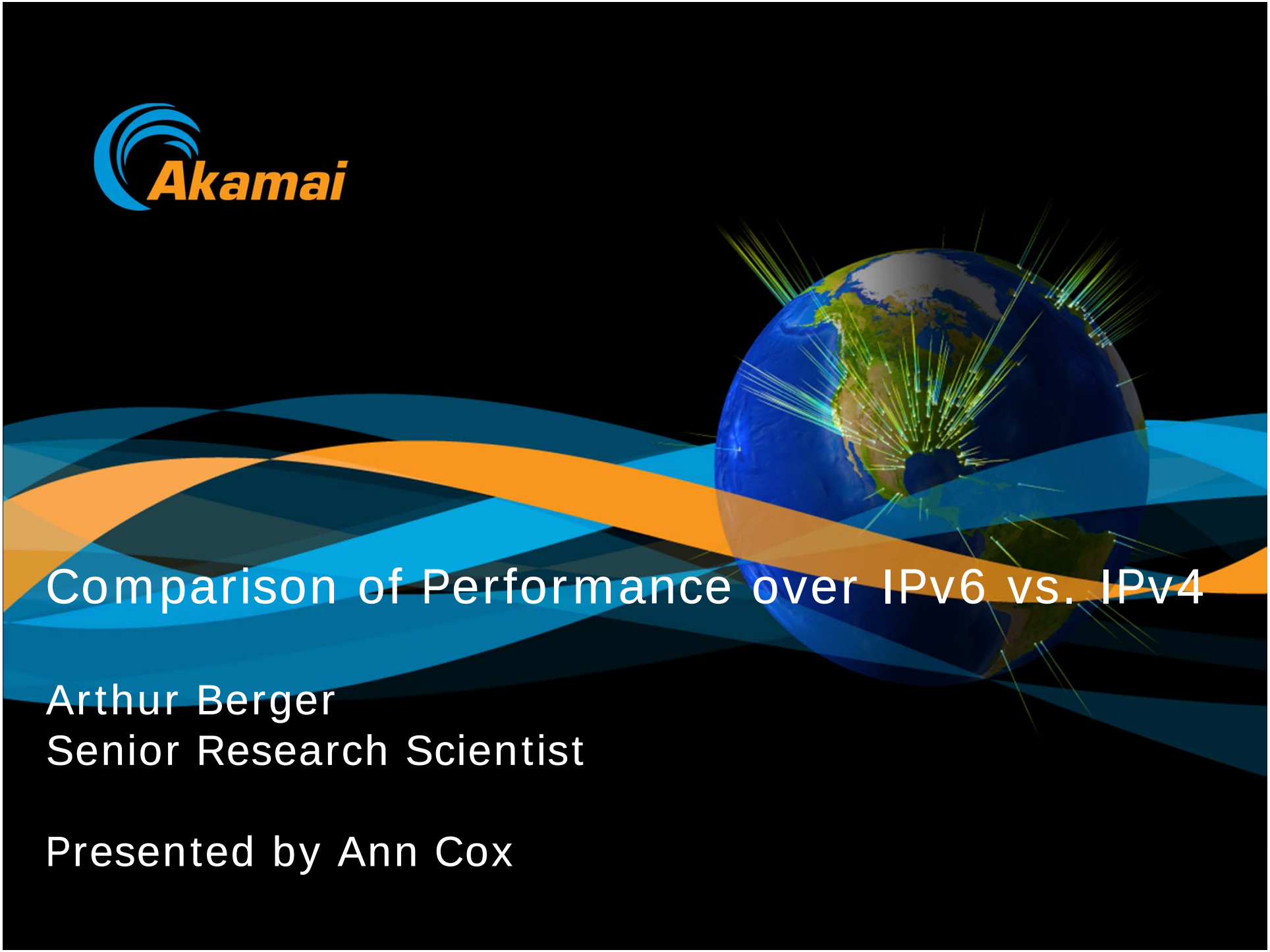


Comparison of Performance over IPv6 vs. IPv4

Arthur Berger
Senior Research Scientist

Presented by Ann Cox

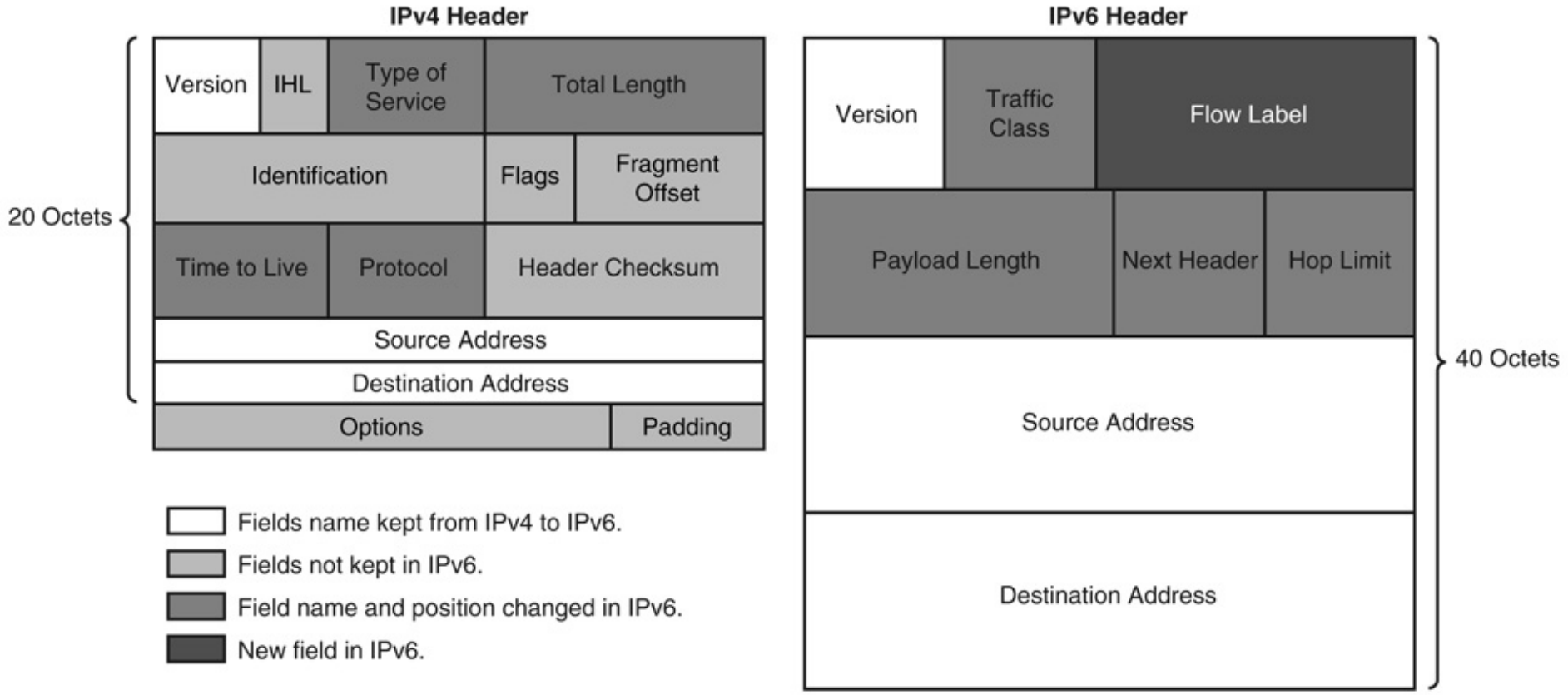
Background

- Address space in IPv4 is getting tight
  - IANA has allocated all v4 addresses
  - Asian regional registry has begun "hyper-austerity"
  - Nortel sold 667,000 v4 addresses to Microsoft for $7.5 million, about $11/address.

Background

- Address space in IPv4 is getting tight
  - IANA has allocated all v4 addresses
  - Asian regional registry has begun "hyper-austerity"
  - Nortel sold 667,000 v4 addresses to Microsoft for $7.5 million, about $11/address
- IPv4 and IPv6 will coexist for a long time
- Opportunity to select based on performance

Background: Header Format



Related Work

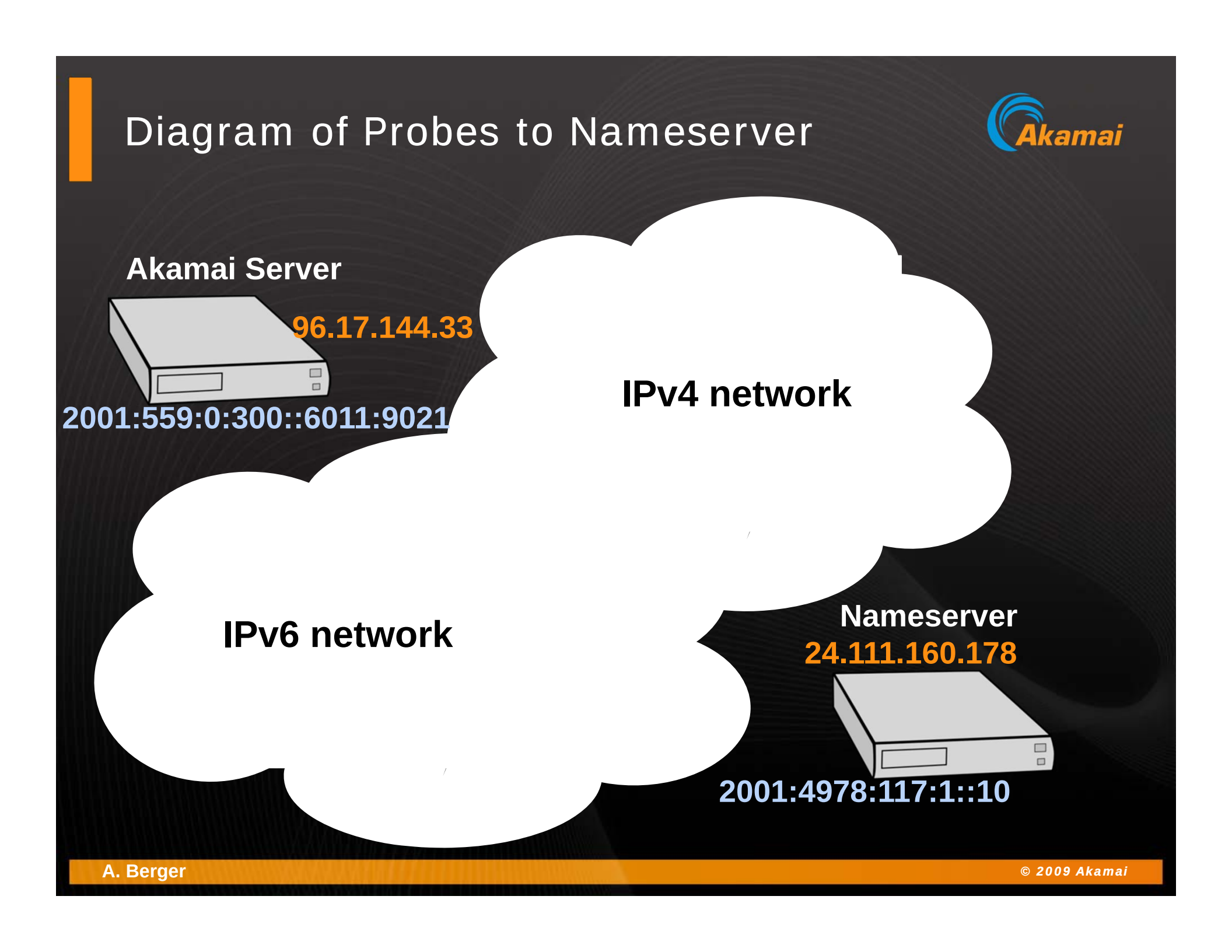
- *ARIN* www.getipv6.info/index.php/IPv6_Penetration_Survey_Results
- *Performance Evaluation of IPv4 and IPv6 on Windows Vista and Linux Ubuntu,* Narayan, Shang & Fan, 2009
- *Empirical performance of IPv6 vs. IPv4 under a dual-stack environment* Law, Lai, Tan & Lau, 2008
- *IPv6 delay and loss performance evaluation* Zhou, Jacobsson, Uijterwaal & Mieghem, 2007
- *Evaluating IPv6 on a large-scale network* Shiau, Li, Chao & Hsu, 2006
- *Hopcount and E2E Delay: IPv6 versus IPv4* Zhou & Mieghem, 2005
- *Understanding Current IPv6 Performance: A measurement study* Wang Ye & Li, 2005
- *Identifying IPv6 Network Problems in the Dual-Stack World*, Cho, Luckie & Huffaker, 2004

Performance: v4 versus v6

Dataset:

- Pings from three locations in the U.S.:
  - San Jose CA, Dallas TX, and Reston, VA.
- to ~7,000 globally distributed dual-stack nameservers
- for period of April – Dec. 2010
- 44 million measurements

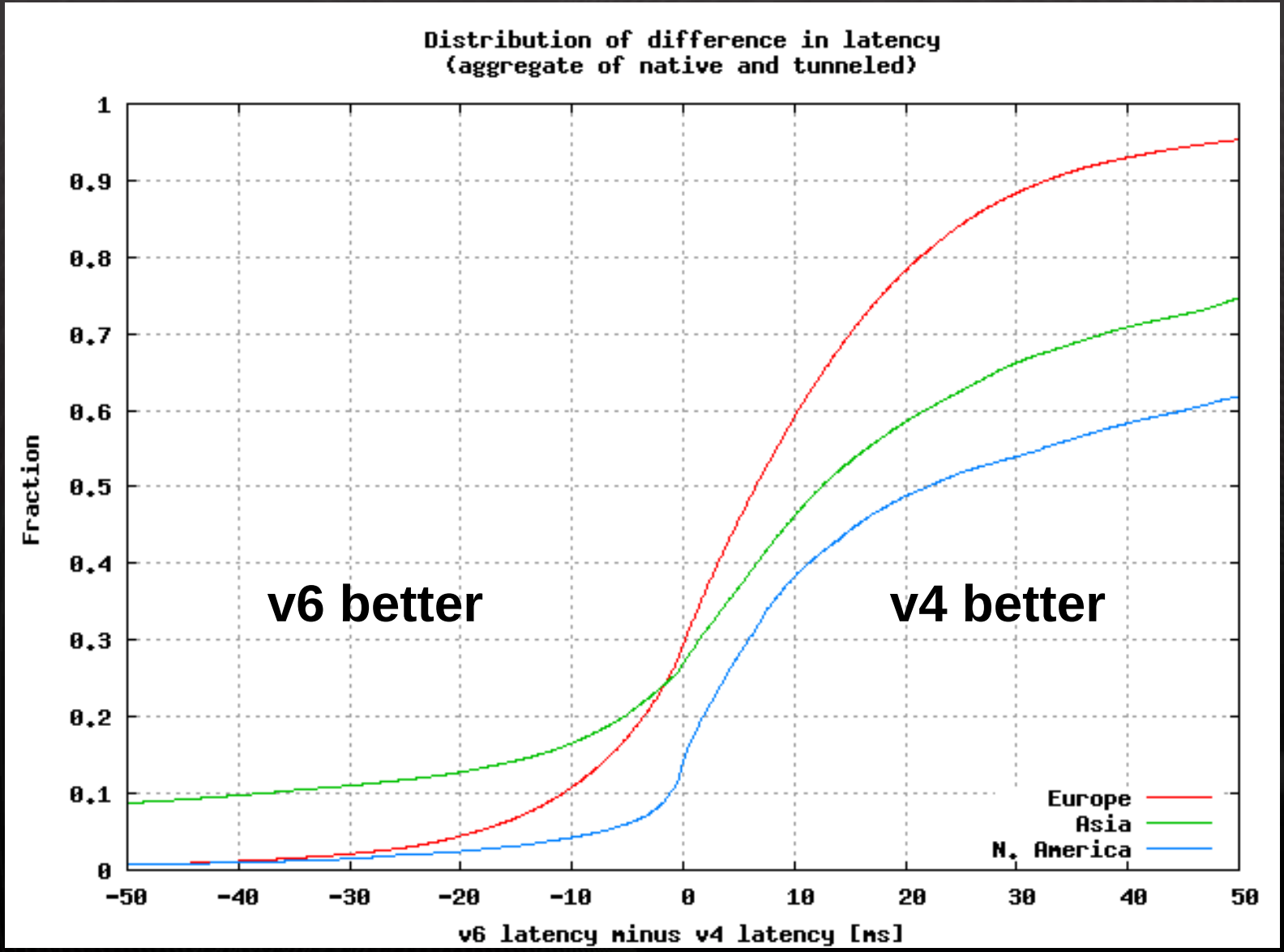
Diagram of Probes to Nameserver



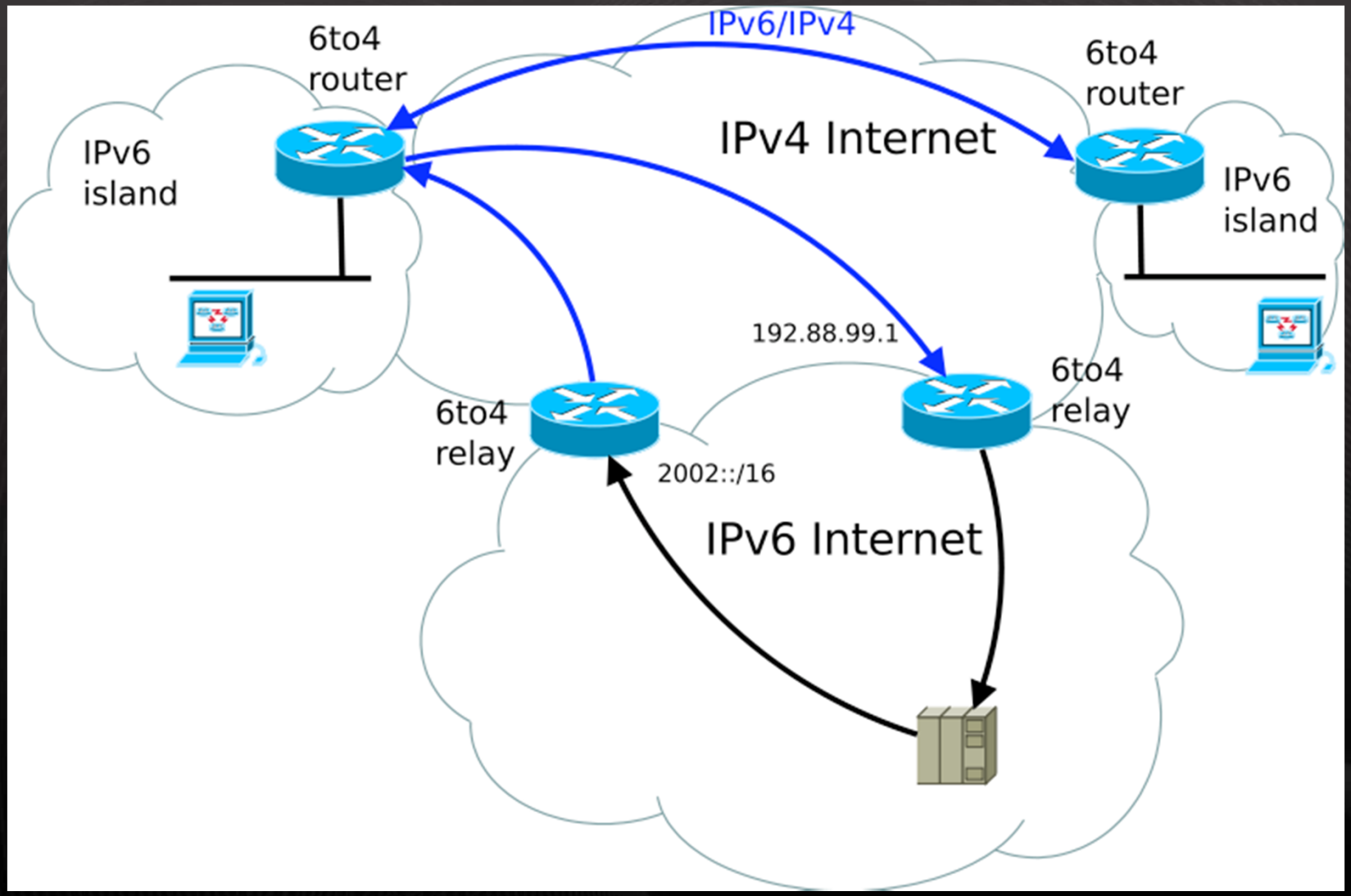
Summary Statistics on Latency

Geo-region	Latency [ms]					
	median		mean		95th percentile	
	v4	v6	v4	v6	v4	v6
North America	49	92	55	101	108	192
Europe	154	166	158	168	224	240
Asia	196	215	216	240	367	388
South America	176	217	186	235	306	392
Africa	348	368	356	379	481	529
Australia	210	227	216	244	298	384

Amount either has better latency



6to4 tunneling



from: en.wikipedia.org/wiki/6to4

Native vs. Tunneled Latency

Geo-region	Set of Nameservers based on v6 interface	Median Latency [ms]	
		v4	v6
North America	native	47	86
	tunneled	53	101
Europe	native	151	162
	tunneled	167	182
Asia	native	184	198
	tunneled	229	313
South America	native	183	198
	tunneled	172	223
Africa	native	344	357
	tunneled	355	377
Australia	native	208	216
	tunneled	225	275

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expected

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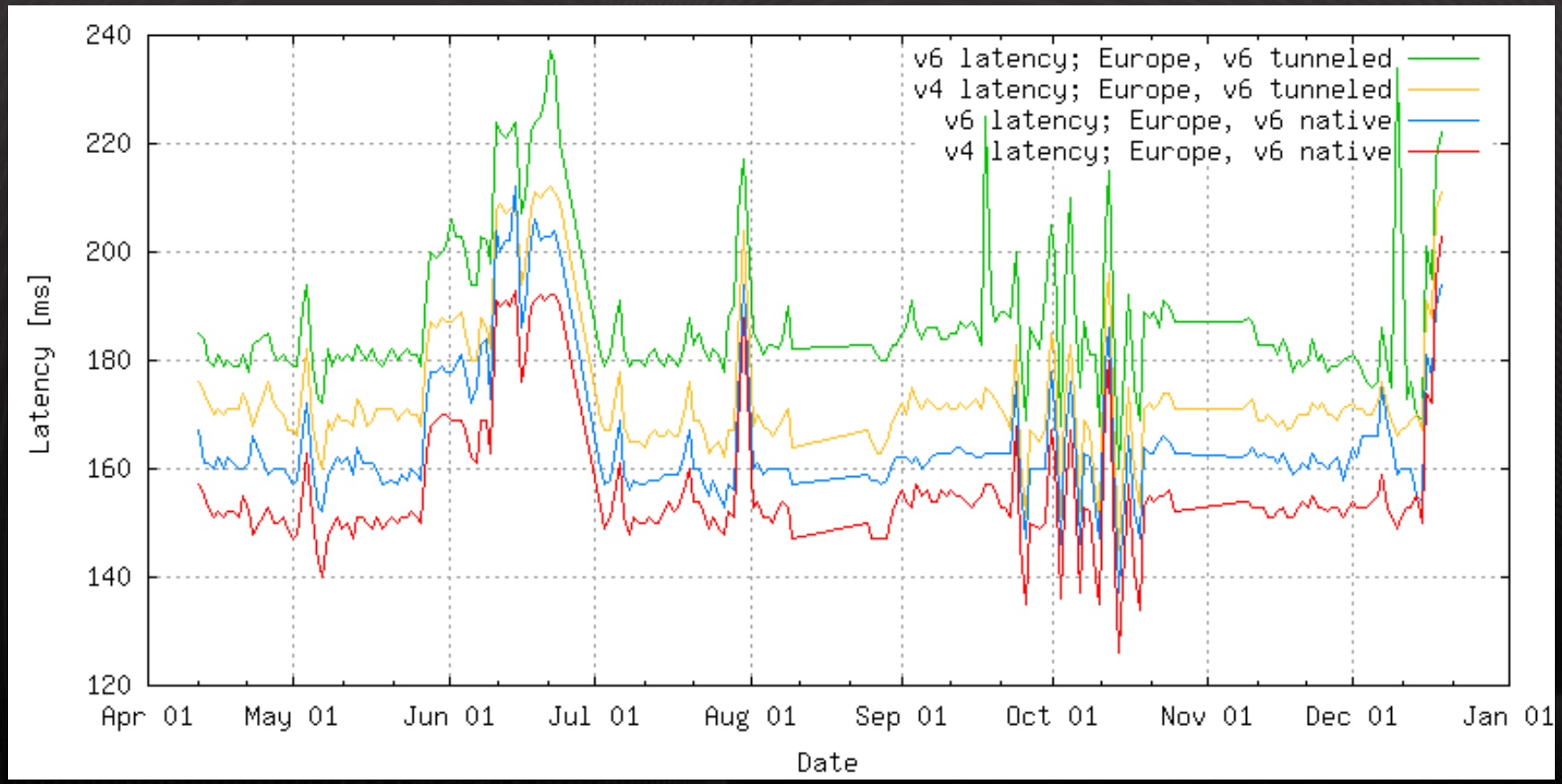
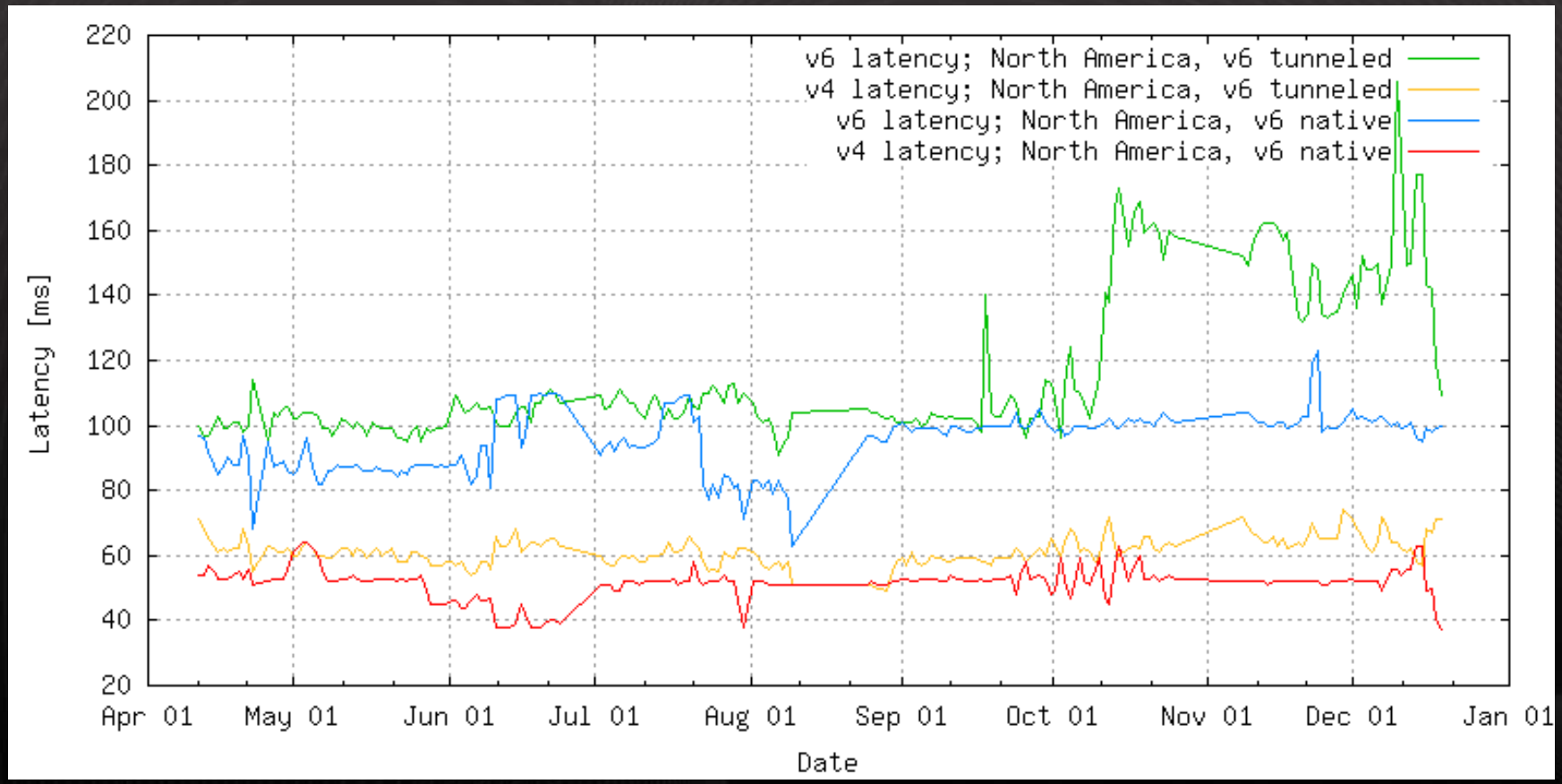
surprise

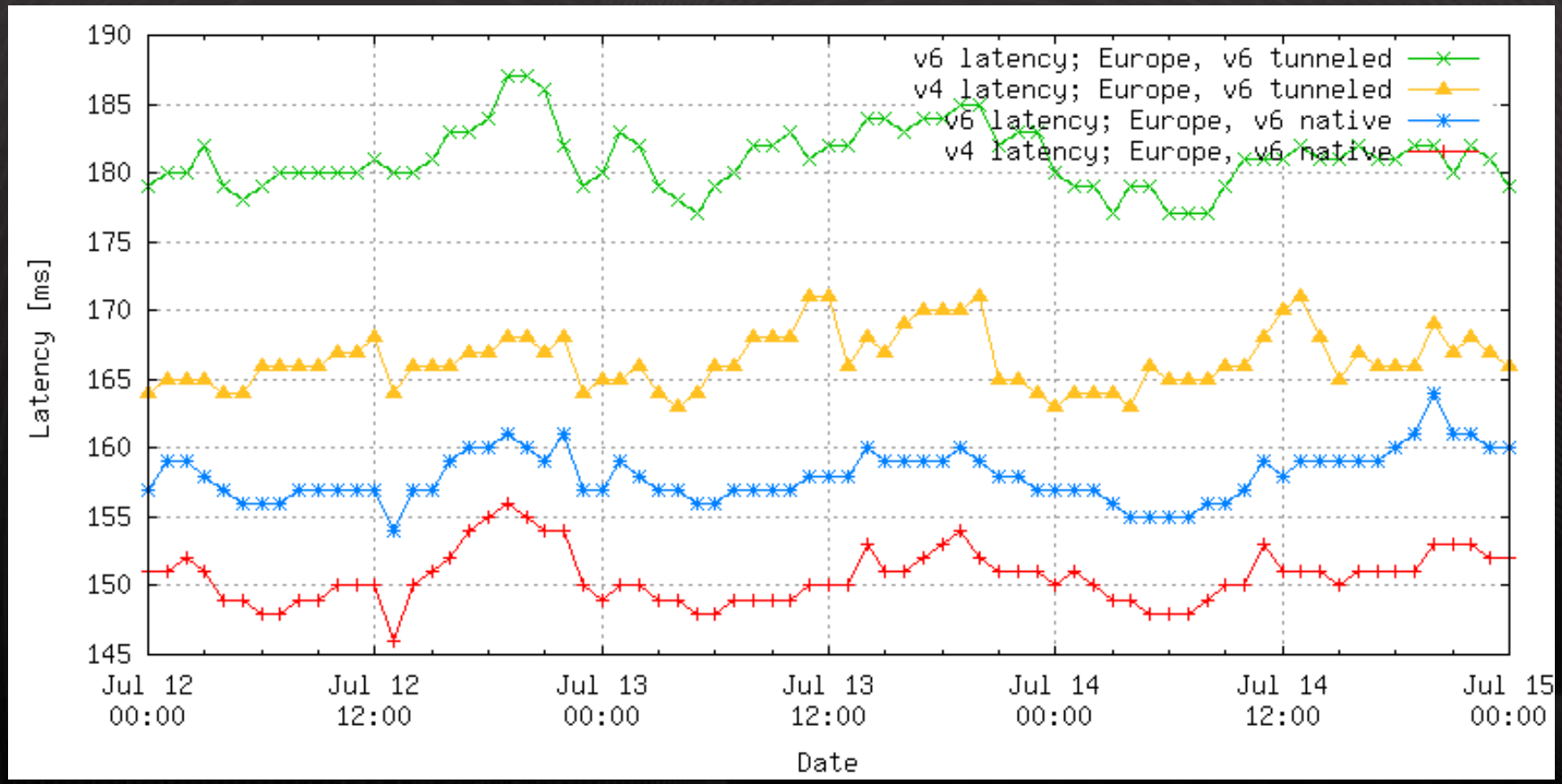
Time History: 8 Months, Latency, Europe



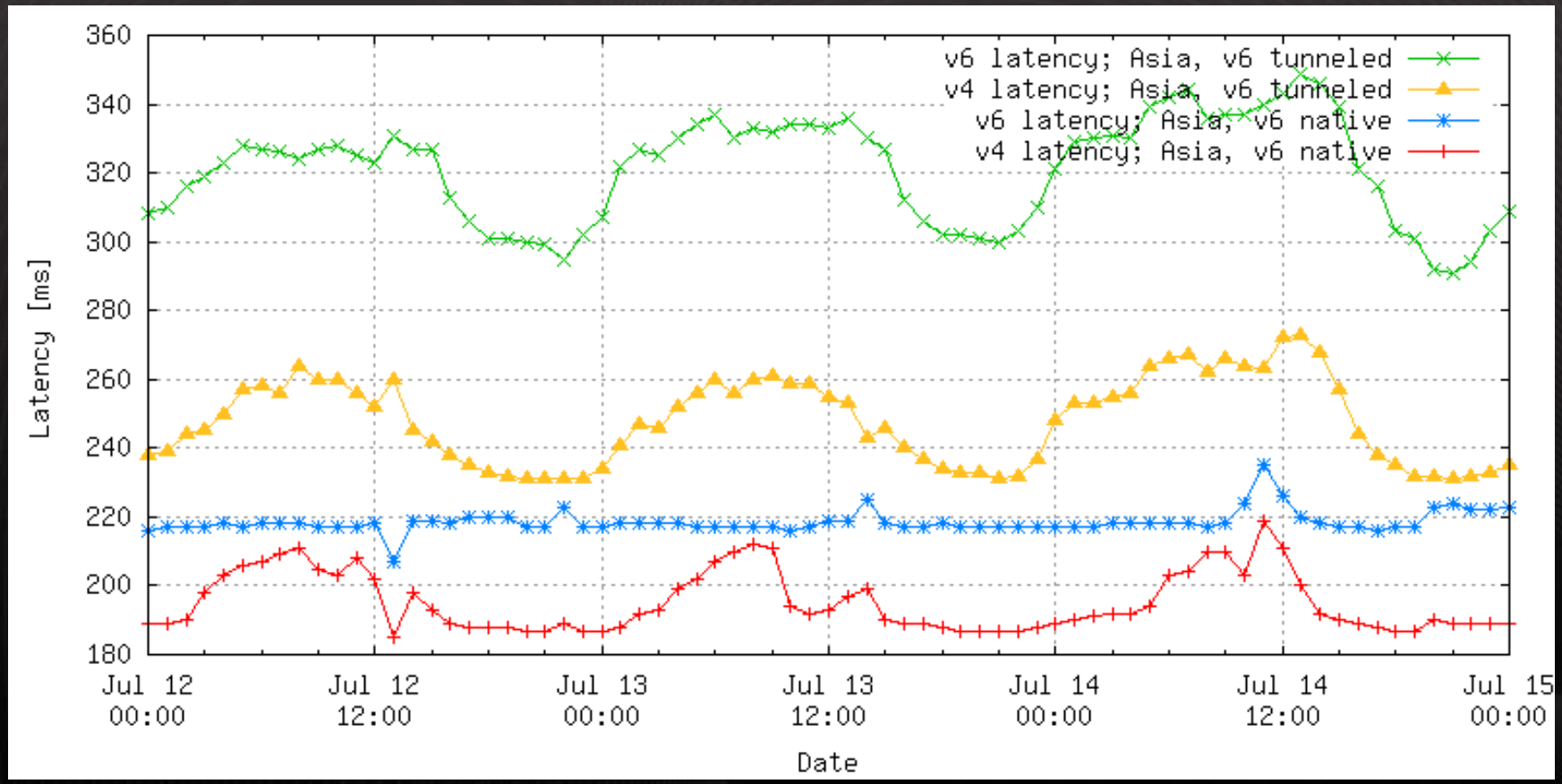
Time History: 8 Months, Latency, North America



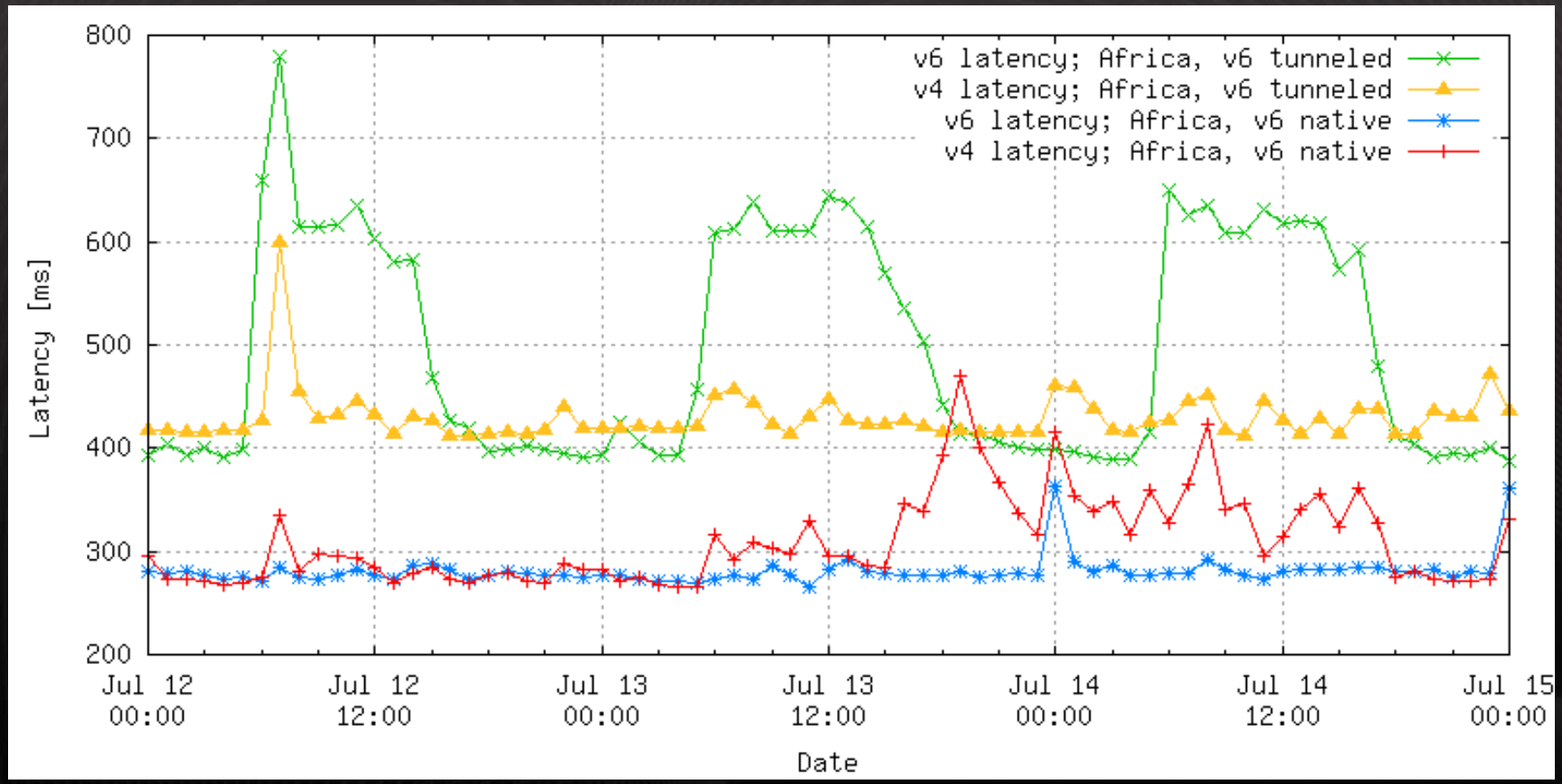
Time History: 3 Days, Latency, Europe



Time History: 3 Days, Latency, Asia



Time History: 3 Days, Latency, Africa

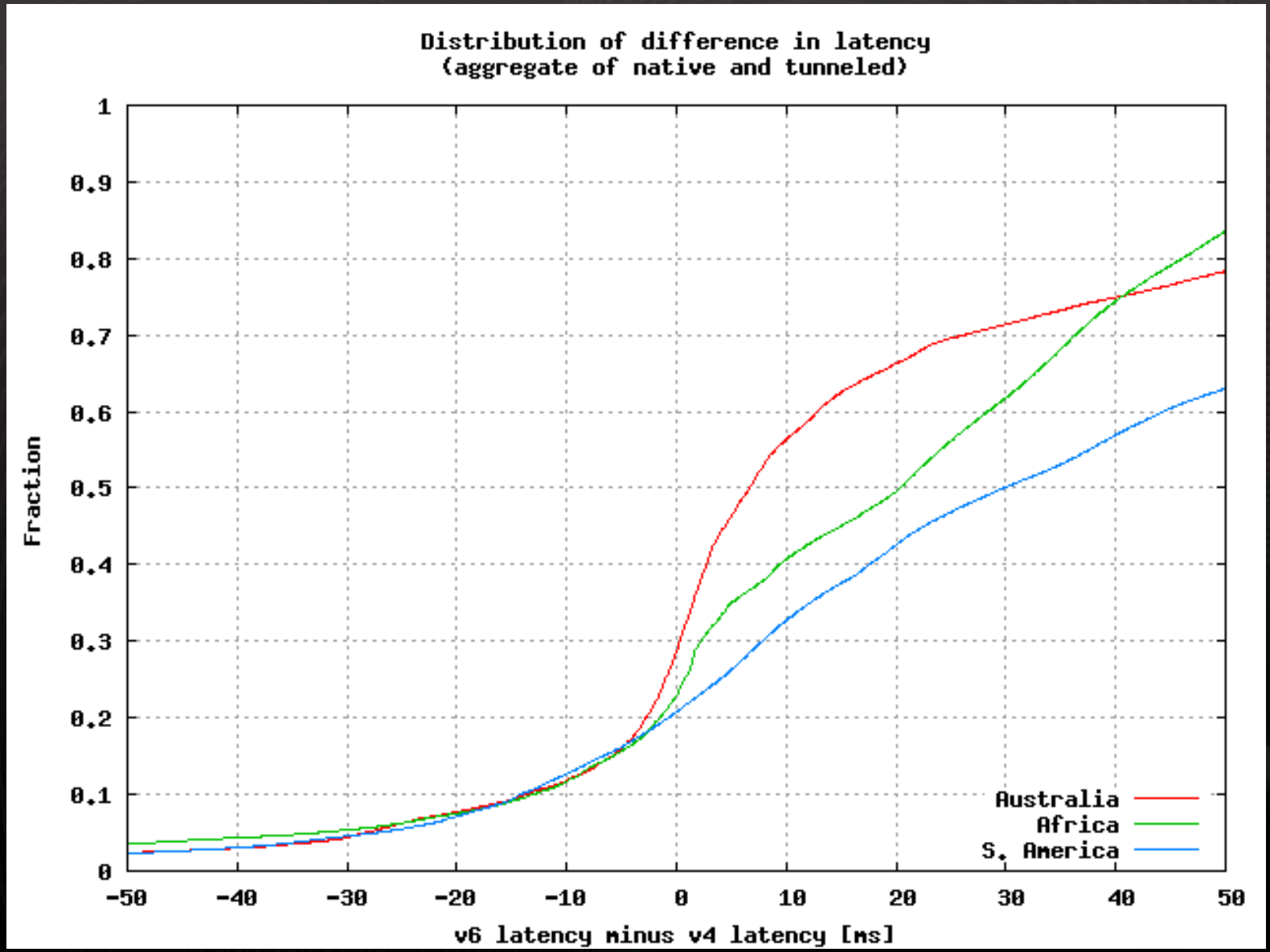


Summary

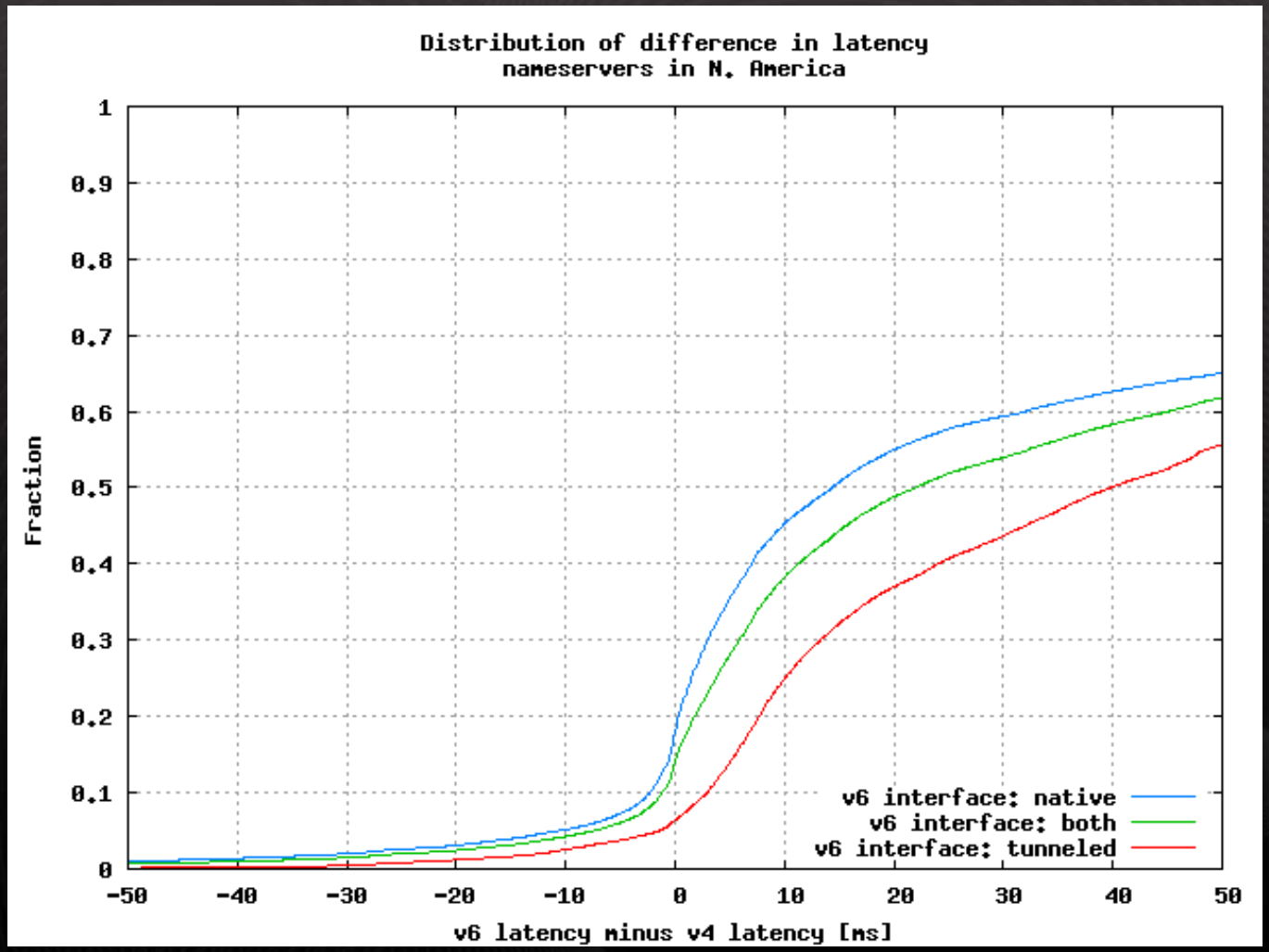
- Increasing pressure to deploy IPv6
- Compared performance over v6 vs. v4
  - Overall, latency and loss is higher on v6,
  - but not always, or for all locations.
  - Opportunity to select based on performance.
  - Potential for insights into network architecture.

Additional Slides

CDF of difference in latency



CDF of difference in latency; native vs. tunneled



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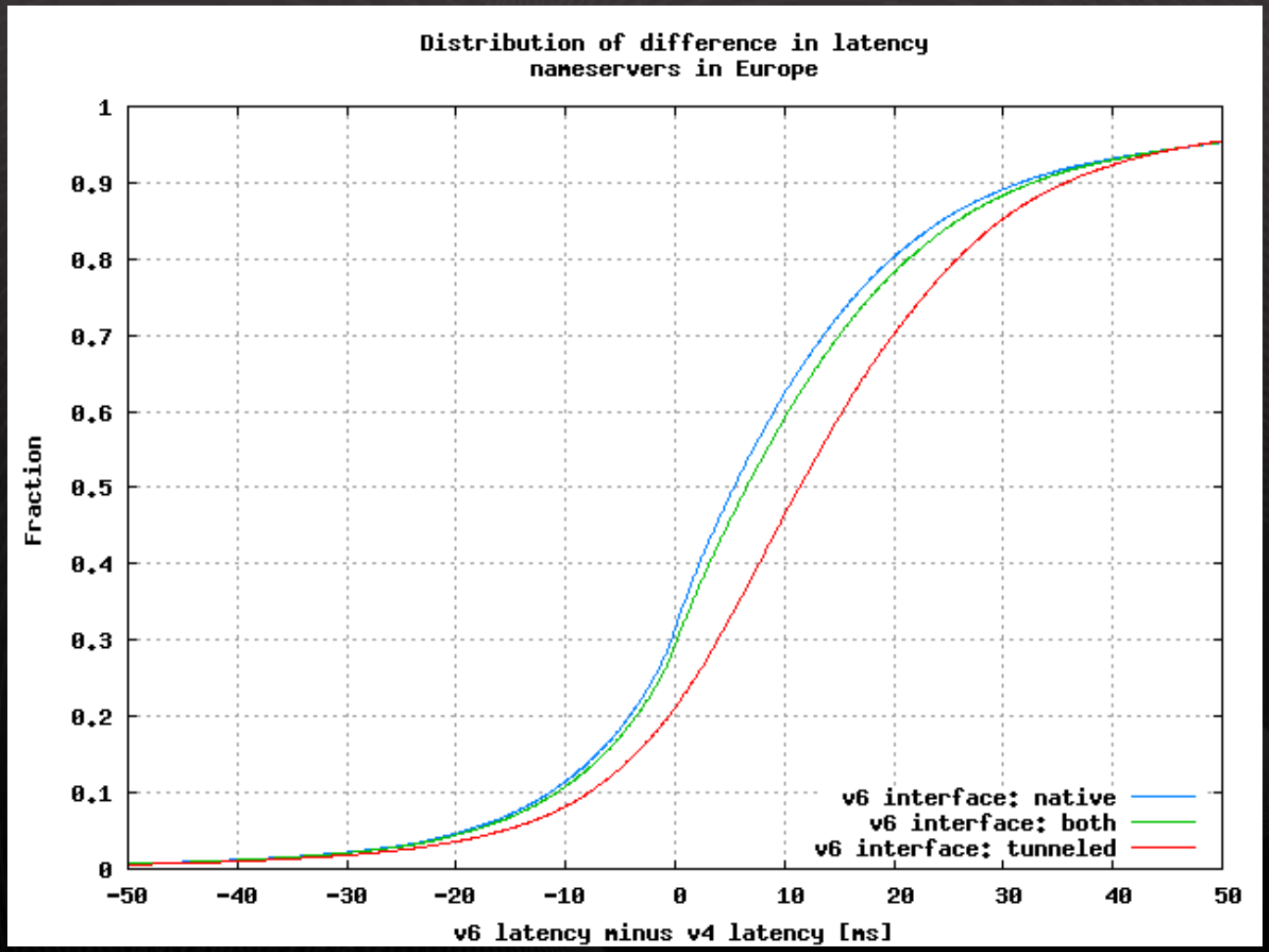
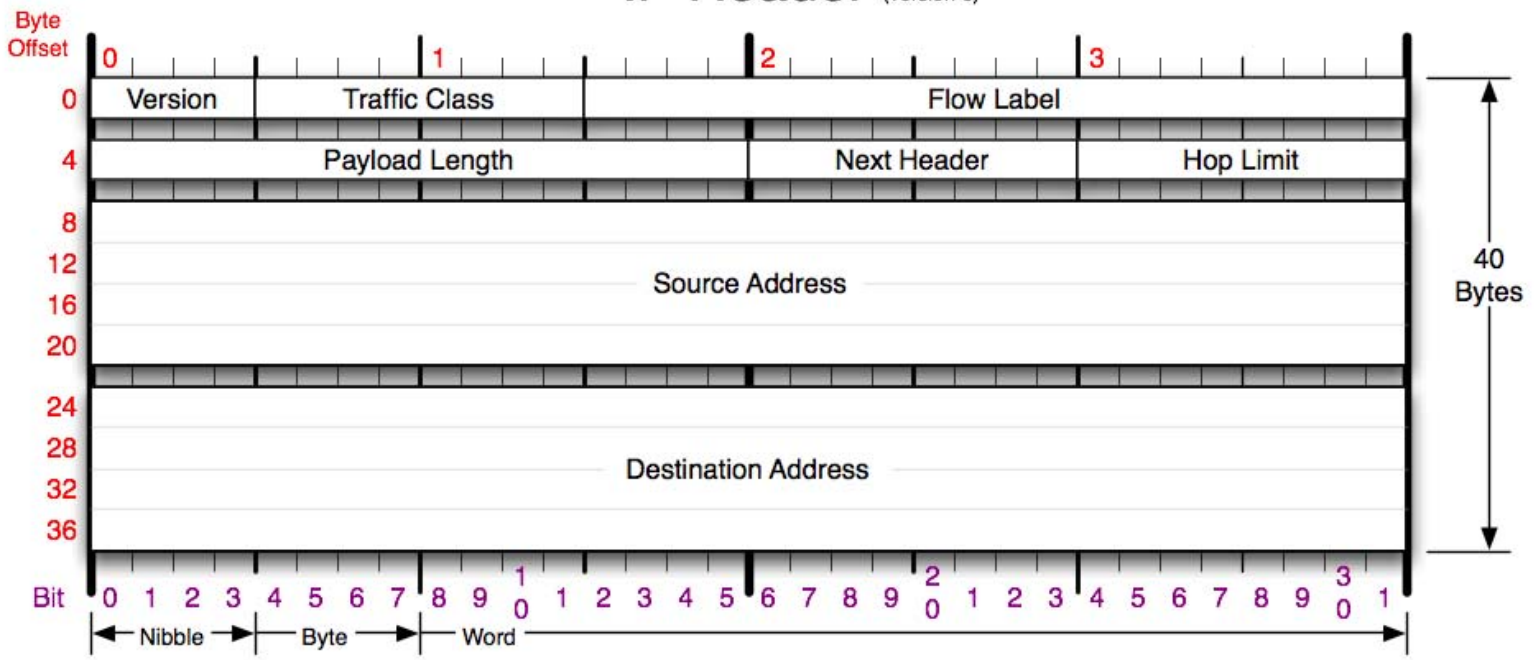


IP Header (version 6)



Version

Version of IP Protocol. 4 and 6 are valid. This diagram represents version 6 structure only.

Traffic Class

8 bit traffic class field.

Flow Label

20 bit flow label.

Payload Length

16-bit unsigned integer. Length of the IPv6 payload, i.e., the rest of the packet following this IPv6 header, in octets. Any extension headers are considered part of the payload.

Source Address

128-bit address of the originator of the packet.

Next Header

8-bit selector. Identifies the type of header immediately following the IPv6 header. Uses the same values as the IPv4 Protocol field.

Destination Address

128-bit address of the intended recipient of the packet (possibly not the ultimate recipient, if a Routing header is present).

Hop Limit

8-bit unsigned integer. Decremented by 1 by each node that forwards the packet. The packet is discarded if Hop Limit is decremented to zero.

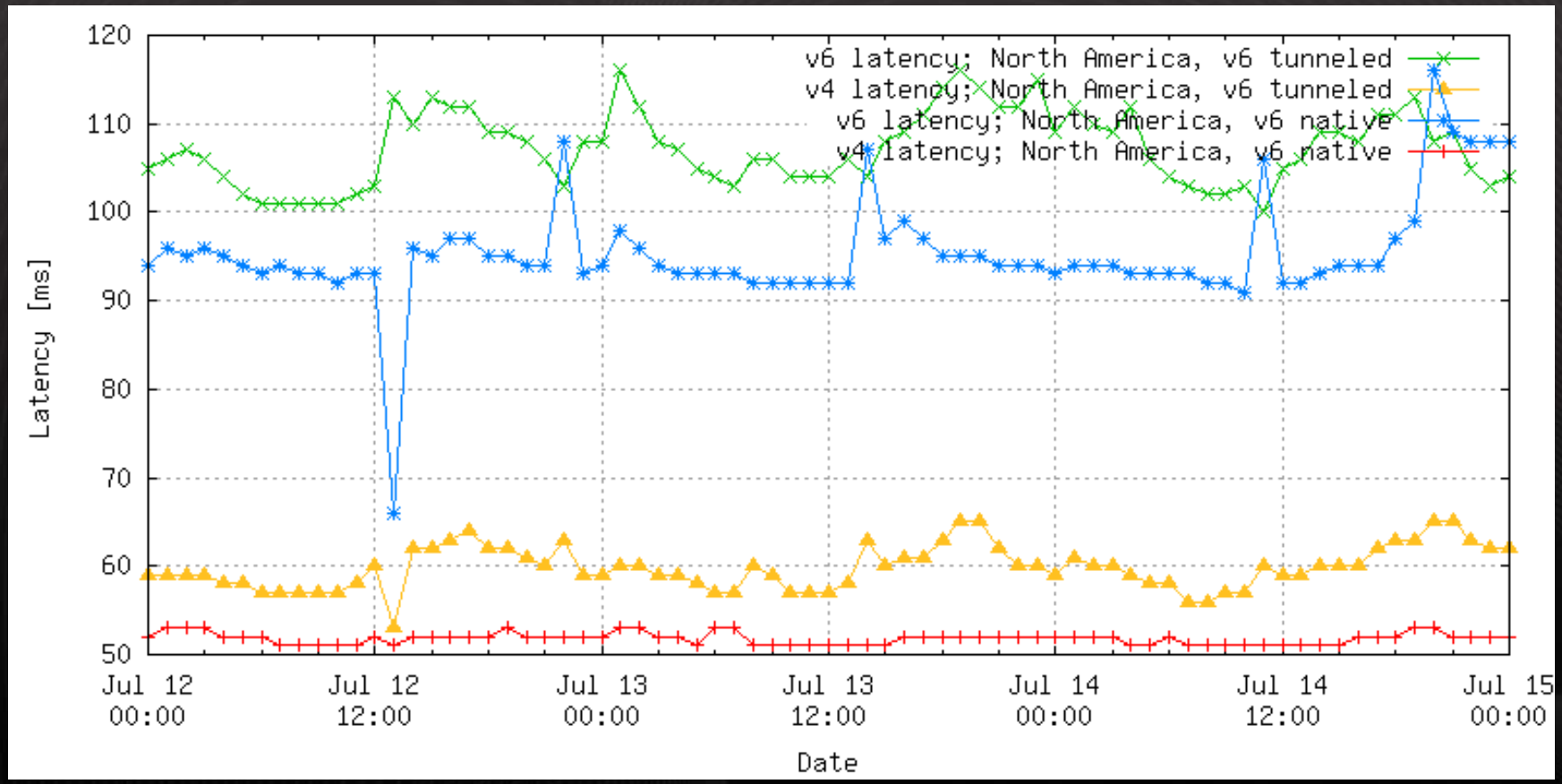
RFC 2460

Please refer to RFC 2460 for the complete Internet Protocol version 6 (IPv6) Specification.

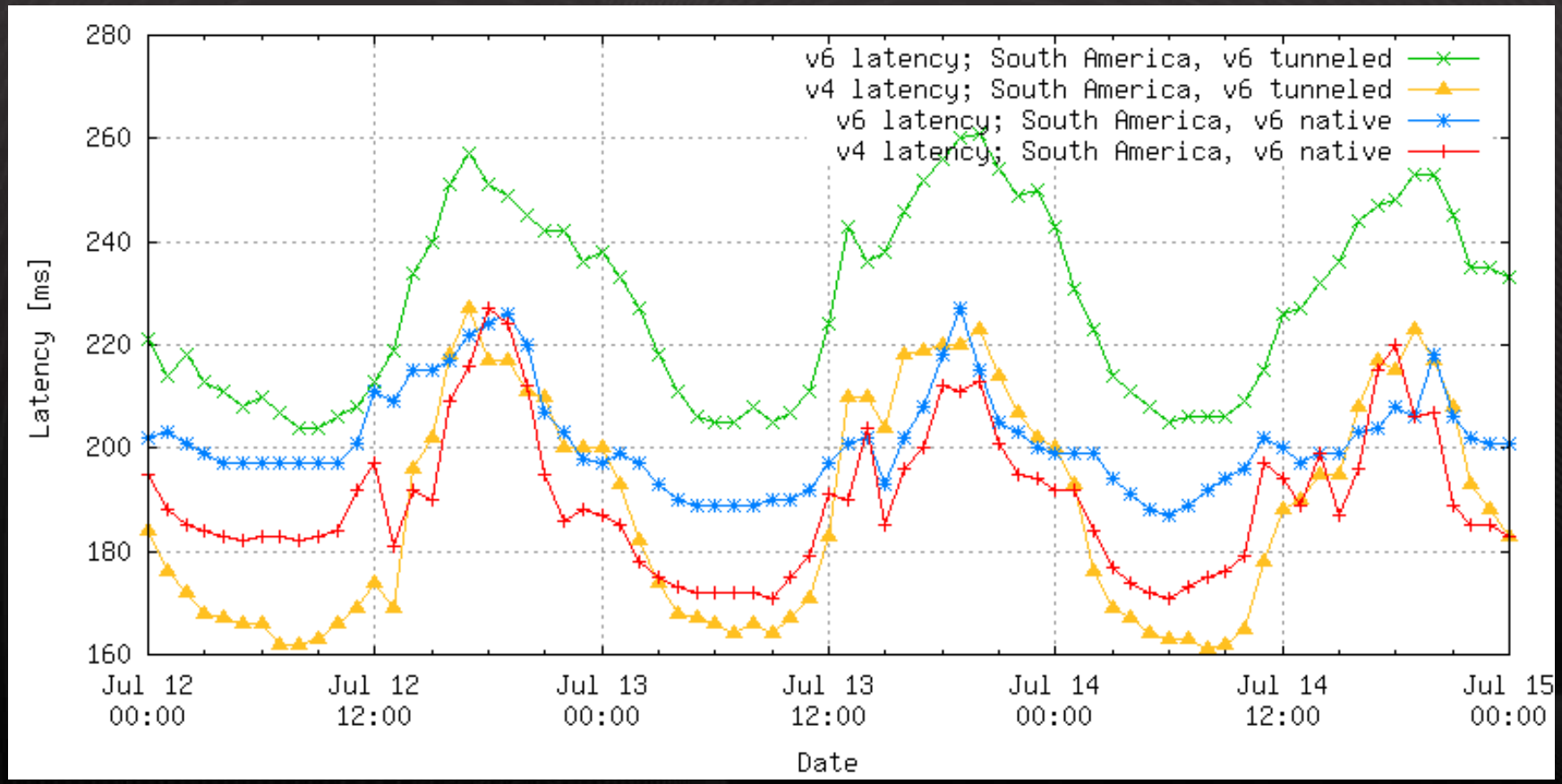
Well-known IPv6 prefixes

Address Type	Prefix
Unspecified	::/128
Loopback	::1/128
Multicast	FF00::/8
Link-local Unicast	FE80::/10
Global Unicast	Everything except above
Unique Local (locally assigned)	FD00::/8
Unique Local (registered)	FC00::/8
6to4 tunnel	2002::/16
Teredo tunnel	2001:0000::/32

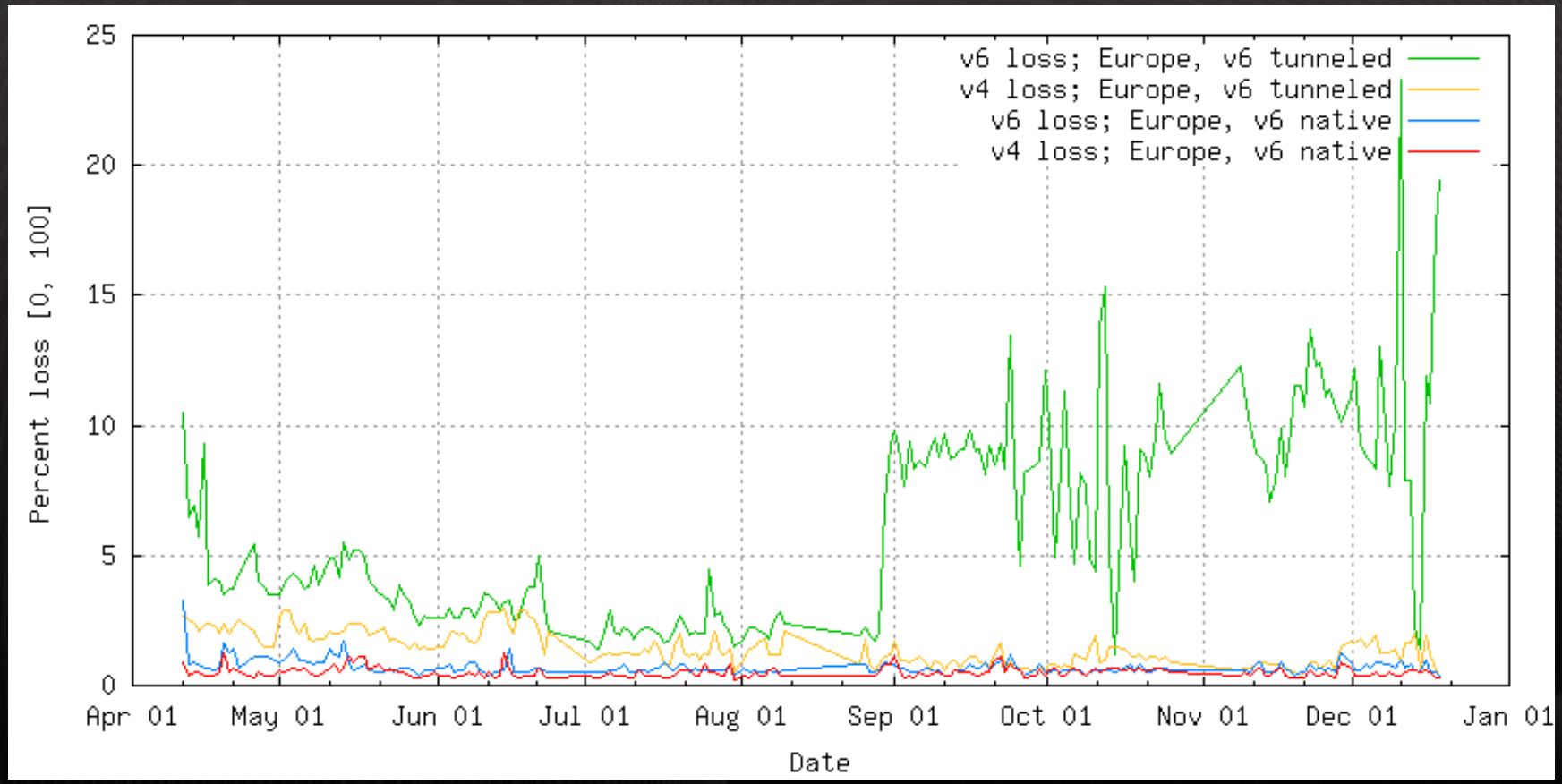
Time History: 3 Days, Latency, North America



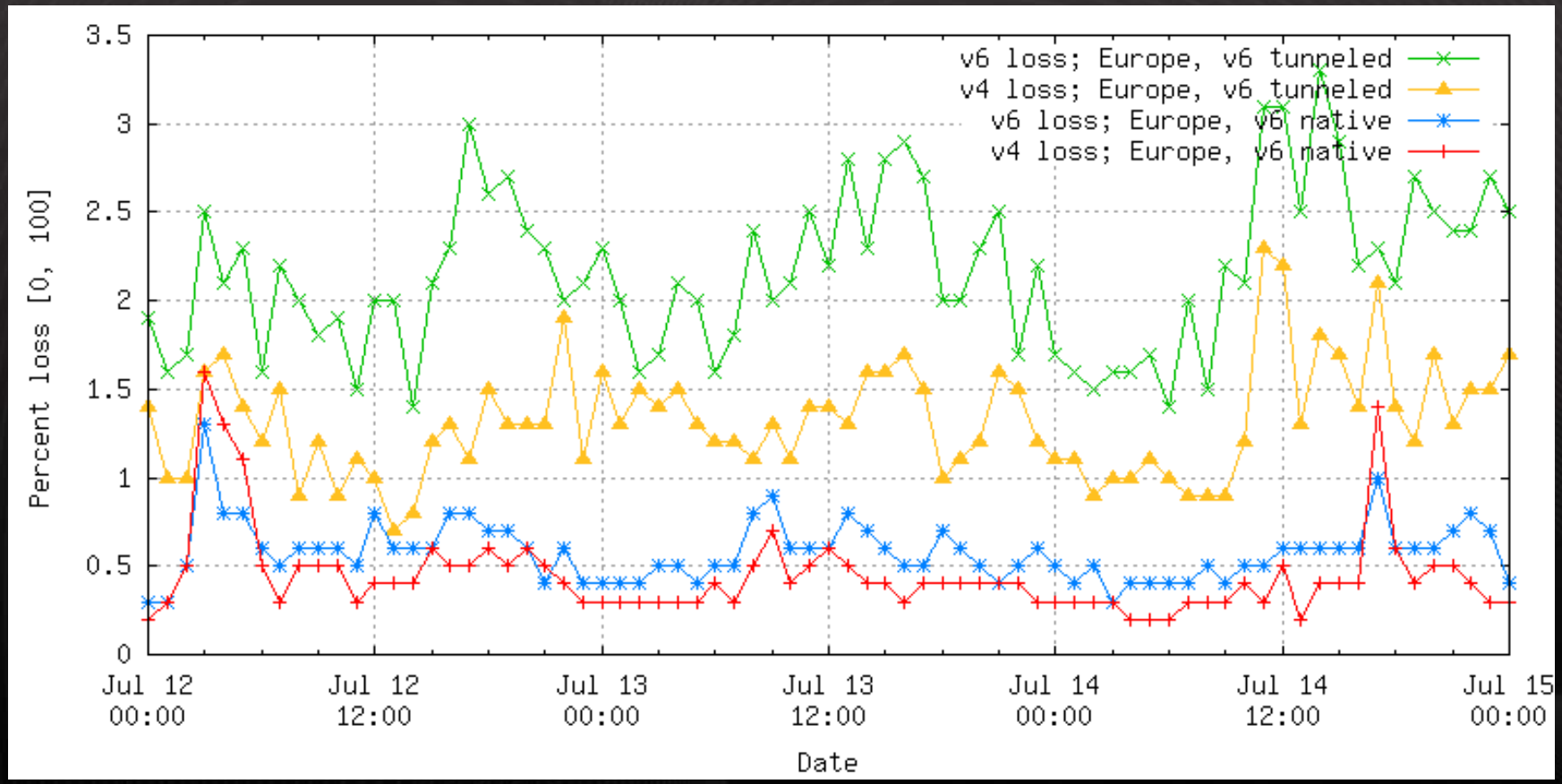
Time History: 3 Days, Latency, South America



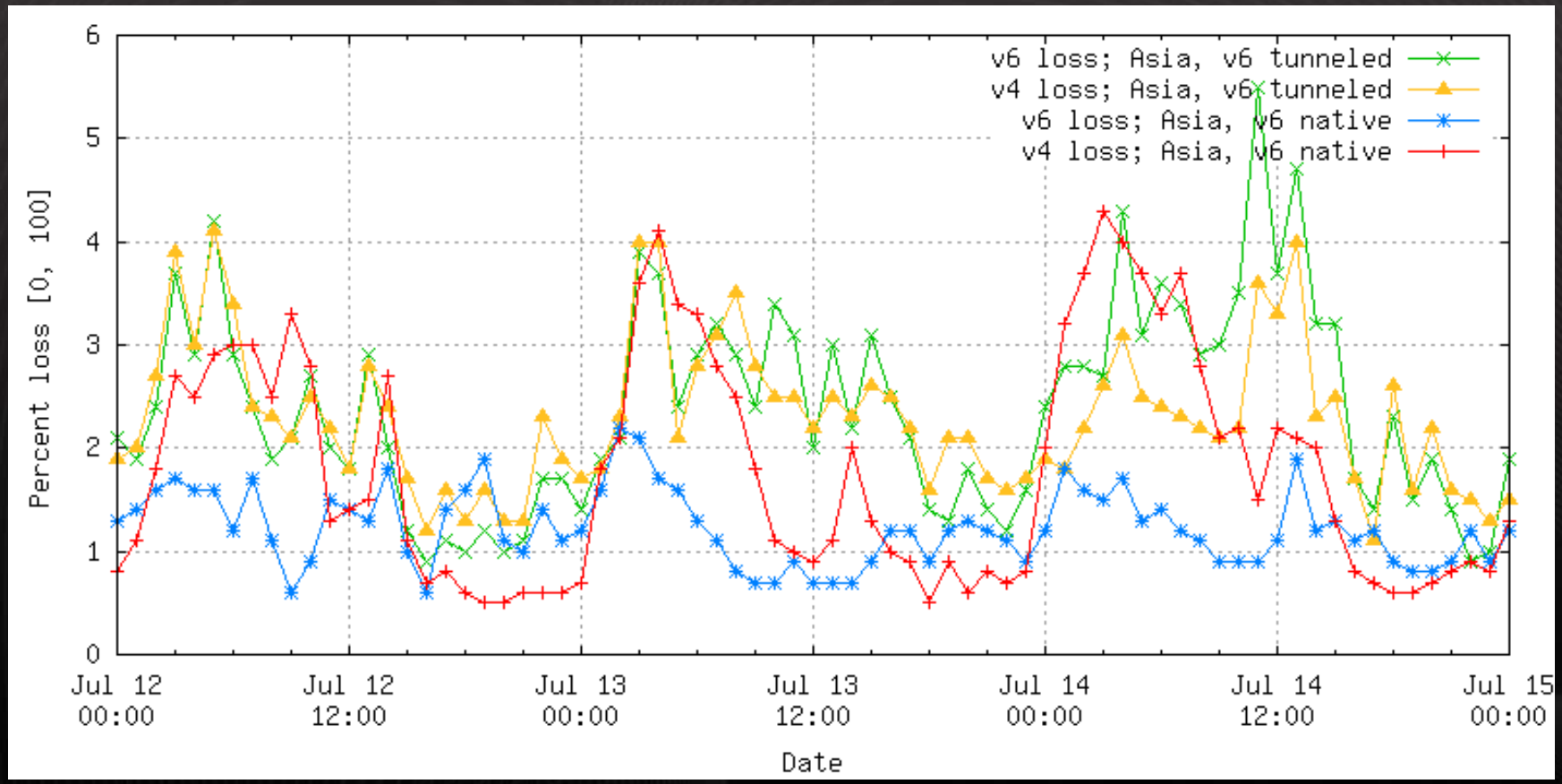
Time History: Loss, Europe

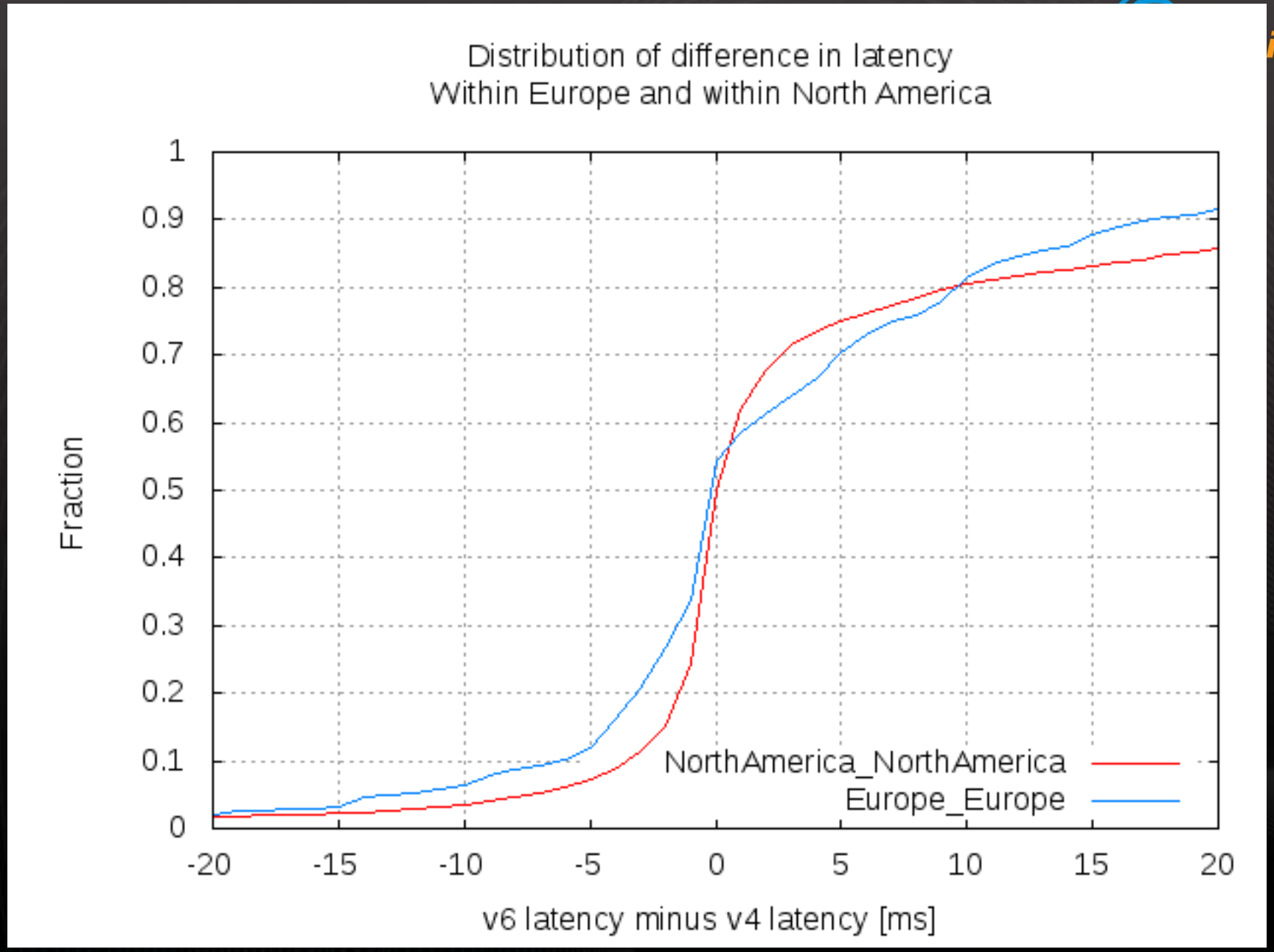


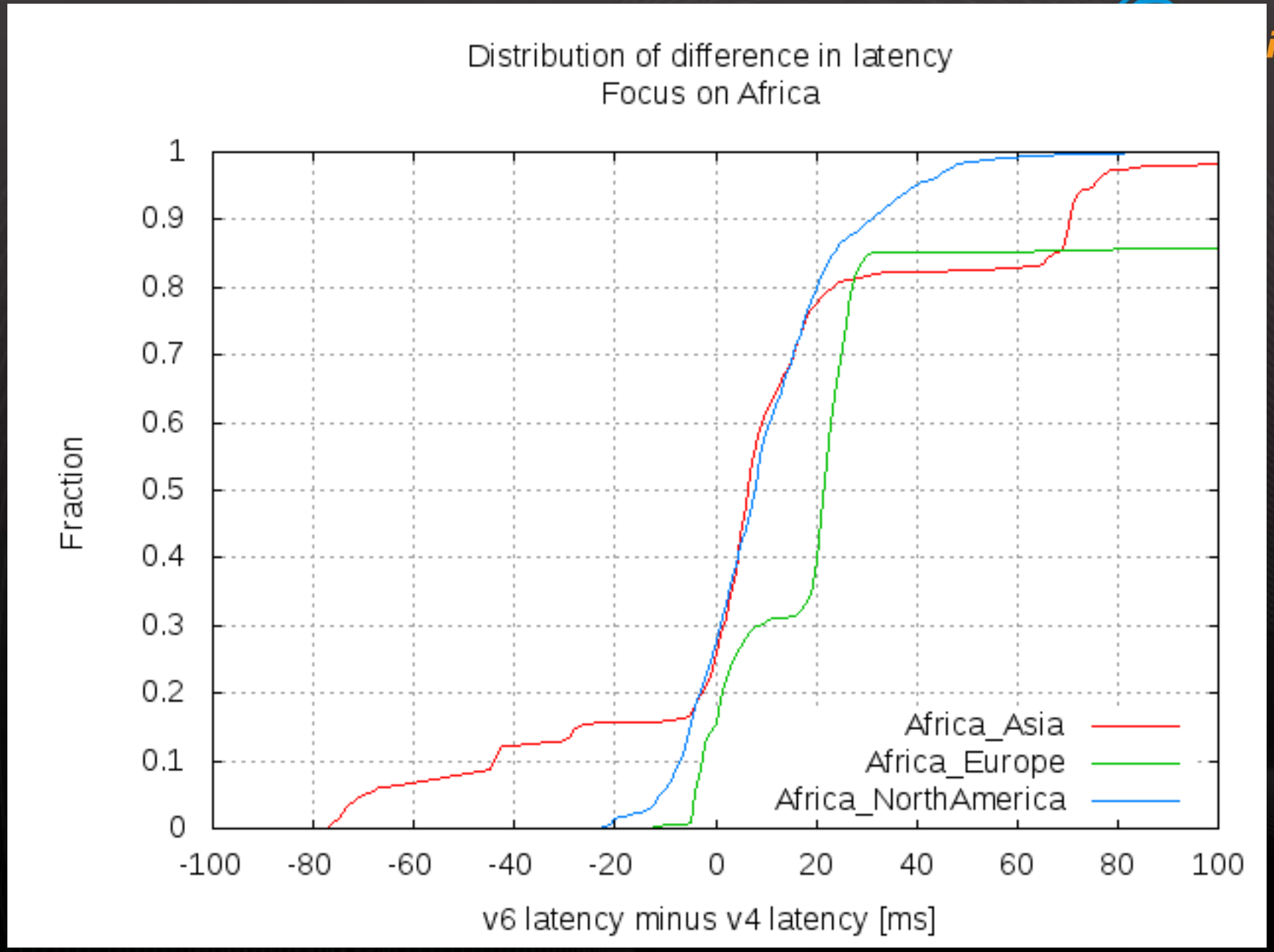
Time History: Loss, Europe



Time History: Loss, Asia

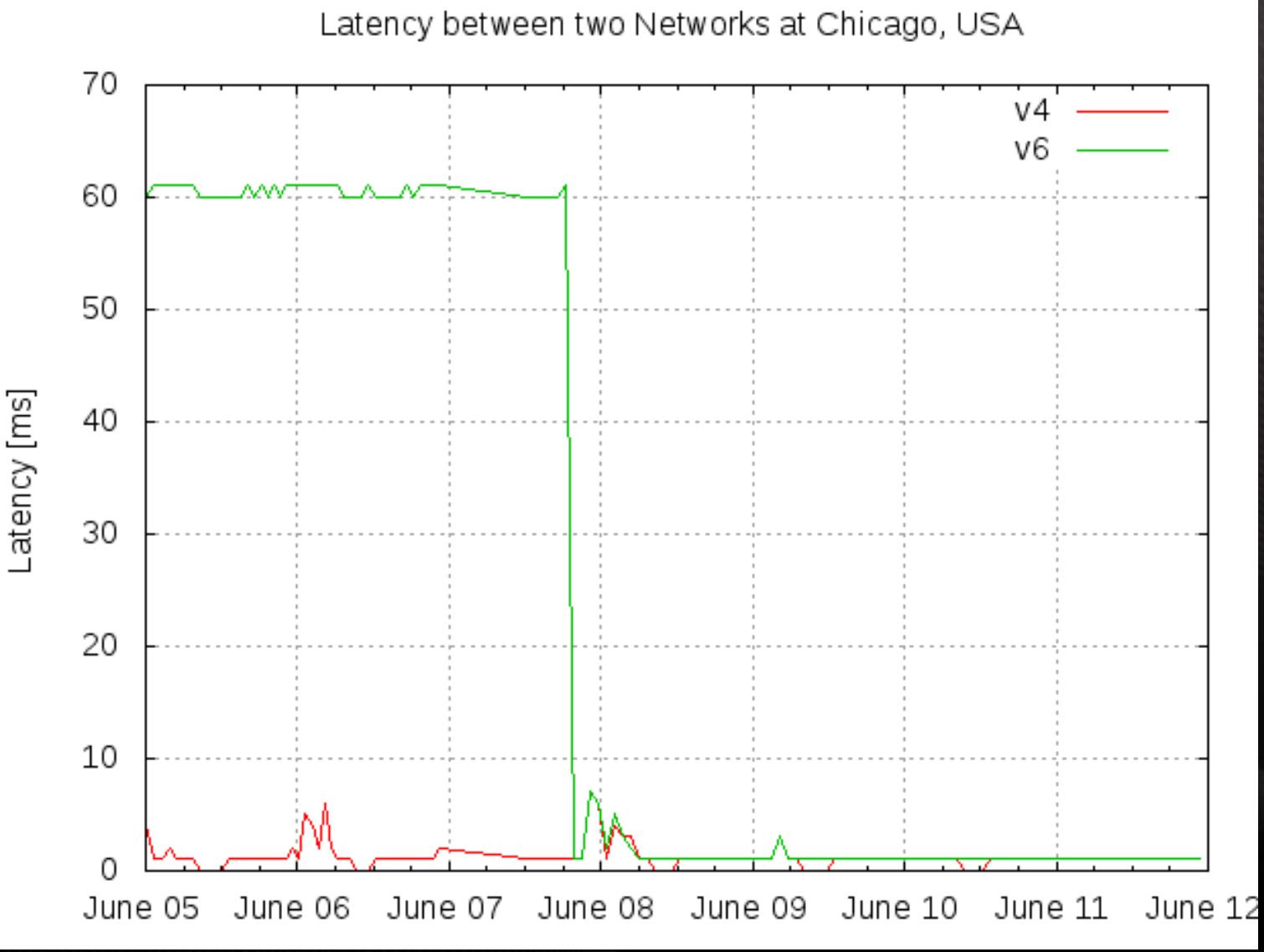


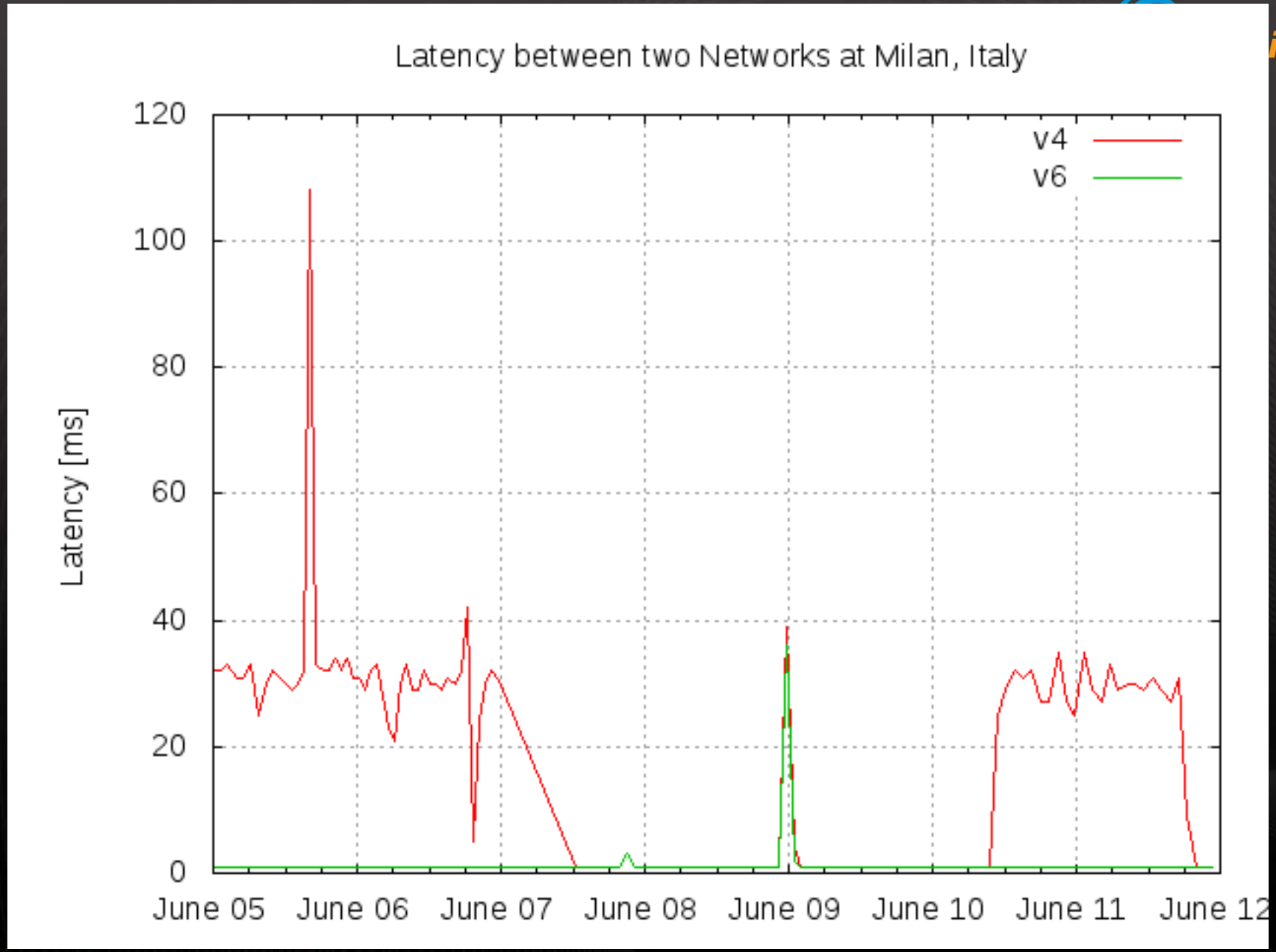

Distribution of difference in latency
Within Europe and within North America
Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-20
-15
-10
-5
0
5
10
15
20
v6 latency minus v4 latency [ms]
NorthAmerica_NorthAmerica
Europe_Europe

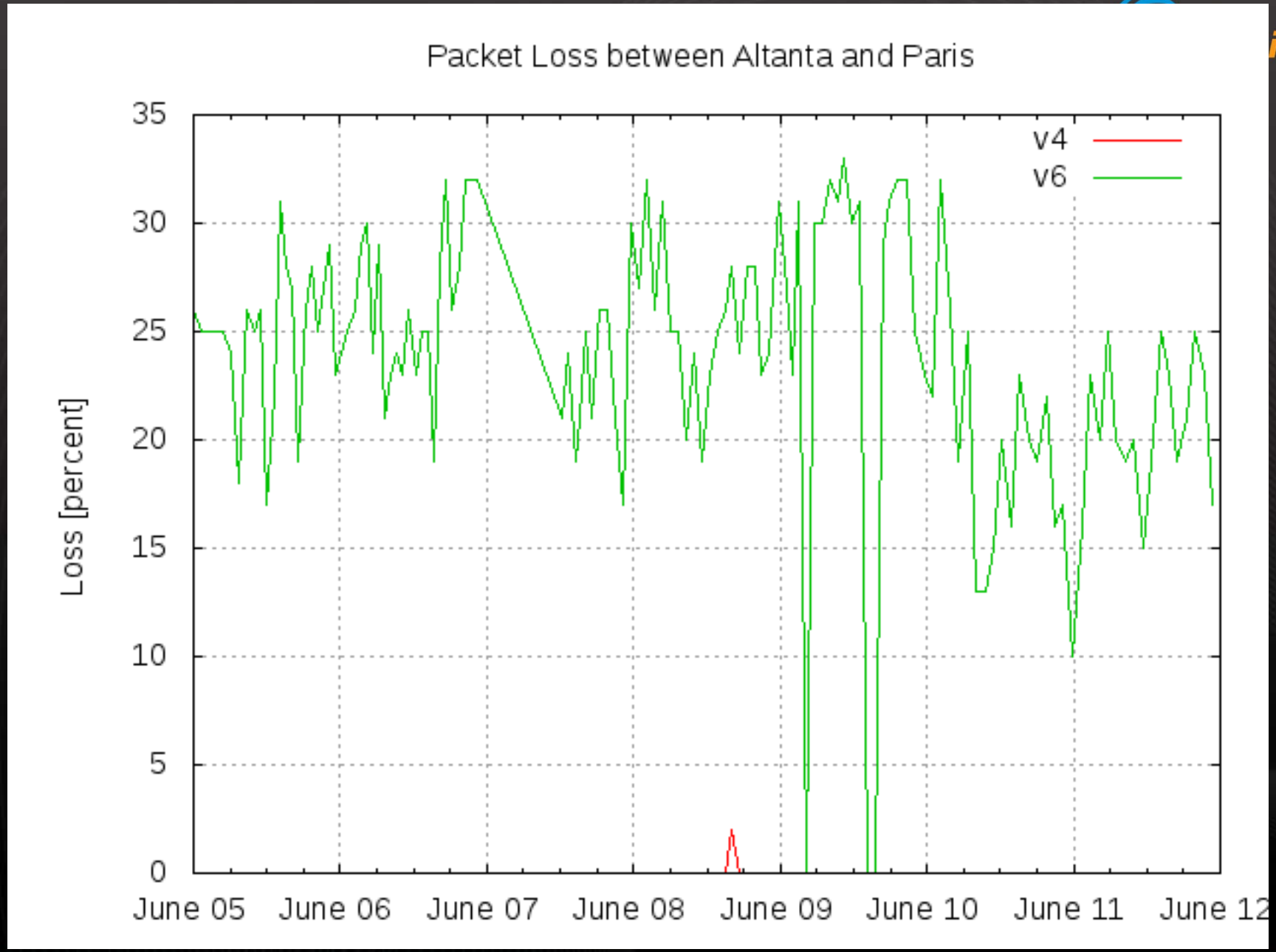

Distribution of difference in latency
Focus on Africa
Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
v6 latency minus v4 latency [ms]
Africa_Asia
Africa_Europe
Africa_NorthAmerica

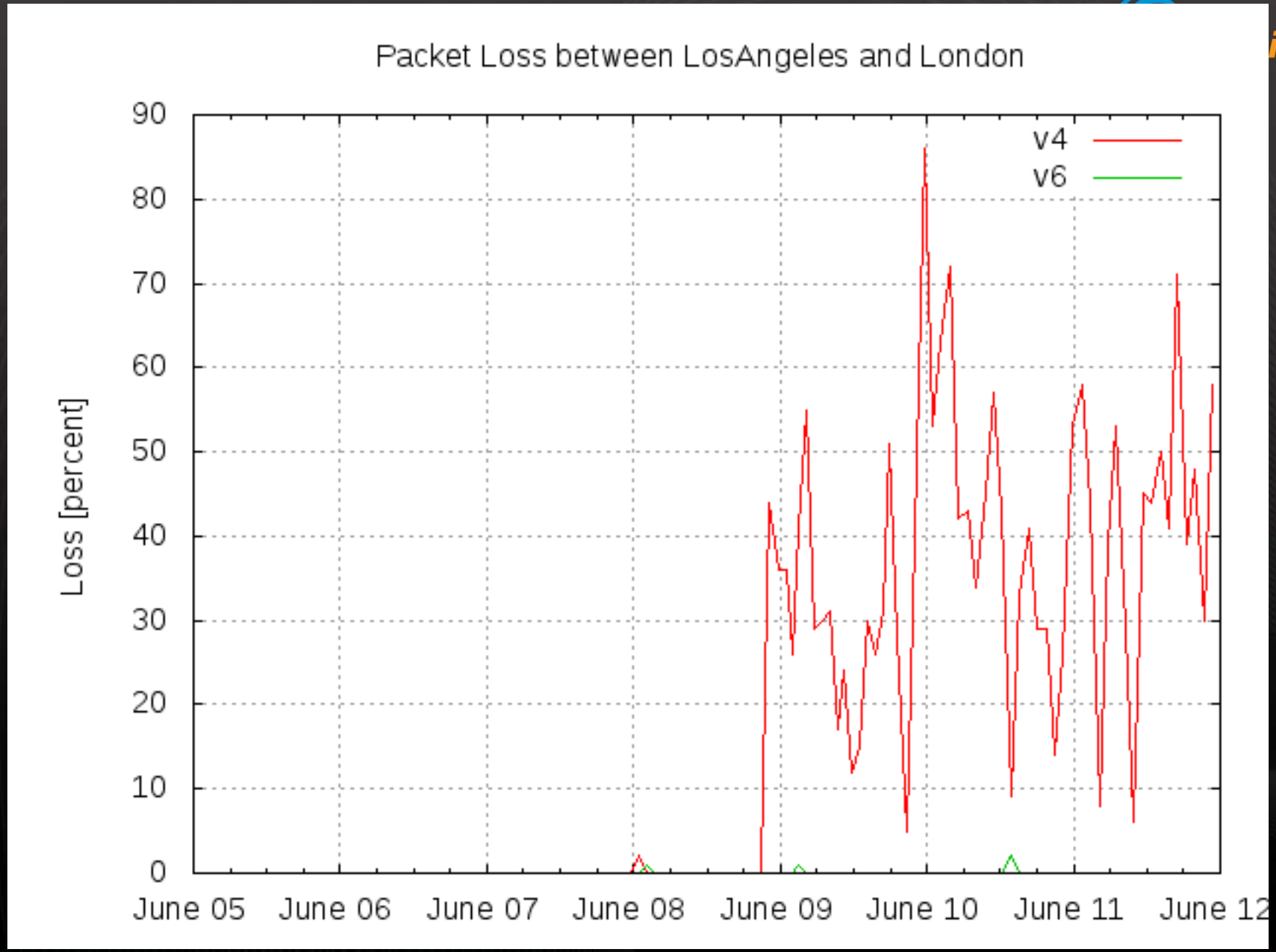
Probes Between Dual-Stack Akamai Servers

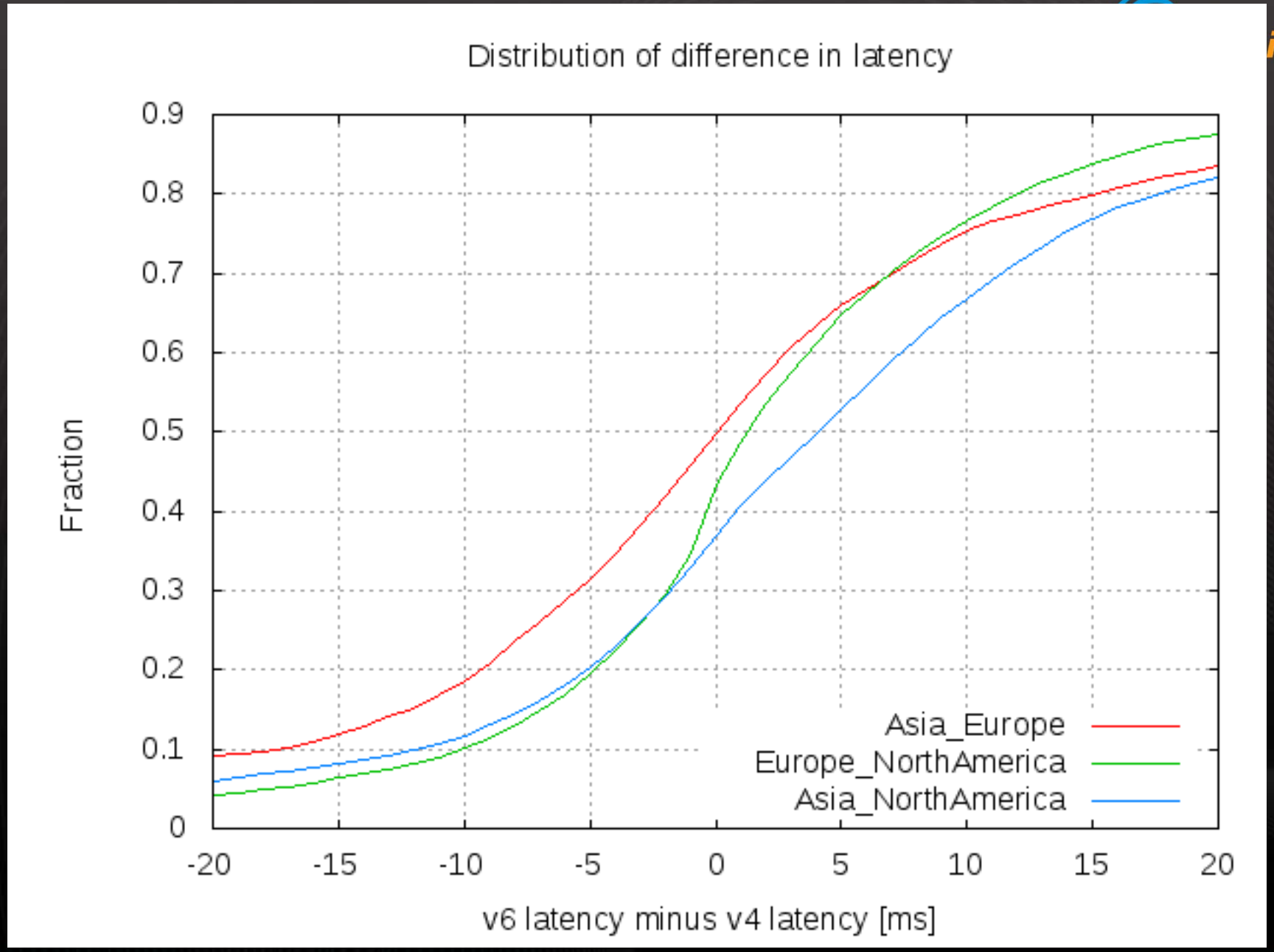
- Deployment of dual-stack servers in:
  - 350 network-city pairs
  - 50 countries
  - all continents (except Antarctica)
- Interfaces are native IPv6
- Measurement taken every minute.

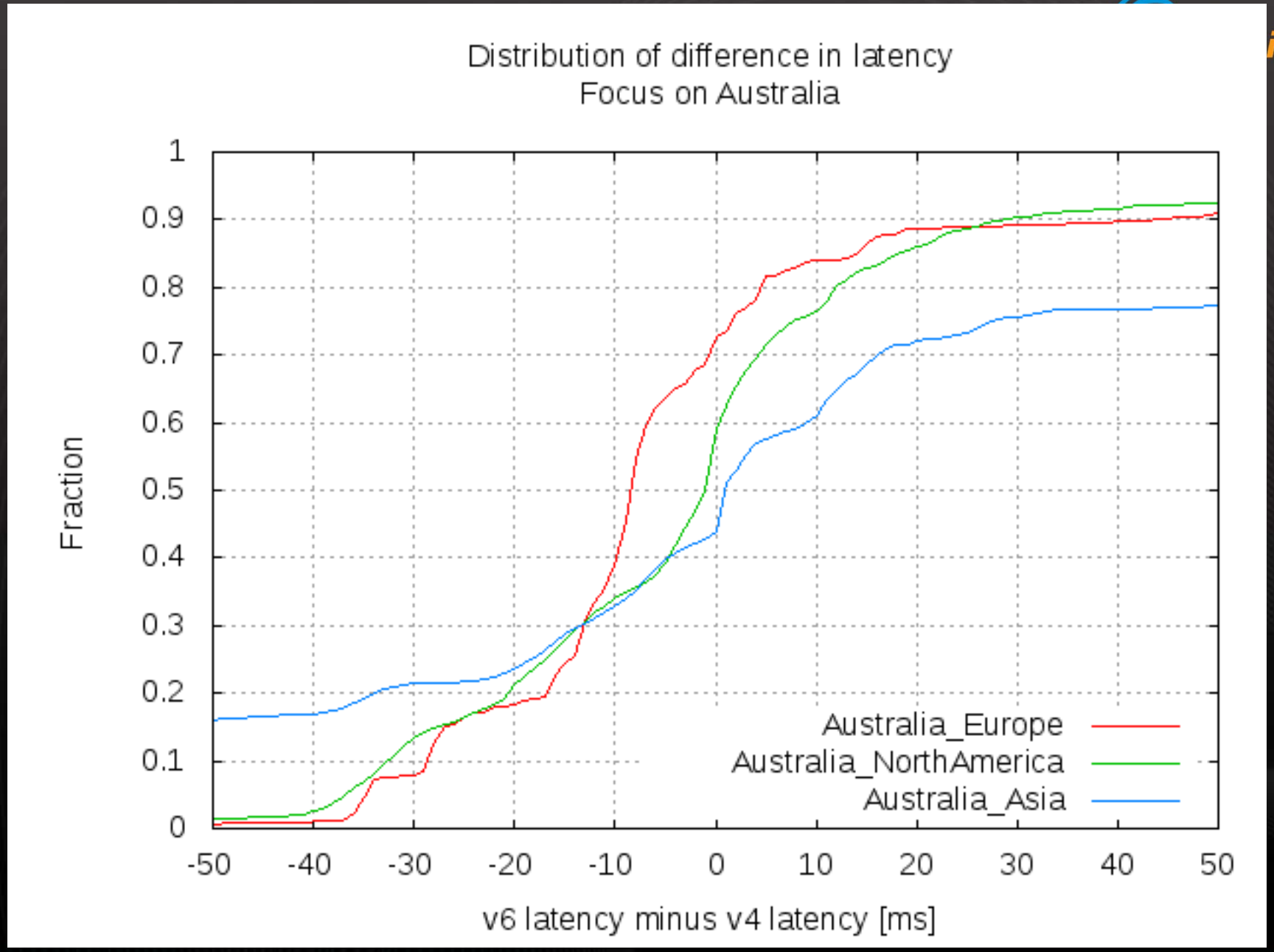

Latency between two Networks at Chicago, USA
Latency [ms]
70
60
50
40
30
20
10
0
June 05
June 06
June 07
June 08
June 09
June 10
June 11
June 12
v4
v6

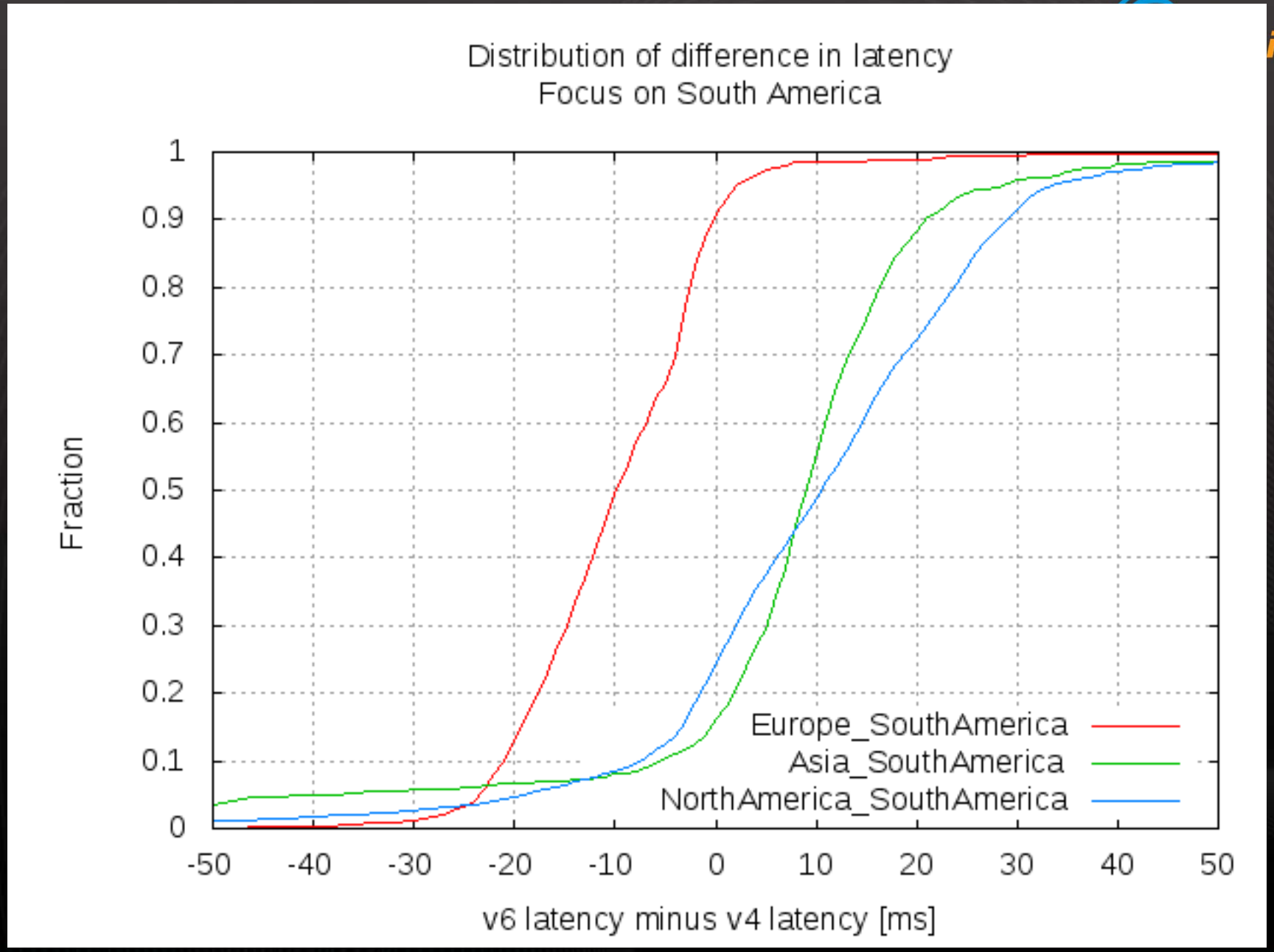

Latency between two Networks at Milan, Italy
Latency [ms]
120
100
80
60
40
20
0
v4
v6
June 05
June 06
June 07
June 08
June 09
June 10
June 11
June 12


Packet Loss between Altanta and Paris
Loss [percent]
35
30
25
20
15
10
5
0
June 05
June 06
June 07
June 08
June 09
June 10
June 11
June 12
v4
v6


Packet Loss between LosAngeles and London
Loss [percent]
90
80
70
60
50
40
30
20
10
0
June 05
June 06
June 07
June 08
June 09
June 10
June 11
June 12
v4
v6


Distribution of difference in latency
Fraction
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-20
-15
-10
-5
0
5
10
15
20
v6 latency minus v4 latency [ms]
Asia_Europe
Europe_NorthAmerica
Asia_NorthAmerica


Distribution of difference in latency
Focus on Australia
Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-50
-40
-30
-20
-10
0
10
20
30
40
50
v6 latency minus v4 latency [ms]
Australia_Europe
Australia_NorthAmerica
Australia_Asia


Distribution of difference in latency
Focus on South America
Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-50
-40
-30
-20
-10
0
10
20
30
40
50
v6 latency minus v4 latency [ms]
Europe_SouthAmerica
Asia_SouthAmerica
NorthAmerica_SouthAmerica