Levine, Barrett Lyon and Todd Underwood)
  - Conclusion:
    - No problem with TCP and anycast
  - Attributes:
    - Large bandwidth provider
    - Carefully engineered their peering
    - Clients used high-bandwidth connections
  - Different environment than DNS root service?

Why This Presentation?

- Others' work on this topic has been tremendous: we are not throwing stones!
- Our initial data was disturbing and we still didn't think we had seen an explanation for what we observed
- Wanted to do our own follow-up analysis with more data

The Data

- *j.root-servers.net*: 19 active anycast instances for this analysis
  - All sourced from AS 26415
  - Mix of “global” and “local” instances
    - Local here means peering-only and upstream route filters
  - Mix of transit and peering
- Two separate packet captures
  - UDP
    - Inbound only
  - TCP
    - Bi-directional
- Each just over 24 hours from different, non-overlapping time periods
- Every active anycast instance represented (!)

Goals: Questions to Answer

- What kind of distribution of source IP addresses across all instances do we see?
- Can we explain what we see?
- Can we determine if what we see is causing a problem?

UDP Packet Capture

- About 26 hours of inbound query data:
  - Start: around 1145 EDT 25 October 2006
  - Stop: around 1345 EDT 26 October 2006
  - Staggered start/stop for packet capture at each site
- High-level statistics:
  - **335,259,322** total queries
    - Around **3,500** queries per second
    - UDP only, 24-hour average
  - **859,784** unique source IP addresses
    - Ratio of **390** queries per unique IP address
  - **5,561** source IP addresses appear at more than one site
    - That’s **0.646%** of total unique source IP addresses (1 out of every 154)
    - Down significantly from 3.69% in mid-2004 (“Life and Times of J-Root”)

Table Columns Explained

- **Source IP:** An IP address that sent a UDP DNS query to one of the *j.root-servers.net* instances
- **Transitions:** Number of times this source IP address switched instances
  - All measurements have one-second resolution
- **Sites:** Number of sites/instances this source IP address appeared at/sent queries to
- **Simultaneous Seconds:** The number of seconds in the packet capture interval when multiple instances received simultaneous queries from this IP address
- **Total Seconds:** The total number of seconds that any of the instances received traffic from this IP address
- **Percent Simultaneous:** (Simultaneous Seconds / Total Seconds) * 100
- **Specific Sites:** Which anycast instances received traffic and for how many seconds each
  - Instance abbreviation magic decoder ring at right

A	Dulles, VA
C	Dulles, VA
E	Los Angeles
F	Seattle
I	Stockholm
J	Tokyo
L	Atlanta
M	Singapore
N	Amsterdam
O	Miami
P	Seoul
Q	Brasilia
R	Cairo
S	Dublin
T	Dulles, VA
U	Dulles, VA
V	Sao Paulo
W	Mountain View
X	Sydney

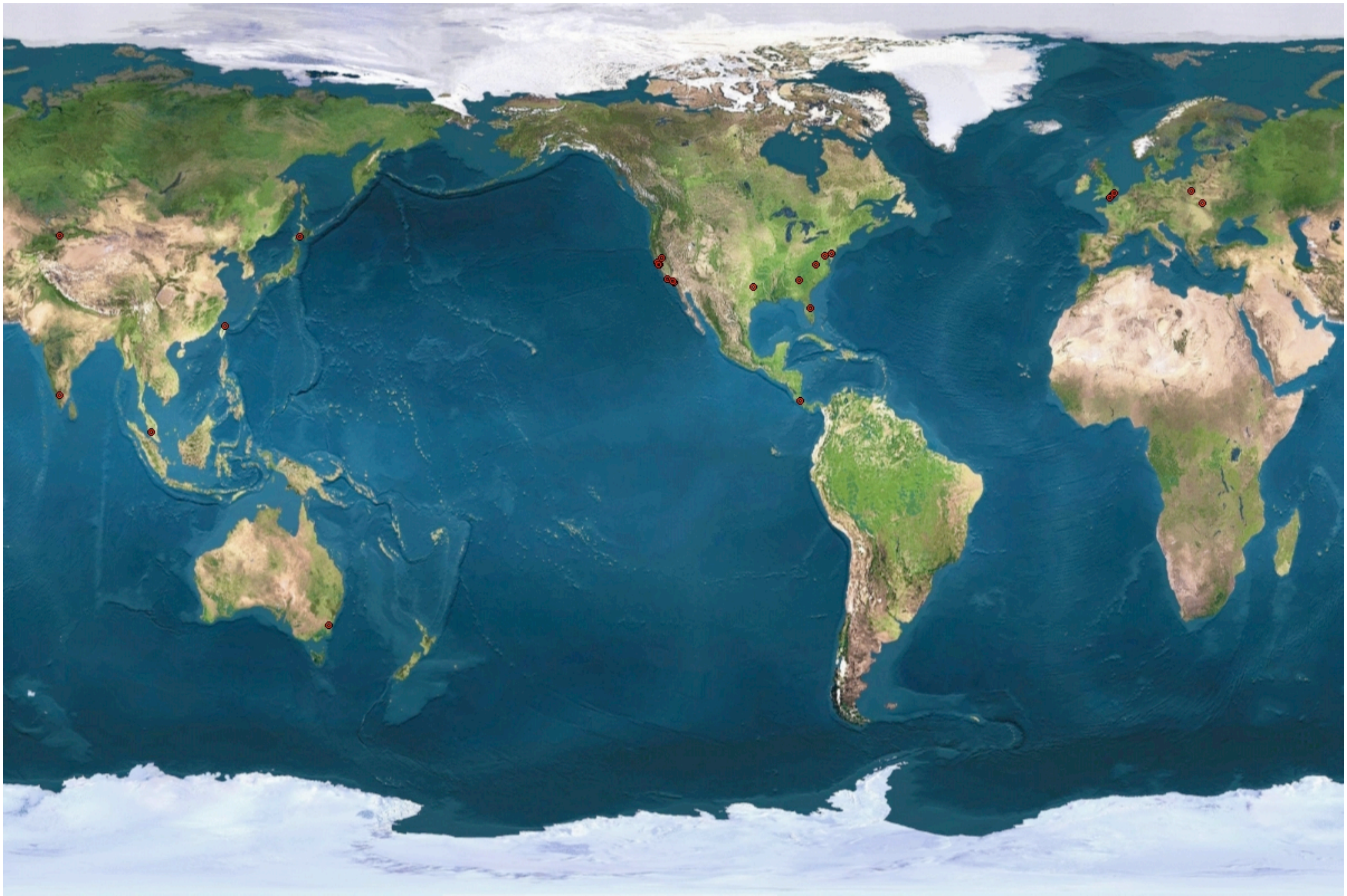
A Difficult Decision

- “The IP addresses you are about to see are true. The addresses have not been changed to protect the innocent.”
- We decided not to anonymize source IP addresses
- We are **not** trying to point out anyone’s problems, shame anyone, etc.
- Rather, we are asking for the community’s help to get to the bottom of the behavior we see
- Do you see an IP you recognize and know what’s up?

Top 30 Source IPs, Descending % Simul. Sites

	Source IP	Trans.	Sites	Simul. Secs.	Total Secs.	**Percent Simul.**	Specific Sites
1	202.45.133.9	1	2	1	2	50.00%	M=1 P=1
2	136.235.14.3	1	2	1	4	25.00%	I=1 J=3
3	207.243.192.15	406	2	158	678	23.30%	J=375 W=303
4	87.247.18.58	3	2	1	5	20.00%	P=3 T=2
5	147.62.42.119	2	2	1	6	16.67%	O=5 P=1
6	207.154.101.48	3	2	2	14	14.29%	T=5 W=9
7	24.248.93.71	2	2	1	7	14.29%	P=4 T=3
8	202.125.10.40	28	2	14	109	12.84%	J=72 P=37
9	202.45.133.3	10	2	5	39	12.82%	M=29 P=10
10	204.80.216.69	3752	2	1248	9739	12.81%	N=5763 T=3976
11	220.128.207.66	2	2	1	10	10.00%	J=9 M=1
12	66.180.96.10	13492	2	5350	54790	9.77%	L=37849 P=16941
13	207.154.75.57	34	2	16	172	9.30%	T=30 W=142
14	66.125.97.2	2	2	1	12	8.33%	P=10 T=2
15	209.4.229.202	6	2	2	31	6.45%	L=26 T=5
16	204.130.244.134	4	2	2	34	5.88%	N=17 W=17
17	220.225.140.98	33	2	4	70	5.71%	P=31 T=39
18	64.60.0.17	7276	2	2740	56345	4.86%	N=13317 T=43028
19	193.115.14.67	4	2	1	21	4.76%	J=3 N=18
20	210.156.102.90	23	2	4	86	4.65%	J=64 P=22
21	66.184.164.100	19	2	3	65	4.62%	L=53 P=12
22	217.9.0.250	74	2	8	220	3.64%	N=139 P=81
23	136.235.12.27	5	2	3	87	3.45%	I=5 J=82
24	209.4.229.201	4	2	1	30	3.33%	L=26 T=4
25	63.103.50.15	699	2	54	1915	2.82%	P=1188 T=727
26	136.235.12.17	4	2	2	77	2.60%	I=5 J=72
27	193.28.226.2	37	2	3	116	2.59%	I=63 N=53
28	198.6.248.11	6	2	1	44	2.27%	N=27 T=17
29	201.206.0.18	10	2	1	49	2.04%	Q=39 T=10
30	193.122.27.34	10	2	5	246	2.03%	J=14 N=232

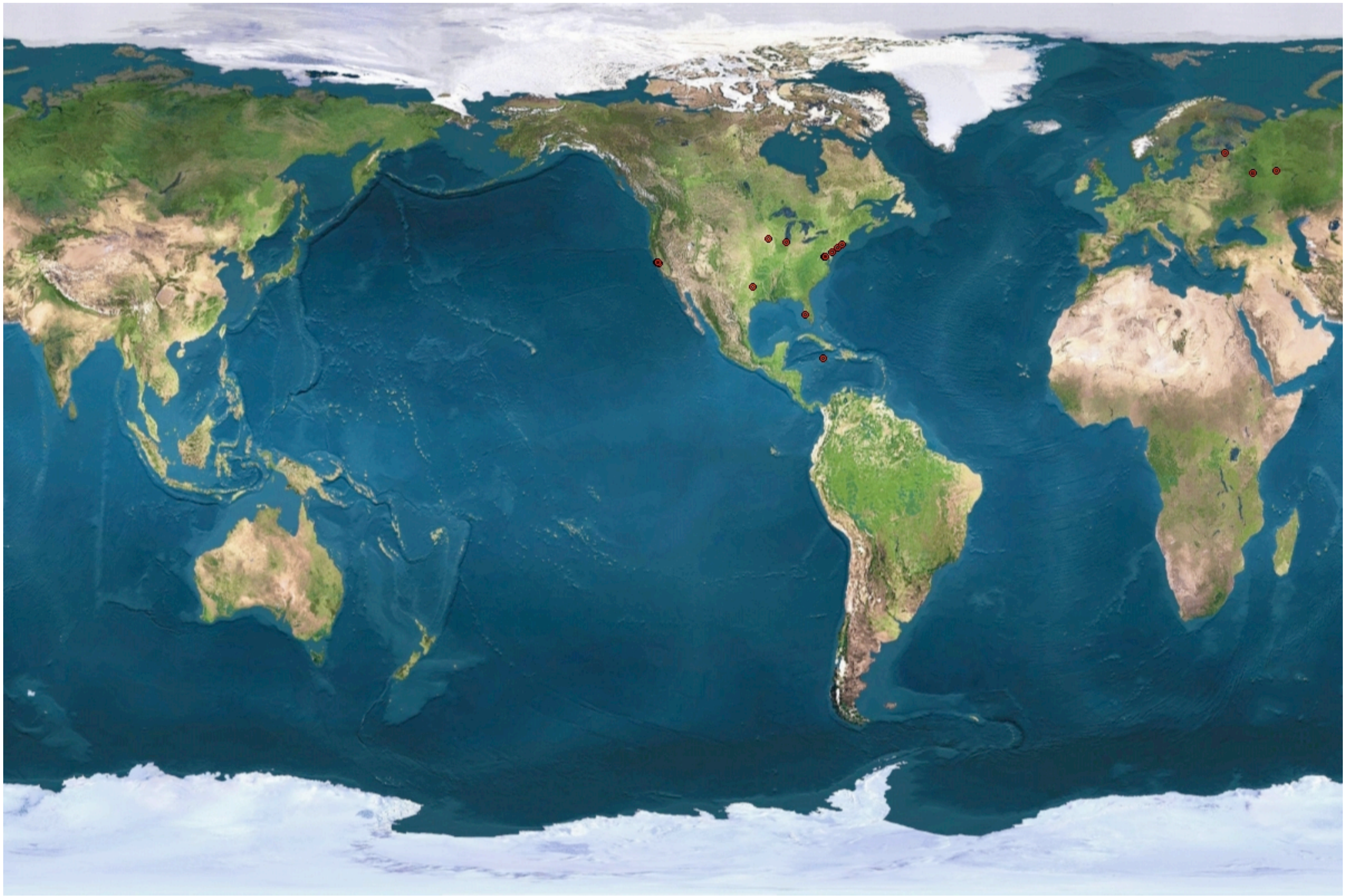
Top 30 Most % Simultaneous Geographic Distribution



Top 30 Source IPs, Descending Site Order

				Simul.	Total	Percent	
	Source IP	Trans.	**Sites**	Secs.	Secs.	Simul.	Specific Sites
1	216.175.203.50	93	4	20	10277	0.20%	J=15 N=1 P=3305 T=6956
2	216.218.195.242	8	4	0	1065	0.00%	J=219 M=2 N=1 P=843
3	65.19.182.2	8	4	0	1012	0.00%	J=309 M=25 N=33 P=645
4	65.19.183.170	8	4	0	3455	0.00%	J=658 M=14 N=60 P=2723
5	209.51.187.132	7	4	0	4380	0.00%	J=1883 M=1 N=20 P=2476
6	64.38.5.242	7	4	0	6715	0.00%	J=1316 M=13 N=32 P=5354
7	209.8.109.153	6	4	0	850	0.00%	J=305 M=2 N=6 P=537
8	192.104.109.190	5	4	0	658	0.00%	J=160 M=1 N=1 P=496
9	216.218.253.190	5	4	0	732	0.00%	J=128 M=2 N=2 P=600
10	66.160.172.128	5	4	0	505	0.00%	J=129 M=2 N=1 P=373
11	66.228.118.71	5	4	0	29333	0.00%	J=4 P=24 Q=29304 T=1
12	194.186.252.34	4	4	0	36824	0.00%	I=2 N=13 O=246 T=36563
13	194.186.88.2	4	4	0	436	0.00%	I=1 N=1 O=10 T=424
14	195.239.16.228	4	4	0	1460	0.00%	I=1 N=8 O=77 T=1374
15	195.68.135.5	4	4	0	2952	0.00%	I=29 N=8 O=61 T=2854
16	212.44.130.6	4	4	0	12090	0.00%	I=54 N=47 O=284 T=11705
17	64.62.197.115	4	4	0	14	0.00%	J=4 M=2 N=6 P=2
18	194.67.21.177	3	4	0	7746	0.00%	I=37 N=27 O=156 T=7526
19	194.67.21.178	3	4	0	7748	0.00%	I=42 N=36 O=167 T=7503
20	194.67.21.179	3	4	0	7896	0.00%	I=45 N=40 O=195 T=7616
21	194.85.128.10	3	4	0	15766	0.00%	I=13 N=22 O=234 T=15497
22	195.28.32.3	3	4	0	396	0.00%	I=5 N=2 O=9 T=380
23	195.98.32.193	3	4	0	582	0.00%	I=3 N=3 O=7 T=569
24	213.33.206.146	3	4	0	1116	0.00%	I=1 N=15 O=88 T=1012
25	217.78.177.250	3	4	0	6706	0.00%	I=36 N=16 O=279 T=6375
26	64.51.133.2	491	3	190	17720	1.07%	J=45 P=13340 T=4335
27	208.163.52.115	82	3	10	18464	0.05%	O=38 Q=18199 T=227
28	217.112.37.10	46	3	21	530391	0.00%	I=189 N=168 O=530034
29	217.112.42.15	46	3	21	311599	0.01%	I=1524 N=159 O=309916
30	209.87.79.232	45	3	10	8276	0.12%	J=2 P=2402 T=5872

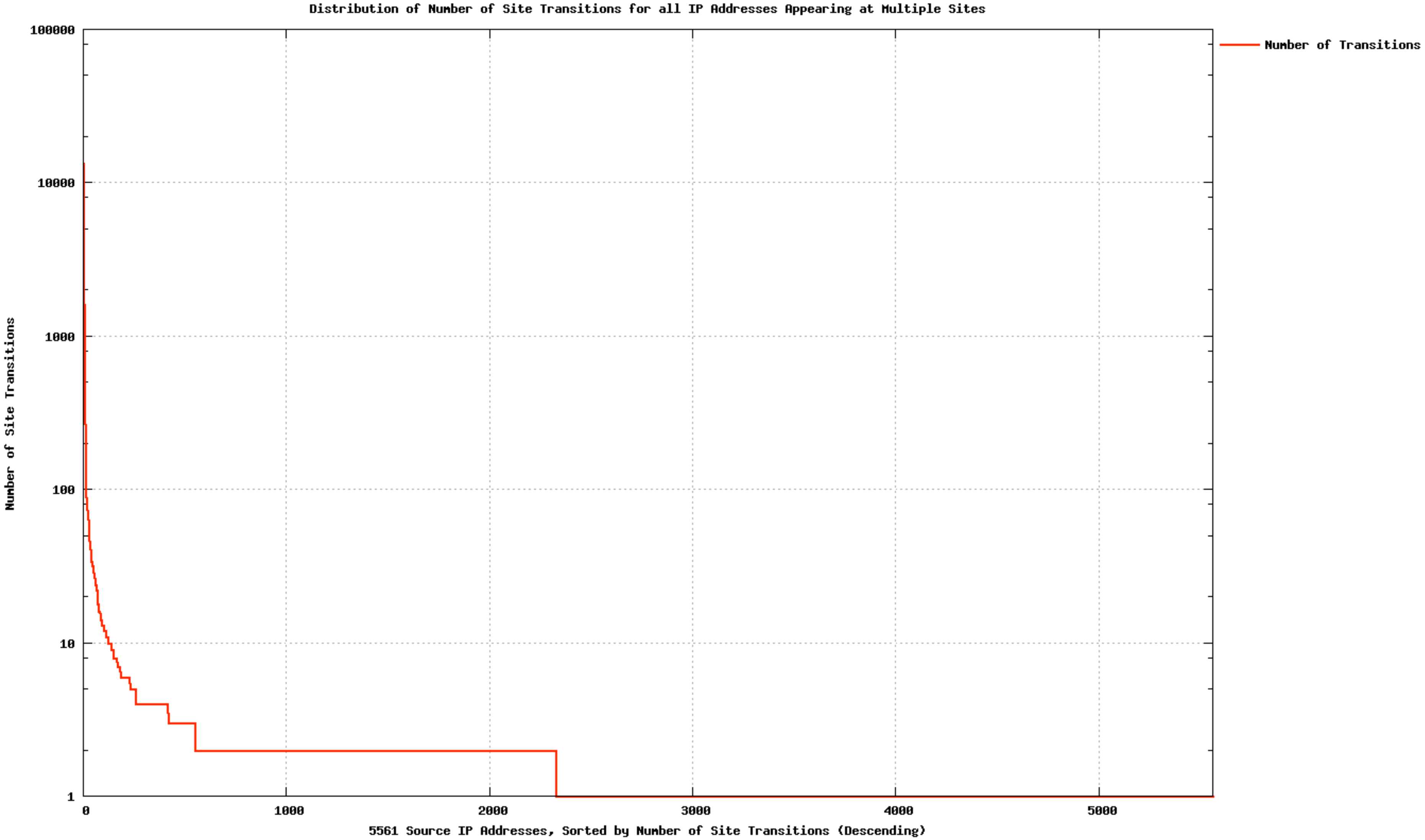
Top 30 Most Sites Geographic Distribution



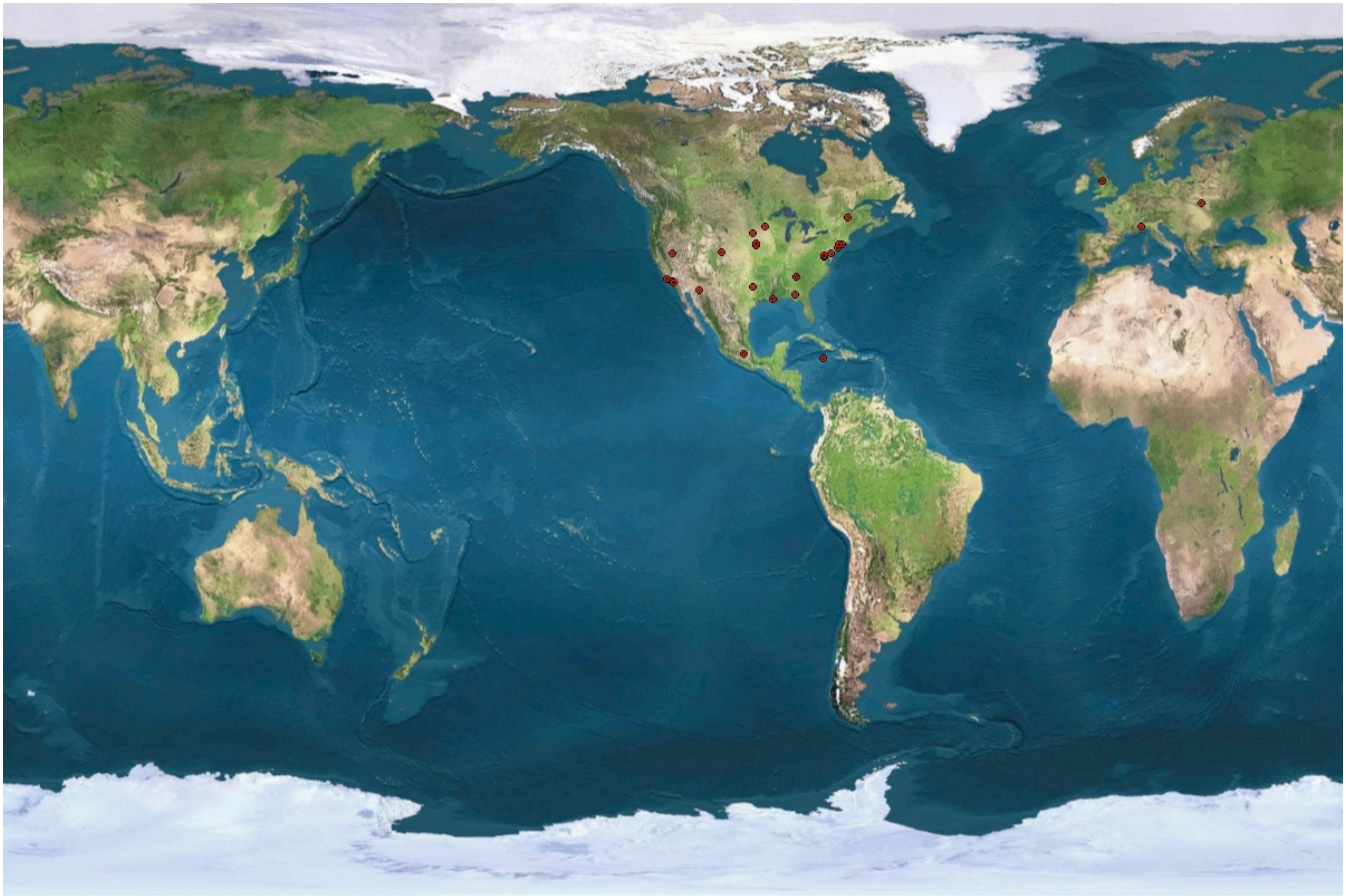
Top 30 Source IPs, Descending Transition Order

				Simul.	Total	Percent	
	Source IP	**Trans.**	Sites	Secs.	Secs.	Simul.	Specific Sites
1	66.180.96.10	13492	2	5350	54790	9.77%	L=37849 P=16941
2	64.60.0.17	7276	2	2740	56345	4.86%	N=13317 T=43028
3	204.80.216.69	3752	2	1248	9739	12.81%	N=5763 T=3976
4	63.103.50.15	699	2	54	1915	2.82%	P=1188 T=727
5	217.17.48.1	648	2	63	4544	1.39%	N=2932 P=1612
6	209.159.192.7	519	2	24	5437	0.44%	L=4845 T=592
7	64.51.133.2	491	3	190	17720	1.07%	J=45 P=13340 T=4335
8	207.243.192.15	406	2	158	678	23.30%	J=375 W=303
9	216.47.210.6	172	2	40	62350	0.06%	L=59198 T=3152
10	199.125.12.1	154	2	0	1537	0.00%	L=1152 T=385
11	64.18.100.11	140	2	5	1944	0.26%	L=1566 T=378
12	64.18.100.17	108	2	3	1389	0.22%	L=1107 T=282
13	206.108.60.11	96	2	0	317	0.00%	P=95 Q=222
14	216.175.203.50	93	4	20	10277	0.20%	J=15 N=1 P=3305 T=6956
15	216.183.68.111	84	2	32	90099	0.04%	P=85839 T=4260
16	208.163.52.115	82	3	10	18464	0.05%	O=38 Q=18199 T=227
17	62.123.17.67	82	2	0	370	0.00%	I=286 T=84
18	199.223.36.10	75	2	0	391	0.00%	P=247 T=144
19	217.9.0.250	74	2	8	220	3.64%	N=139 P=81
20	199.125.13.1	72	2	0	731	0.00%	L=603 T=128
21	200.38.100.210	66	2	0	407	0.00%	L=320 T=87
22	204.86.34.1	65	2	0	46758	0.00%	L=3842 W=42916
23	32.97.110.142	65	2	1	77043	0.00%	L=4802 W=72241
24	200.38.96.10	64	2	2	562	0.36%	L=426 T=136
25	204.96.181.75	62	2	0	870	0.00%	L=627 Q=243
26	207.154.65.10	53	2	0	243	0.00%	T=62 W=181
27	64.113.160.162	52	2	0	1053	0.00%	T=93 W=960
28	129.42.4.117	49	2	0	1516	0.00%	L=102 W=1414
29	216.171.238.66	47	2	0	220	0.00%	P=57 T=163
30	217.112.37.10	46	3	21	530391	0.00%	I=189 N=168 O=530034

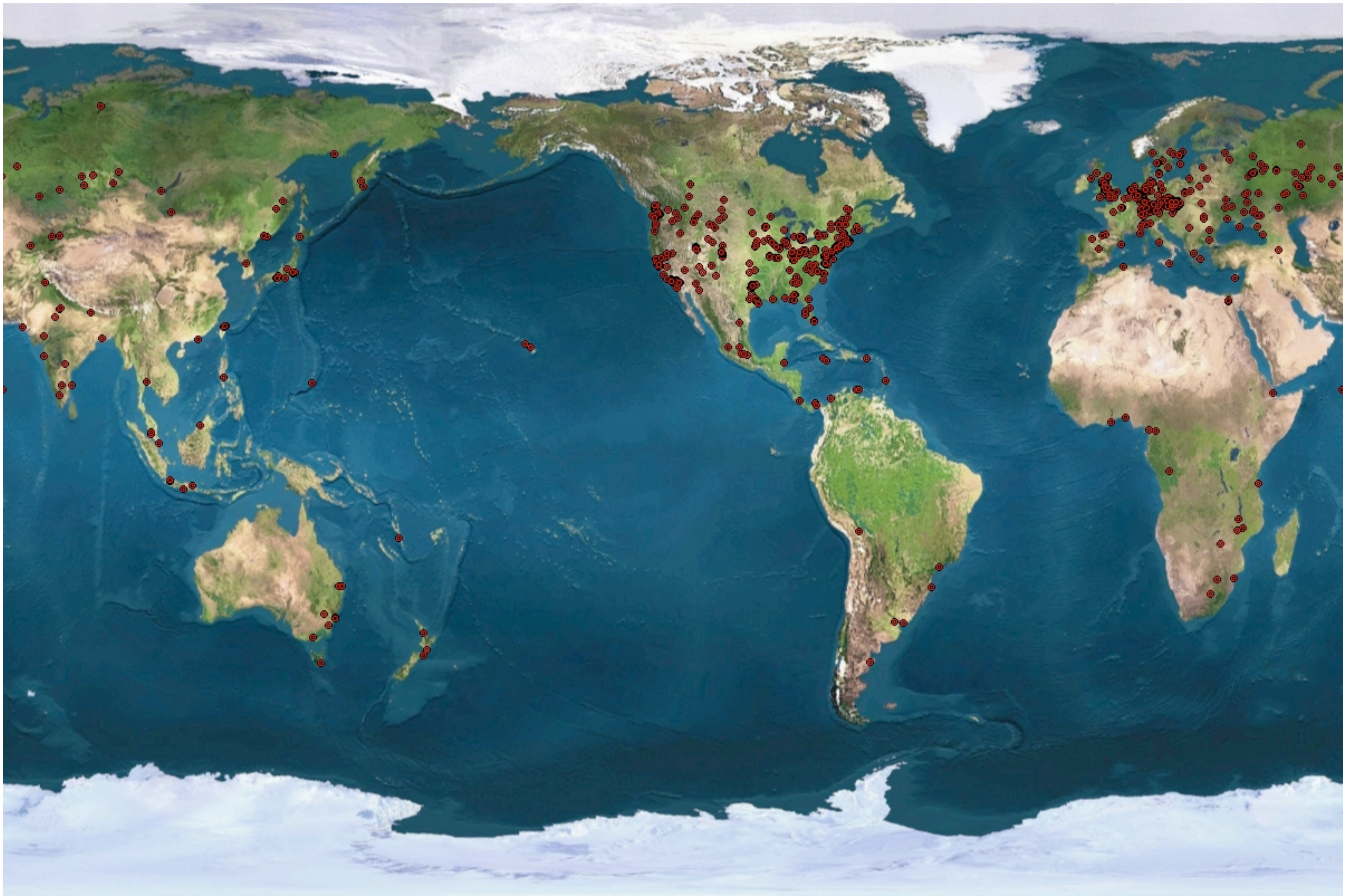
Transitions



Top 30 Most Transitions Geographic Distribution



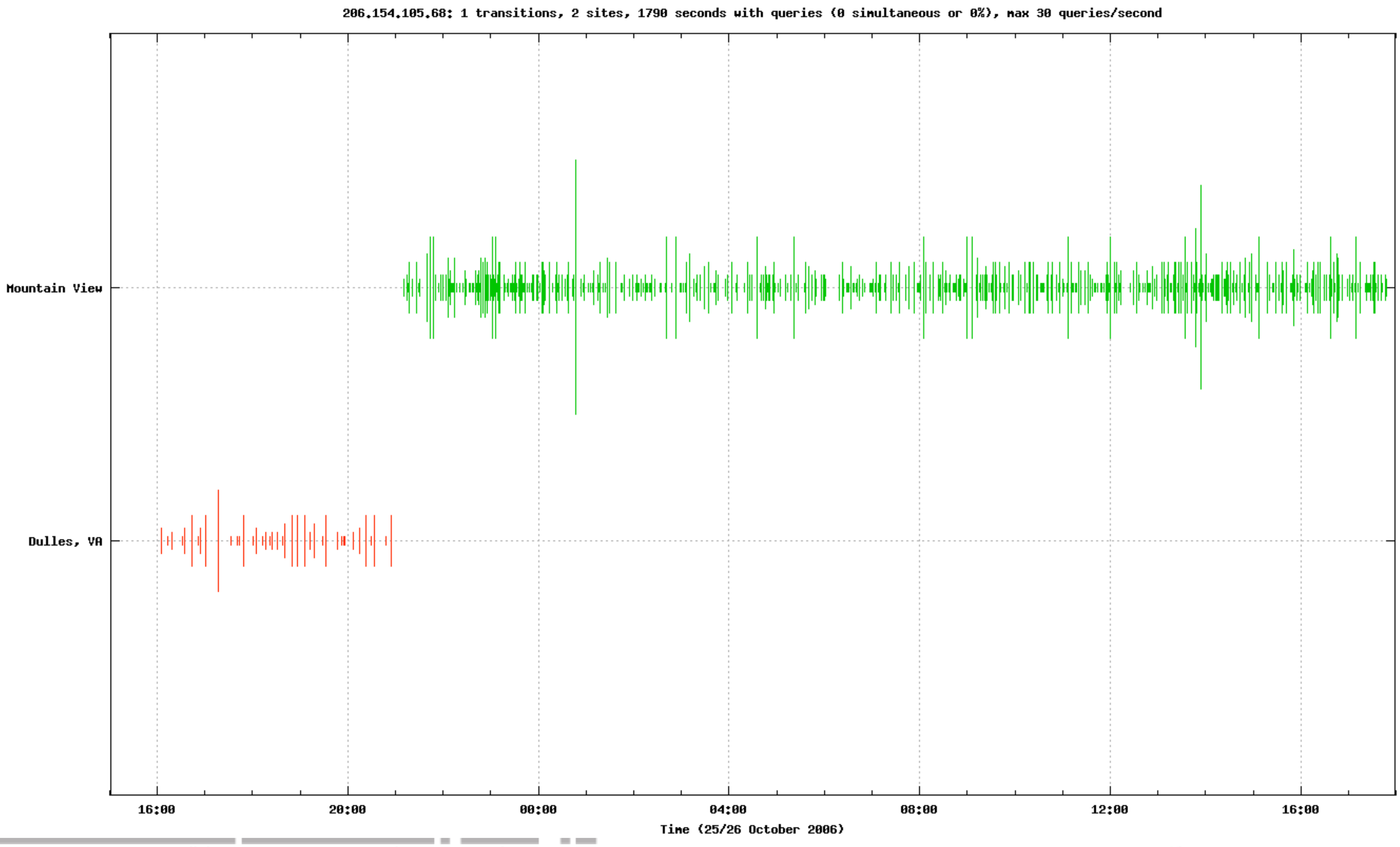
Geographic Distribution of All Multi-site IPs



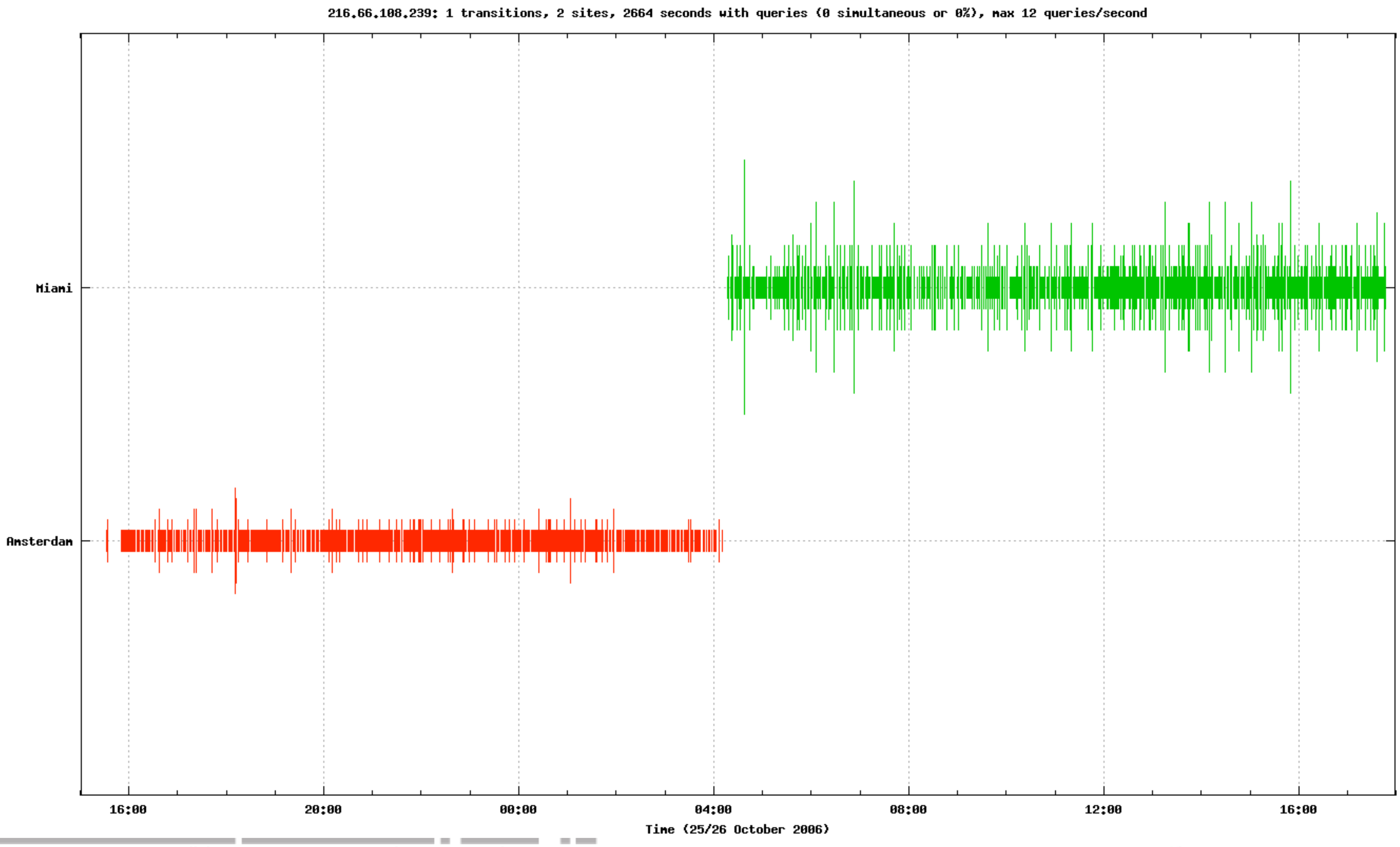
Graphs of “Interesting” Query Source IP Addresses

- Plotted queries over time for “interesting” source IP addresses
- Only sites/instances receiving queries from a given IP address are shown on its graph
- Amplitude indicates query volume at that instance
- Two graphs showing expected switching behavior, followed by several interesting ones

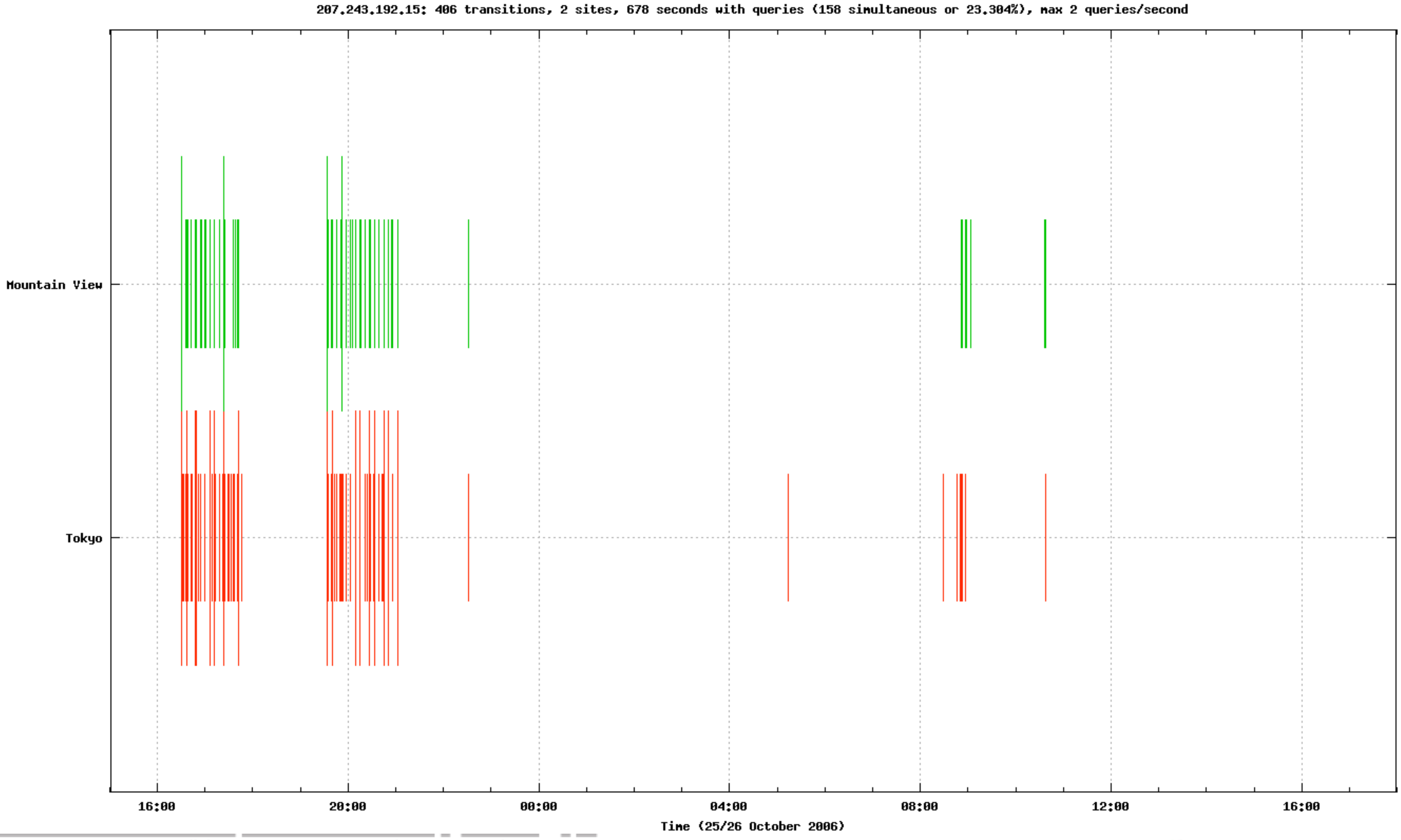
An Expected Transition, Graph #1



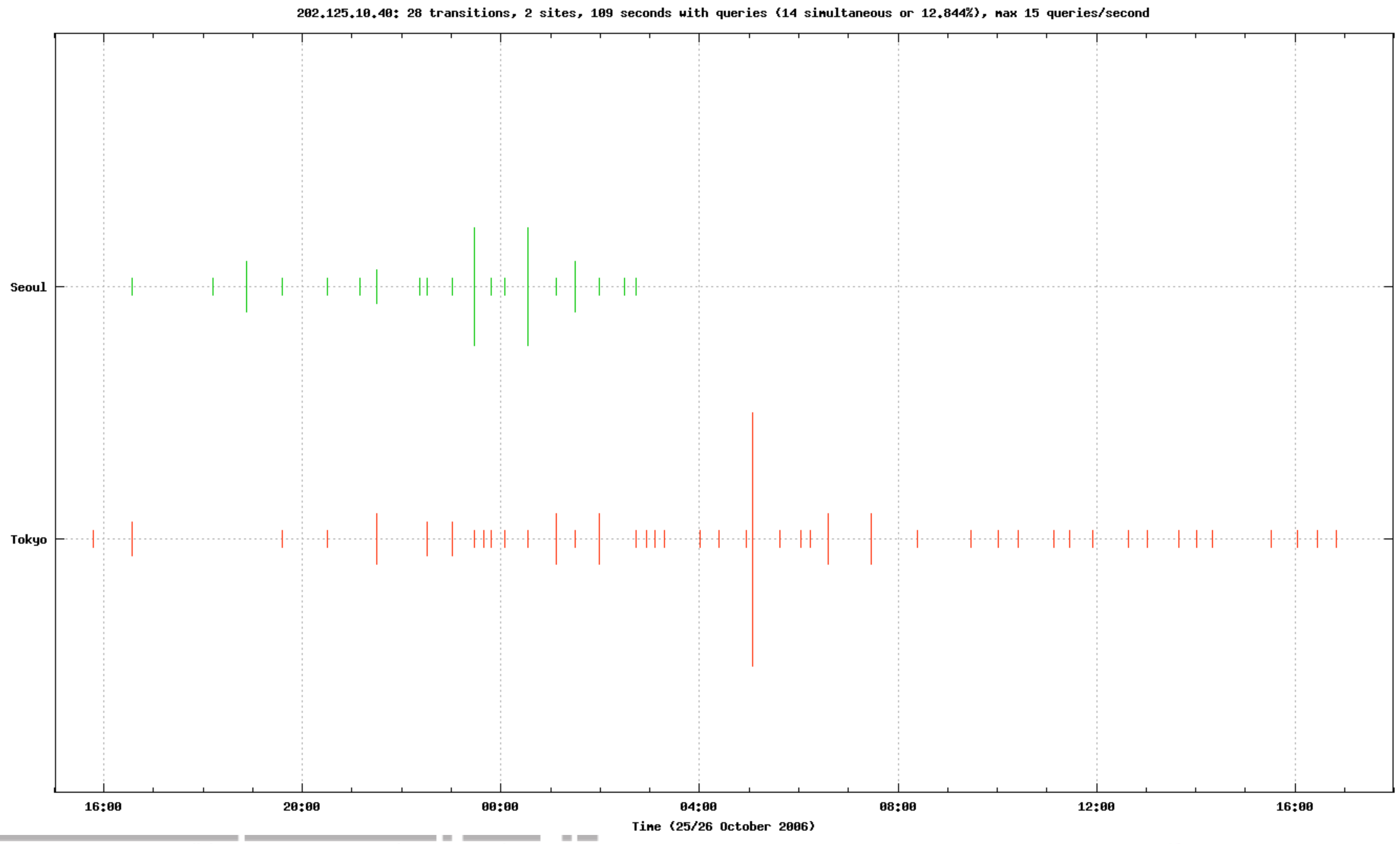
An Expected Transition, Graph #2



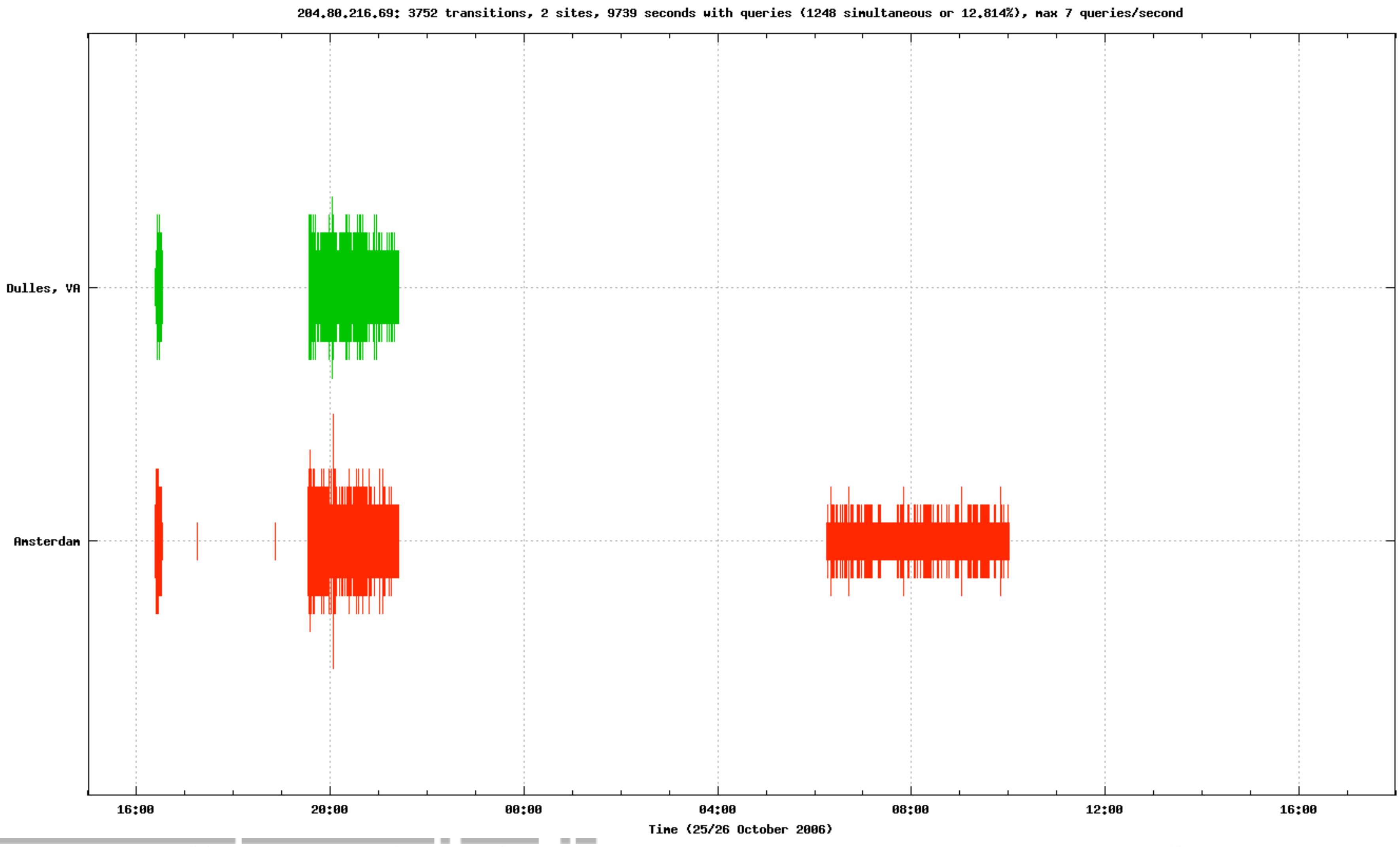
Simultaneous Sites, Graph #1 (3rd on Top 30 List)



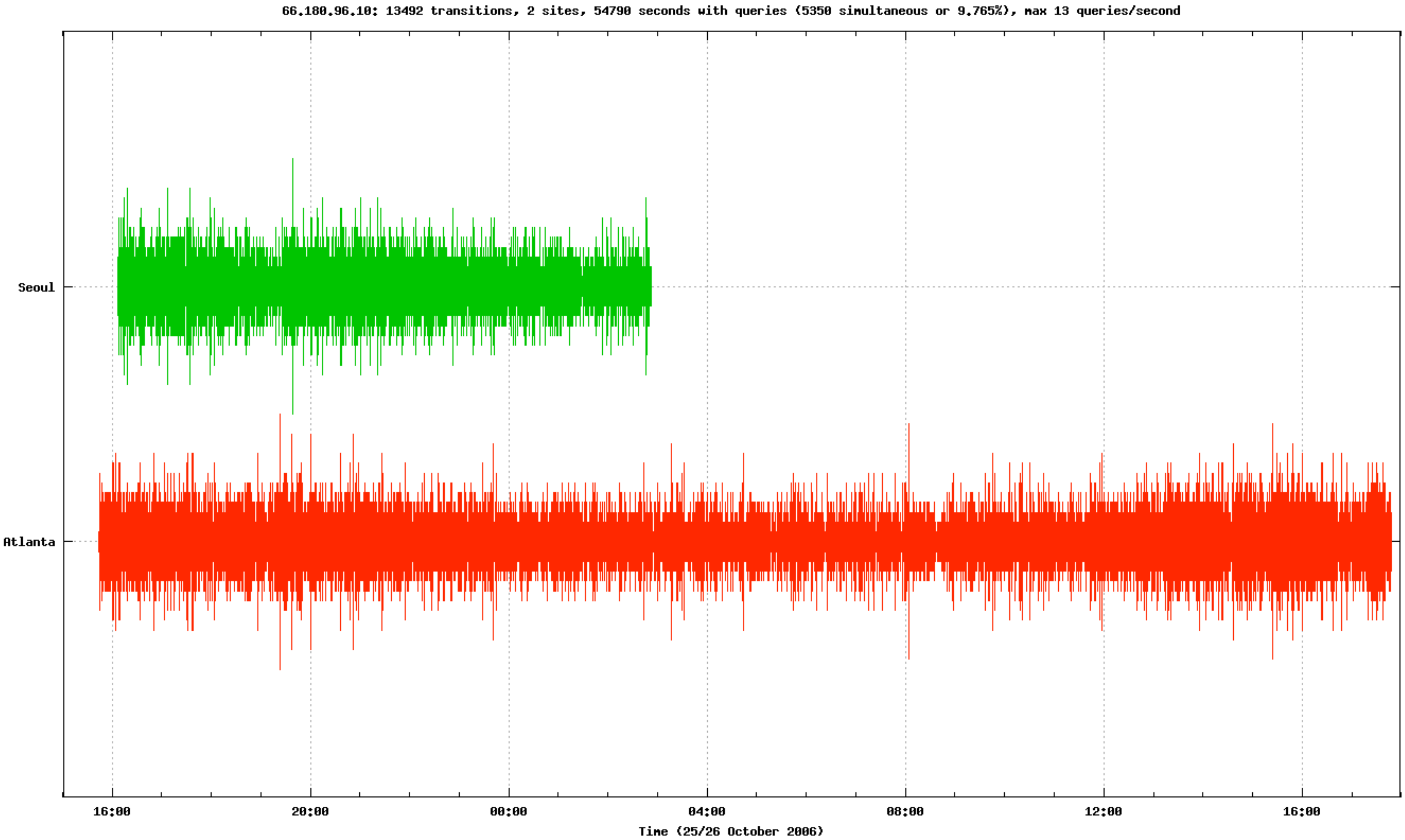
Simultaneous Sites, Graph #2 (8th on Top 30 List)



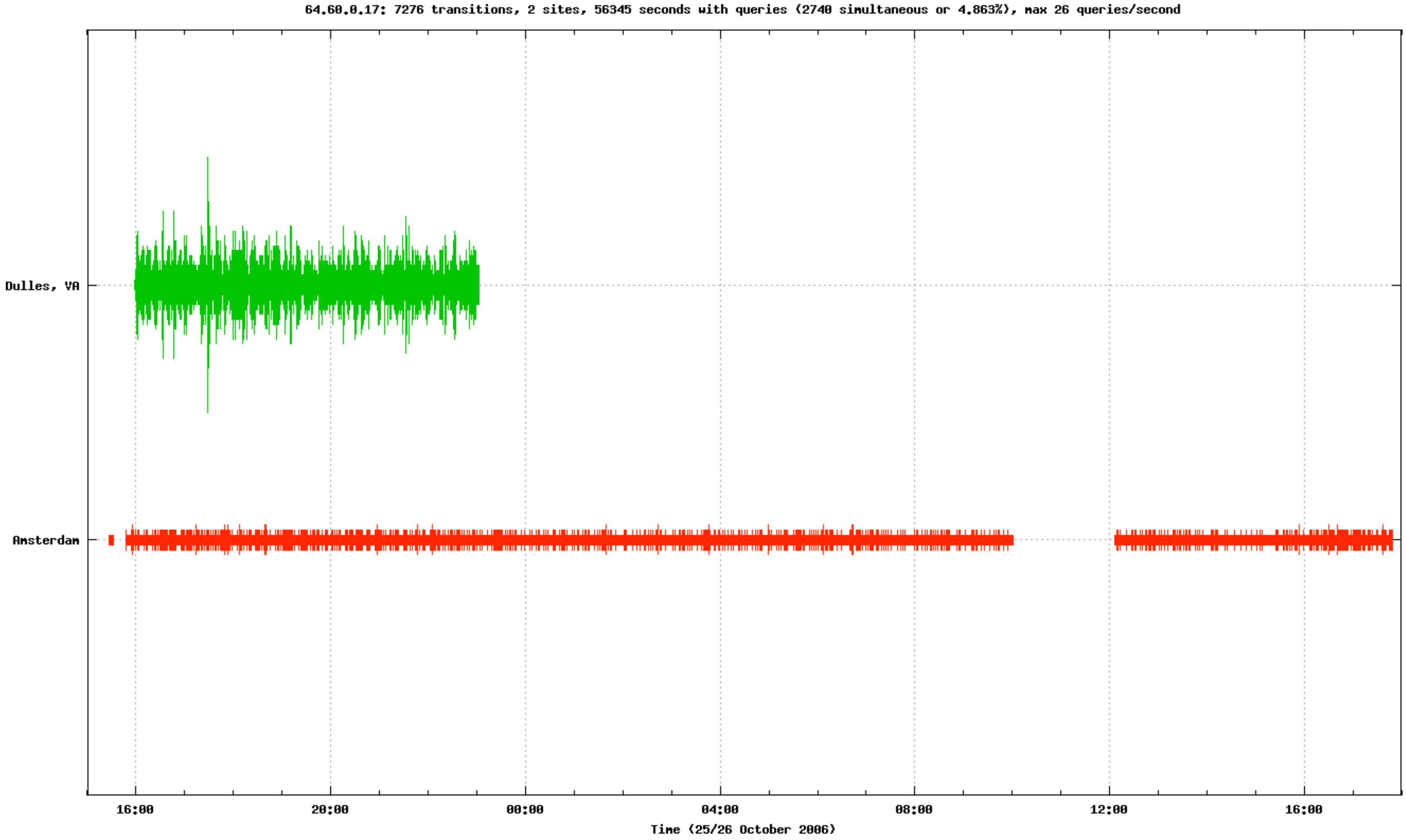
Simultaneous Sites, Graph #3 (10th on Top 30 List)



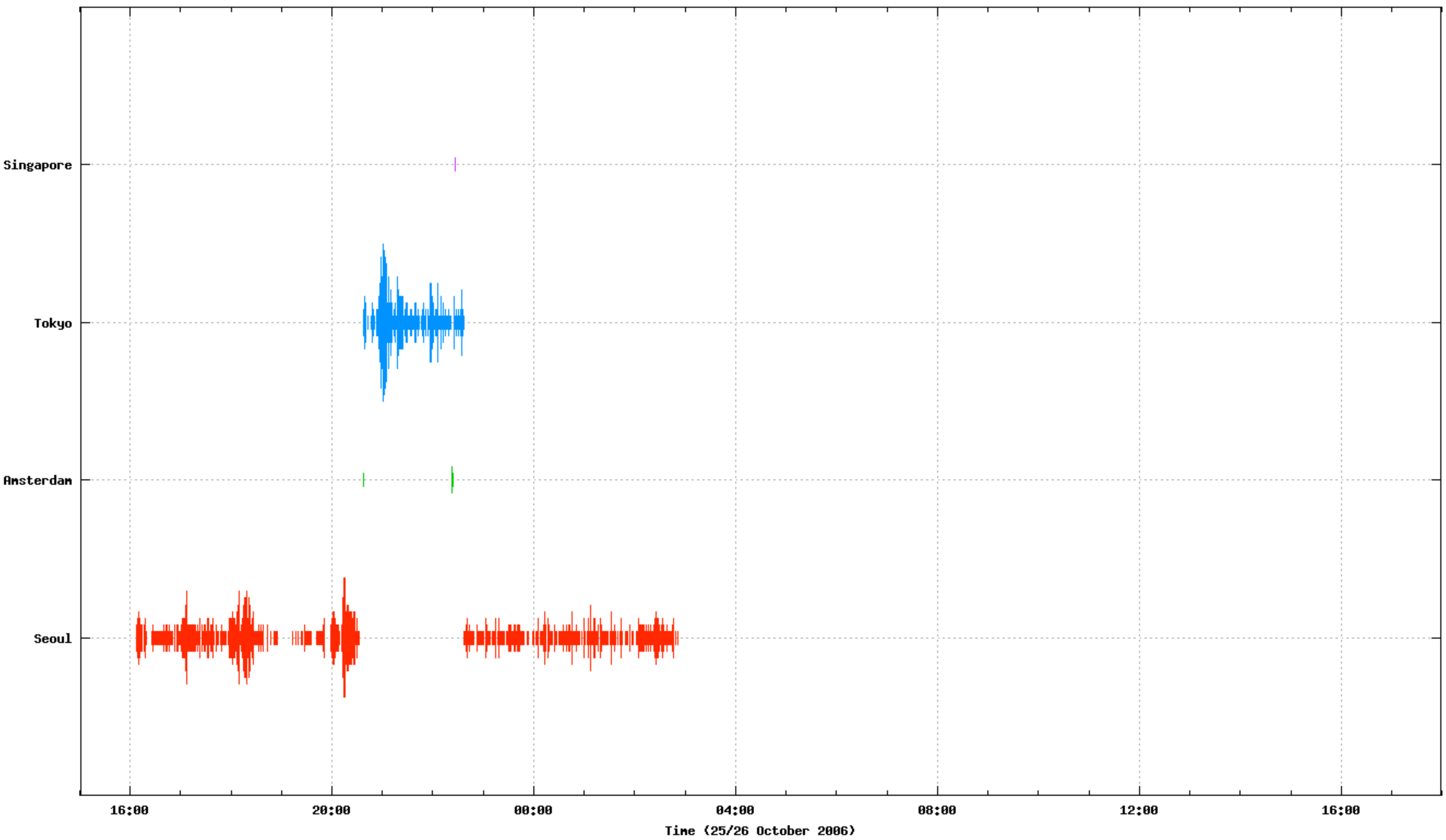
Simultaneous Sites, Graph #4 (12th on Top 30 List)



Simultaneous Sites, Graph #5 (18th on Top 30 List)

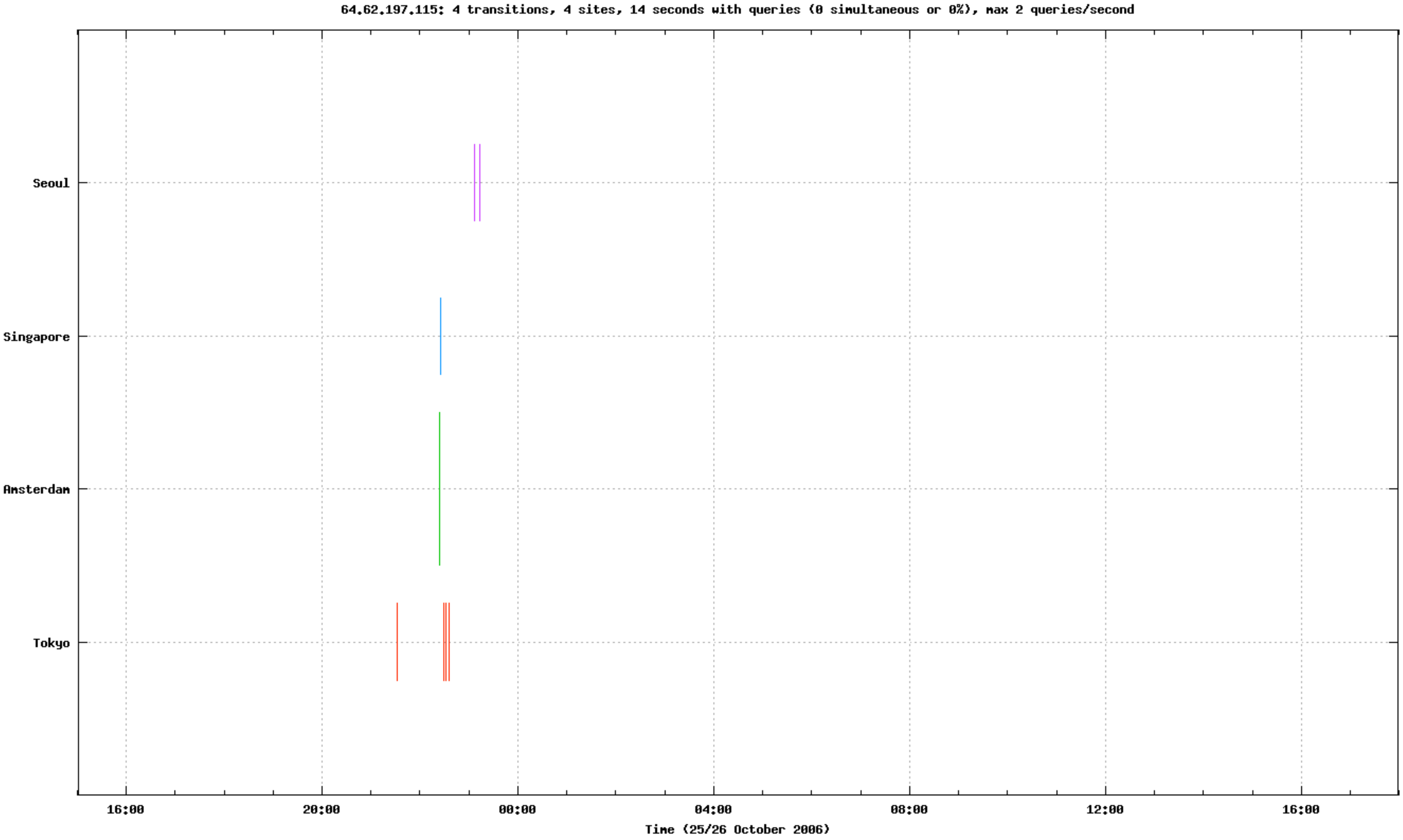


Many Sites, Graph #1 (5th on Top 30 List)

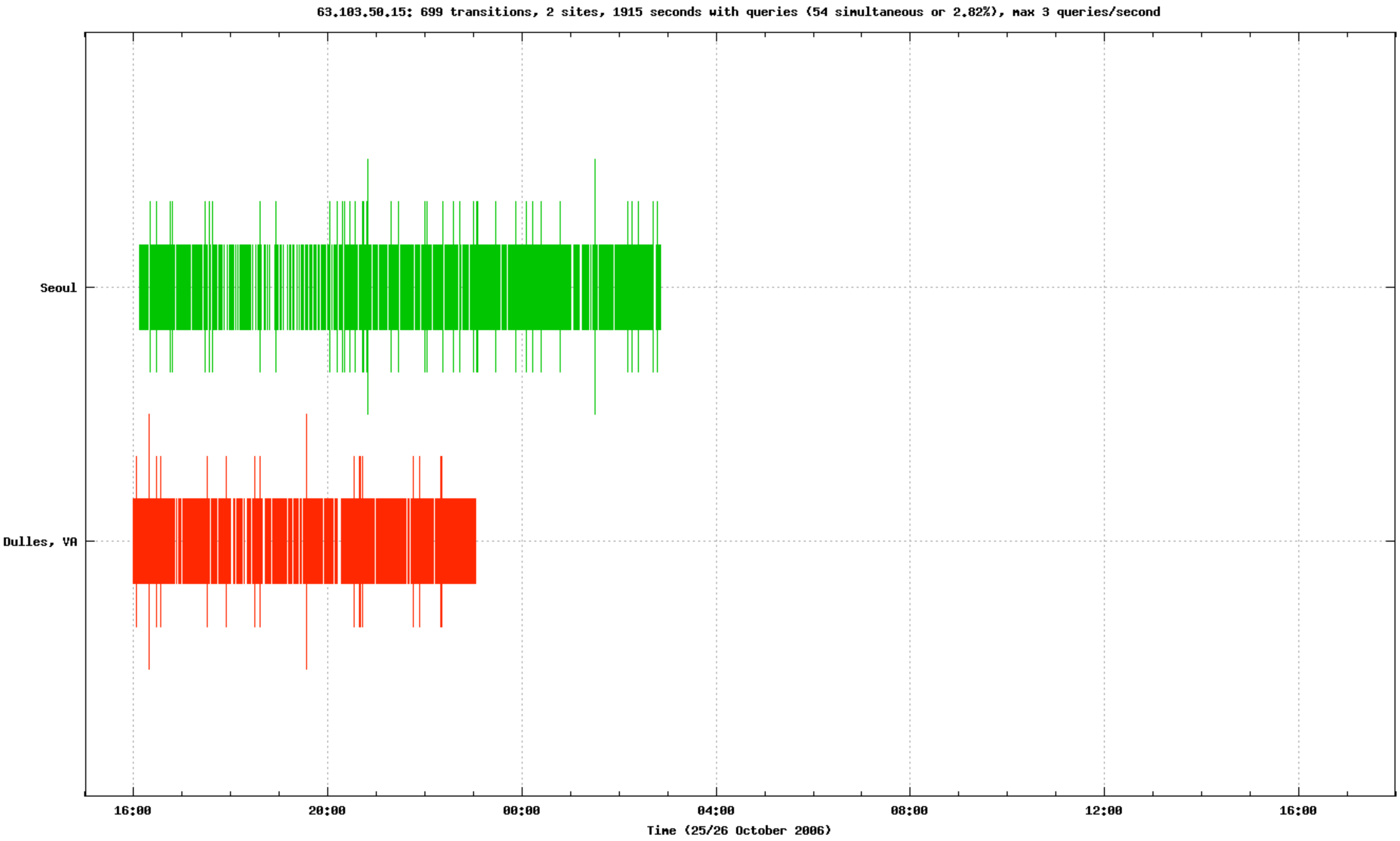


209.51.187.132: 7 transitions, 4 sites, 4380 seconds with queries (0 simultaneous or 0%), max 12 queries/second

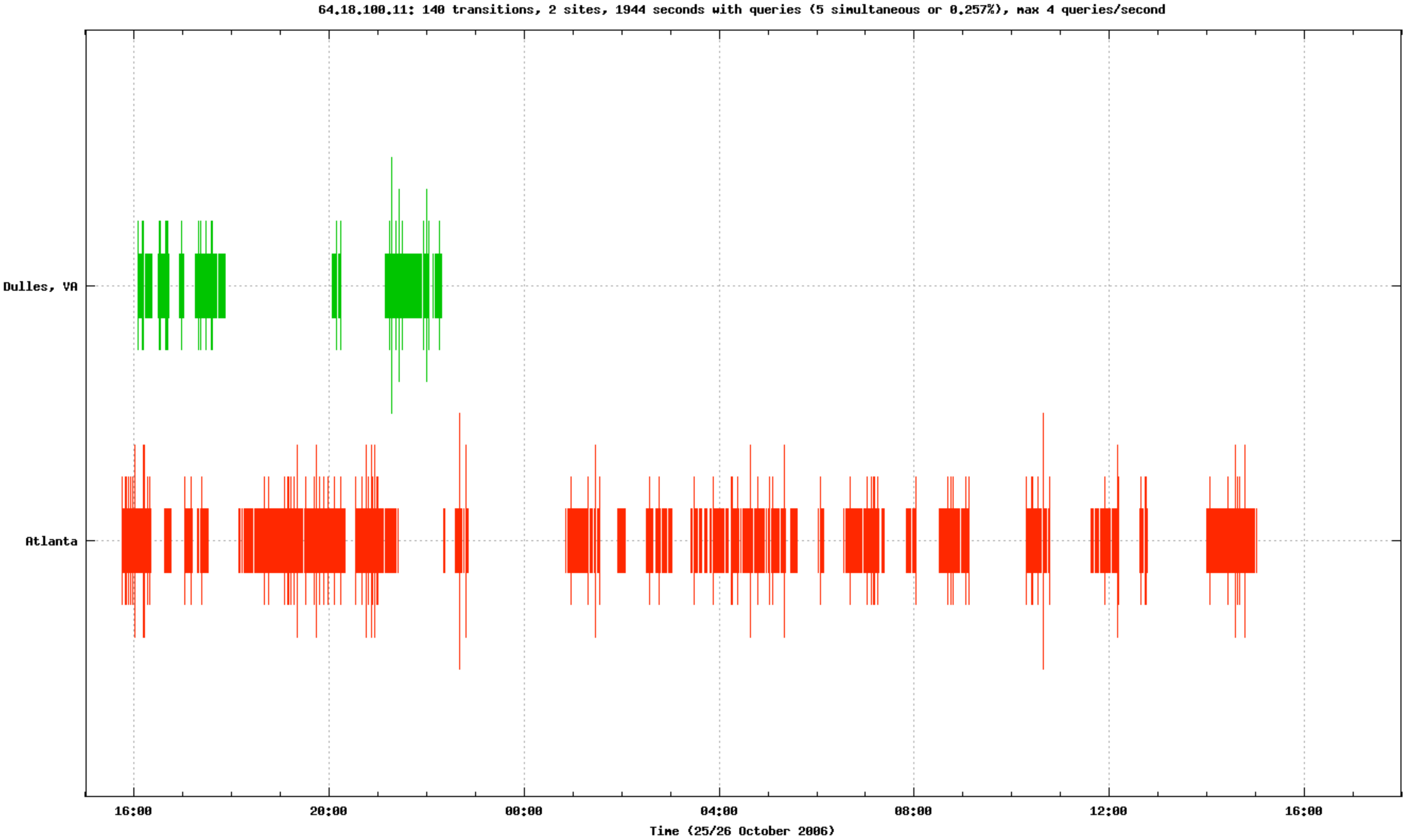
Many Sites, Graph #2 (17th on Top 30 List)



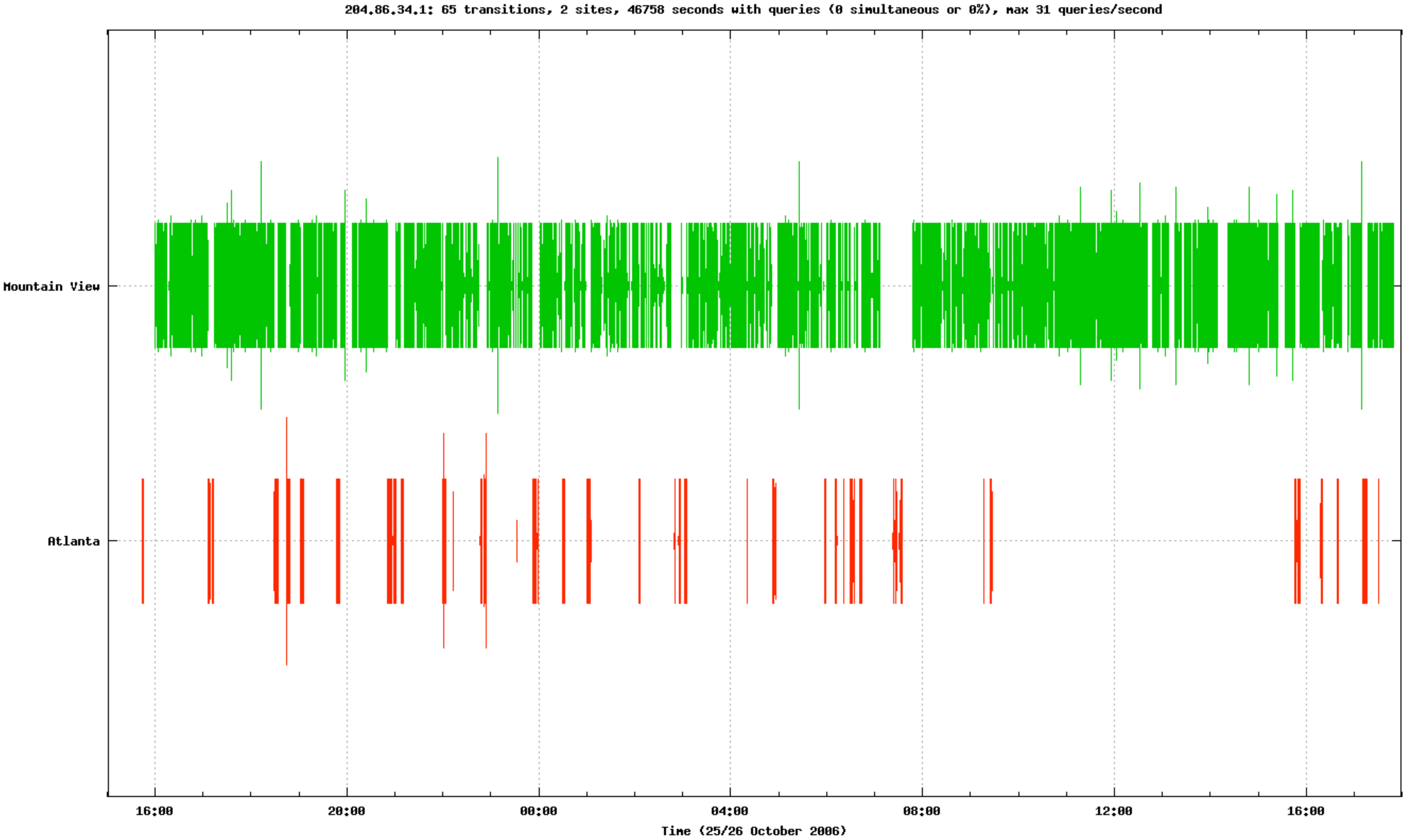
Many Transitions, Graph #1 (4th on Top 30)



Many Transitions, Graph #2 (11th on Top 30)



Many Transitions, Graph #3 (22nd on Top 30)



TCP Packet Capture

- About 25.5 hours of inbound query data:
  - Start: around 1100 EST 31 October 2006
  - Stop: around 1330 EST 1 November 2006
  - Staggered start/stop for packet capture at each site
- High-level statistics:
  - **606,822** total DNS responses sent
    - TCP queries harder to count and analyze
    - DNS query message can and did span multiple segments/packets
  - **238,932** TCP connections established
    - Counted SYN+ACK sent by server
    - Ratio of **2.5** queries per TCP connection
  - **22,854** unique source IP addresses
    - Ratio of **26.5** queries per unique IP address

TCP Resets Sent

- Some TCP resets sent by J root servers would indicate a potential problem
  - E.g., route change during connection, new server instance sends reset in response to unrecognized TCP segment from client
- But some resets legitimate
  - E.g., server closes idle connection
- Counted unmatched resets sent
  - RST sent to <IP,port> not preceded by SYN received from <IP,port>
- **9320** unmatched resets sent to **481** unique IP addresses
  - One unmatched reset sent every **10 seconds**
  - Ratio of one unmatched reset sent for every **25** successful TCP connections
- Resets sent to **5** source IP addresses from two different sites
- Why so many resets? More analysis needed!

TCP Queries to J Root

- But why is *j.root-servers.net* receiving **any** TCP queries?
- Either:
  - Root servers are sending truncated (TC bit set) DNS replies over UDP to prompt requery over TCP, or
  - Resolvers are querying over TCP first before UDP
- 26-hour UDP capture is inbound only, so couldn’t check for TC bit on replies
  - But only 4 out of 495,714 responses had TC bit set in quick capture from Dulles, VA instance
- TCP queries are overwhelmingly QTYPE MX
  - See chart at right for QTYPE breakdown
- In actual UDP traffic:
  - Truncated replies from the root are hard to provoke
  - QTYPE A predominates (> 50%)
- Suspect TCP querying without UDP first: Who and why? More research needed!

TCP query QTYPEs

QTYPE	Count	% Total
WKS	3	0.0005%
A6	4	0.0007%
IXFR	13	0.0021%
CNAME	126	0.0208%
AAAA	258	0.0426%
SRV	302	0.0498%
AXFR	389	0.0642%
PTR	1,842	0.3040%
ANY	1,942	0.3206%
SOA	2,602	0.4295%
NS	3,609	0.5957%
TXT	11,353	1.8740%
A	16,194	2.6731%
MX	**567,185**	**93.6224%**

Conclusions / Findings

- Much of the “interesting” IP multi-site traffic looks explainable by per-packet load balancing
- A puzzling and as-yet-unexplained large number of unmatched TCP resets sent by J root servers
- Some iterative resolvers appear to send TCP queries without trying UDP first, particularly for MX records

- Looks like TCP DNS over anycast is not exactly the same as unicast
  - **We do not think there is a problem here**
  - But more research would be good

For The Record…

- “Life and Times of J-ROOT” (NANOG 32, October 2004) has this statement:
  - “DO NOT RUN Anycast with Stateful Transport”
- What it did not mean / what we never said:
  - “Don’t run DNS over anycast”
- DNS over anycast works great!
  - VeriSign is a big proponent of anycasting critical DNS infrastructure
  - VeriSign anycasts root and *.com*/*.net* name servers
- TCP DNS is not broken by anycast
  - It clearly works (in most cases)
- But longer-running TCP sessions may have problems
  - We see that over transitions
  - Per-packet load balancing sites may have issues
  - Want to warn those who don't engineer these anycast solutions carefully

Future Research

- Reasons for and circumstances surrounding unmatched TCP resets sent
- Source of (which implementation) initial TCP queries not preceded by UDP queries
- Investigate transitions in “global node” vs. “local node” context

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Thank You

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