

Comparing the Performance of Public DNS Resolvers

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Why Compare Public DNS Resolver Performance?

- DNS performance impacts overall web experience
- Many DNS provider choices – how to differentiate?
- Limited data on IPv6 performance

Other Selection Considerations Not Covered

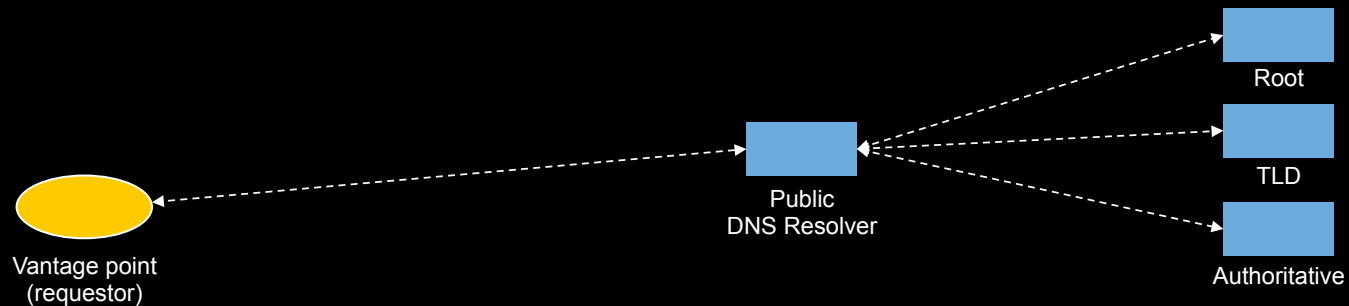
- Security
 - Transport encryption (DNS over TLS, DNS over HTTPS, etc.)
 - DNSSEC
 - Cache purging
- Privacy
 - Log purging
 - ECS — EDNS Client Subnet
- Content filtering
 - Malicious
 - Adult content
- Org intent/values
 - Commercial versus non-profit, etc.

Public DNS Resolvers Measured (all Anycast)

	IPv4	IPv6
CleanBrowsing (safe)	185.228.168.9	2a0d:2a00:1::2
Cloudflare	1.1.1.1	2606:4700:4700::1111
Comodo	8.26.56.26	-
DNS.WATCH	84.200.69.80	2001:1608:10:25::1c04:b12f
Dyn	216.146.35.35	-
FreeDNS	37.235.1.174	-
Google	8.8.8.8	2001:4860:4860::8888
Level3	209.244.0.3	-
OpenDNS	208.67.222.222	2620:0:ccc::2
OpenNIC	185.121.177.177	-
Quad9	9.9.9.9	2620:fe::fe
SafeDNS	195.46.39.39	-
Neustar (UltraRecursive)	156.154.70.1	2610:a1:1018::1
Verisign	64.6.64.6	-
Yandex	77.88.8.8	2a02:6b8::feed:0ff

- Three newish Public DNS Resolvers
 - Cloudflare
 - Quad9
 - CleanBrowsing
- Region-focused Providers
 - Yandex
 - DNS.WATCH
- Not all providers support IPv6
- Not covering alternate DNS IP addresses (e.g. Google's 8.8.4.4)

Performance Measurement: Resolution Time



Cached

- Network latency (VP<->Public Resolver)
- Public DNS server processing

Not in Cache

- Network latency (VP<->Resolver)
- Public DNS server processing
- Network latency (Resolver<->Root server)
- Root server processing
- Network latency (Resolver<->TLD server)
- TLD server processing
- Network latency (Resolver<->Authoritative server)
- Authoritative server processing

Measurement Methodology: Scope

- Global sites
 - 252 (IPv4)
 - 58 (IPv6)
- Managed vantage points
 - Not volunteer vantage points
 - Located in data centers around the globe
 - “Always-on”
 - Consistent measurement



	Testing Frequency	Testing Period*	Vantage Points	Total Measurements per resolver
IPv4	30 min	30 days	252	362,880
IPv6	30 min	30 days	58	83,520

*08/20/18-09/19/18

Measurement Methodology: Transport/Query

	Query			Record	
Network Layer	Domain	Record Type	Recursive	TTL	IP Address
IPv4	example.com	A	✓	86400	93.184.216.34
IPv6	example.com	AAAA		86400	2606:2800:220:1:248:1893:25c8:1946

```

com. 172800 IN NS a.gtld-servers.net.
com. 172800 IN NS b.gtld-servers.net.
com. 172800 IN NS c.gtld-servers.net.
com. 172800 IN NS d.gtld-servers.net.
com. 172800 IN NS e.gtld-servers.net.
com. 172800 IN NS f.gtld-servers.net.
com. 172800 IN NS g.gtld-servers.net.
com. 172800 IN NS h.gtld-servers.net.
com. 172800 IN NS i.gtld-servers.net.
com. 172800 IN NS j.gtld-servers.net.
com. 172800 IN NS k.gtld-servers.net.
com. 172800 IN NS l.gtld-servers.net.
com. 172800 IN NS m.gtld-servers.net.
;; Received 489 bytes from 198.41.0.4(a.root-servers.net.) in 84 ms

example.com. 172800 IN NS a.iana-servers.net.
example.com. 172800 IN NS b.iana-servers.net.
;; Received 165 bytes from 192.12.94.30(e.gtld-servers.net.) in 28 ms

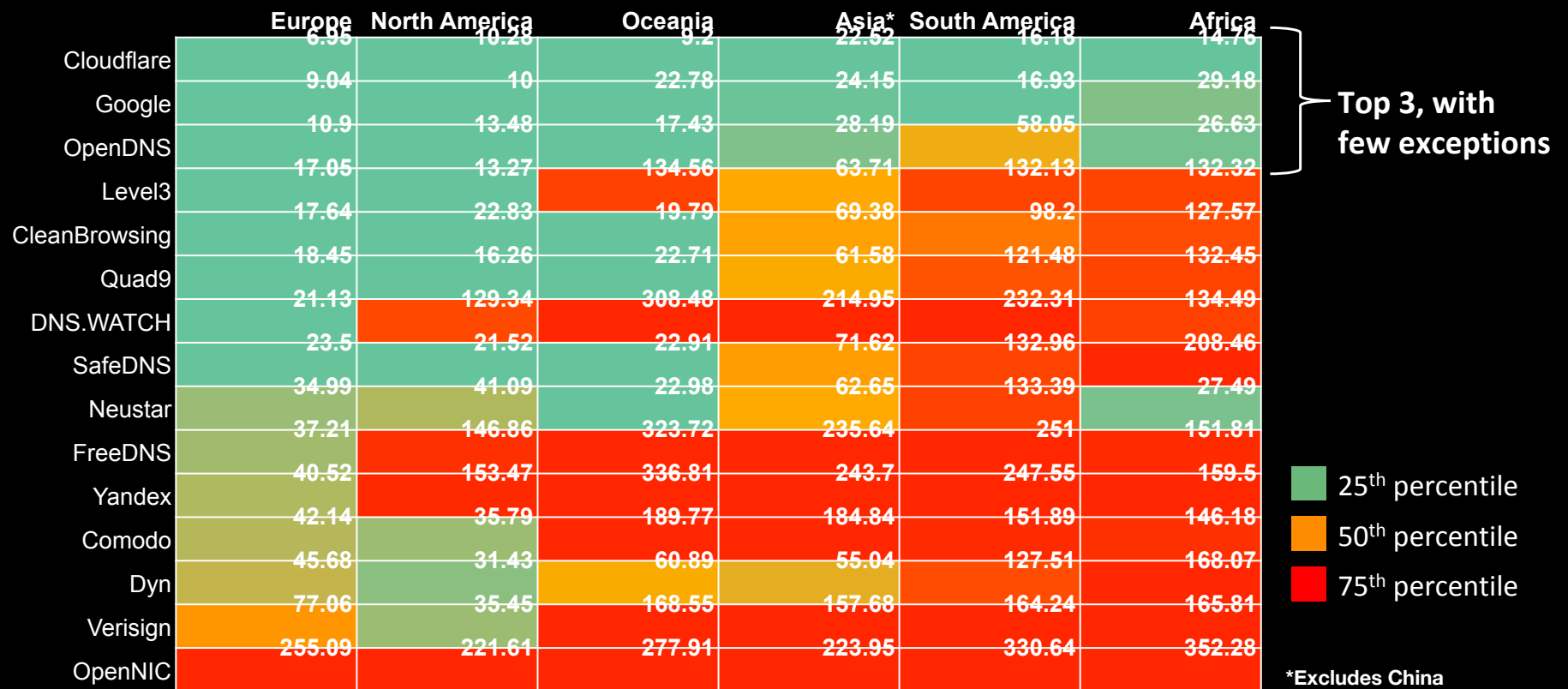
example.com. 86400 IN A 93.184.216.34
;; Received 181 bytes from 199.43.133.53(b.iana-servers.net.) in 8 ms
  
```

No CNAME

long TTL (24 hours)

Performance Findings: IPv4

Performance Variations Across Regions



Provider Rankings

	Europe	North America	Oceania	Africa	Asia*	South America
1	Cloudflare (6.95)	Google (10)	Cloudflare (9.2)	Cloudflare (14.76)	Cloudflare (22.52)	Cloudflare (16.18)
2	Google (9.04)	Cloudflare (10.28)	OpenDNS (17.43)	OpenDNS (26.63)	Google (24.15)	Google (16.93)
3	OpenDNS (10.9)	Level 3 (13.27)	CleanBrowsing (19.79)	Neustar (27.49)	OpenDNS (28.19)	OpenDNS (58.05)
4	Level 3 (17.05)	OpenDNS (13.48)	Quad9 (22.71)	Google (29.18)	Dyn (55.04)	CleanBrowsing (98.2)
5	CleanBrowsing (17.64)	Quad9 (16.27)	Google (22.78)	CleanBrowsing (127.57)	Quad9 (61.58)	Quad9 (121.48)

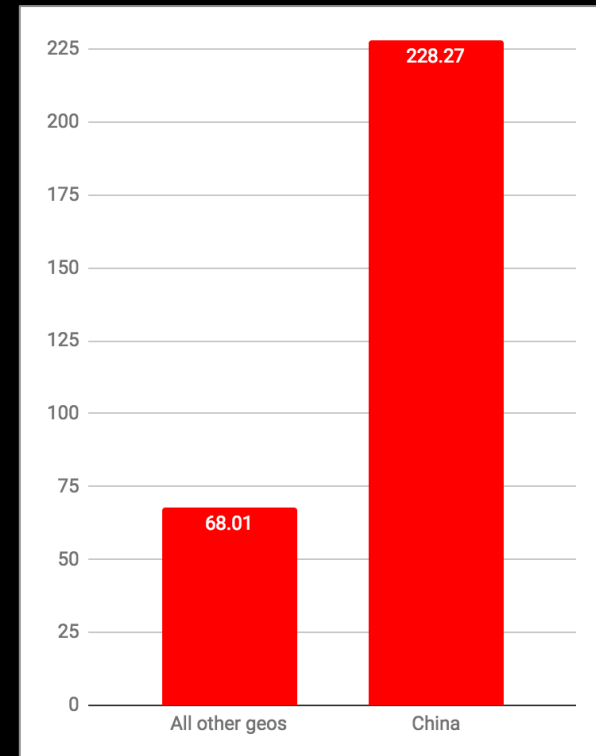
*Excludes China

Why Exclude China?

- DNS proxies interfere with query resolution
- High resolution time vs other geos
- Metrics from 15 China-located vantage points

	44.32
Google	74.23
Neustar	150.31
OpenDNS	175.24
Cloudflare	178.75
CleanBrowsing	232.48
SafeDNS	236.88
Quad9	237.75
Verisign	257.88
Comodo	260.37
DNS.WATCH	261.22
Level3	267.44
Dyn	295.28
FreeDNS	304.39
Yandex	390.12
OpenNIC	

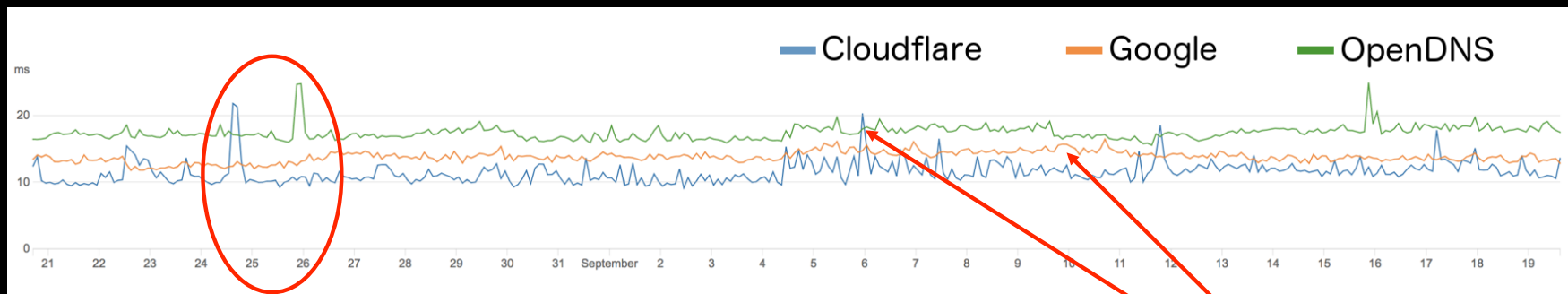
Poor performance overall, but Google fares best. Cloudflare most impacted in terms of rank



Mean Resolution Time other geos vs China

A Closer Look at the Top 3 Providers

Mean Resolution Time over Time







	Mean	Standard Deviation	Minimum	25th Percentile	Median	75th Percentile	Maximum
Cloudflare	11.49	33.37	0	1	3	11	2979
Google	13.78	24.86	0	1	6	17	1043
OpenDNS	17.4	31.87	0	2	7	20	2903







Google performance is consistent over time versus newcomer Cloudflare

Spikes in Resolution Time

Cloudflare

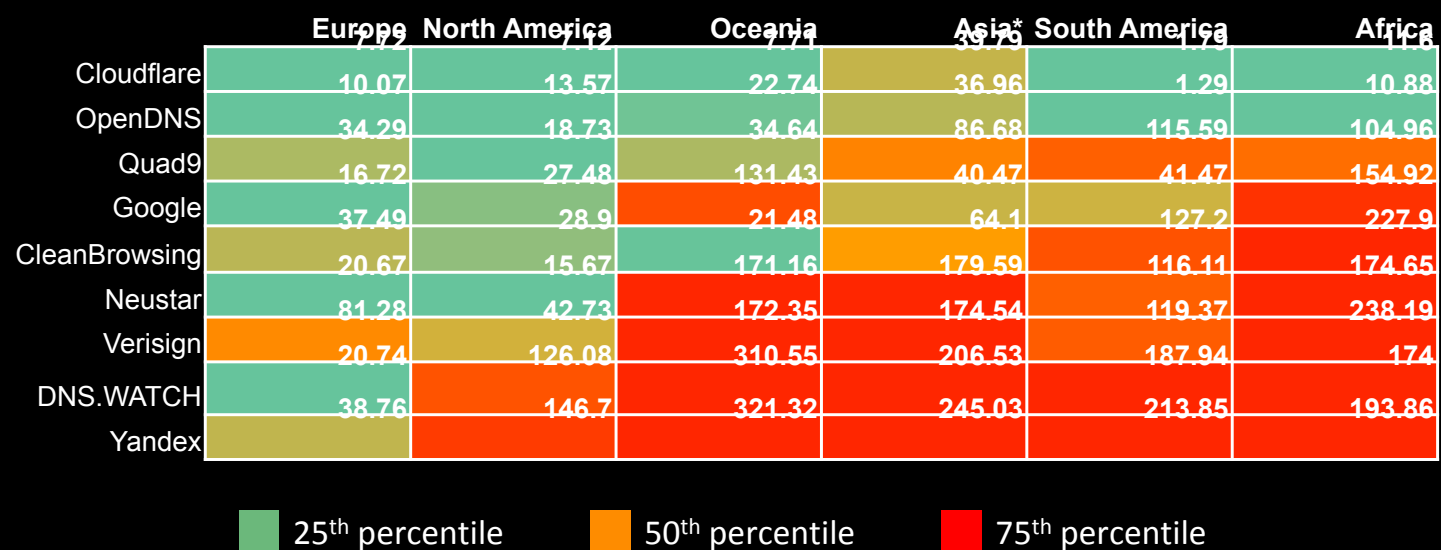
Vantage Points	Date (PDT)	Mapping		Resolution Time	Network Latency
Perth, Australia	2018-08-24 18:02:51	93.184.216.34	—	 2979	<1ms
Newark, NJ	2018-08-24 18:04:55	93.184.216.34	—	 1981	<1ms
Hyderabad, India	2018-08-24 18:01:52	93.184.216.34	—	 1258	16ms
Mumbai, India (Azure westindia)	2018-08-24 18:00:39	93.184.216.34	—	 254	62ms

OpenDNS

Vantage Points	Date (PDT)	Mapping		Resolution Time	Network Latency
Raleigh, NC	2018-08-25 22:00:13	93.184.216.34	—	 2903	<1ms
Moncks Corner, SC (GCP us-east1)	2018-08-25 22:00:13	93.184.216.34	—	 2274	12ms
Ashburn, VA (Comcast)	2018-08-25 22:00:15	93.184.216.34	—	 1008	7ms
Ashburn, VA (CenturyLink)	2018-08-25 22:00:17	93.184.216.34	—	 584	2ms
Jakarta, Indonesia	2018-08-25 22:00:27	93.184.216.34	—	 402	368ms
Chicago, IL (Comcast)	2018-08-25 22:00:16	93.184.216.34	—	 381	3ms

Performance Findings: IPv6

IPv6 Performance Variations Across Regions



*No vantage points in China

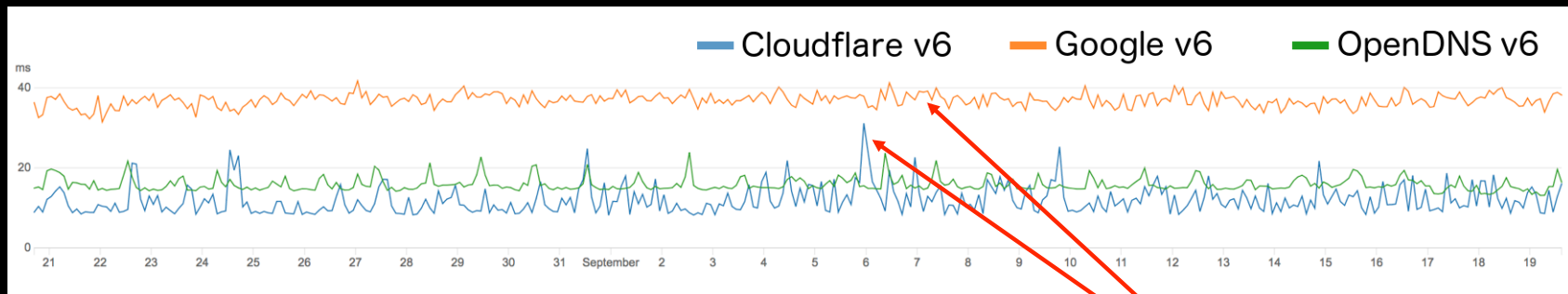
Provider Rankings — v6

	Europe	North America	Oceania	Africa	Asia*	South America
1	Cloudflare (7.72)	Cloudflare (7.12)	Cloudflare (7.71)	Cloudflare (11.6)	OpenDNS (36.96)	OpenDNS (1.29)
2	OpenDNS (10.07)	OpenDNS (13.57)	CleanBrowsing (21.48)	OpenDNS (10.88)	Cloudflare (39.76)	Cloudflare (1.79)
3	Google (16.72)	Neustar (15.67)	OpenDNS (22.74)	Quad9 (104.96)	Google (40.47)	Google (41.47)
4	Neustar (20.67)	Quad9 (18.73)	Quad9 (34.64)	Google (154.92)	CleanBrowsing (64.1)	Quad9 (115.59)
5	DNS.WATCH (20.74)	Google (27.48)	Google (131.43)	DNS.WATCH (174)	Quad9 (86.68)	Neustar (116.11)

*No vantage points in China

A Closer Look at the Top 3 Providers

Mean Resolution Time over Time

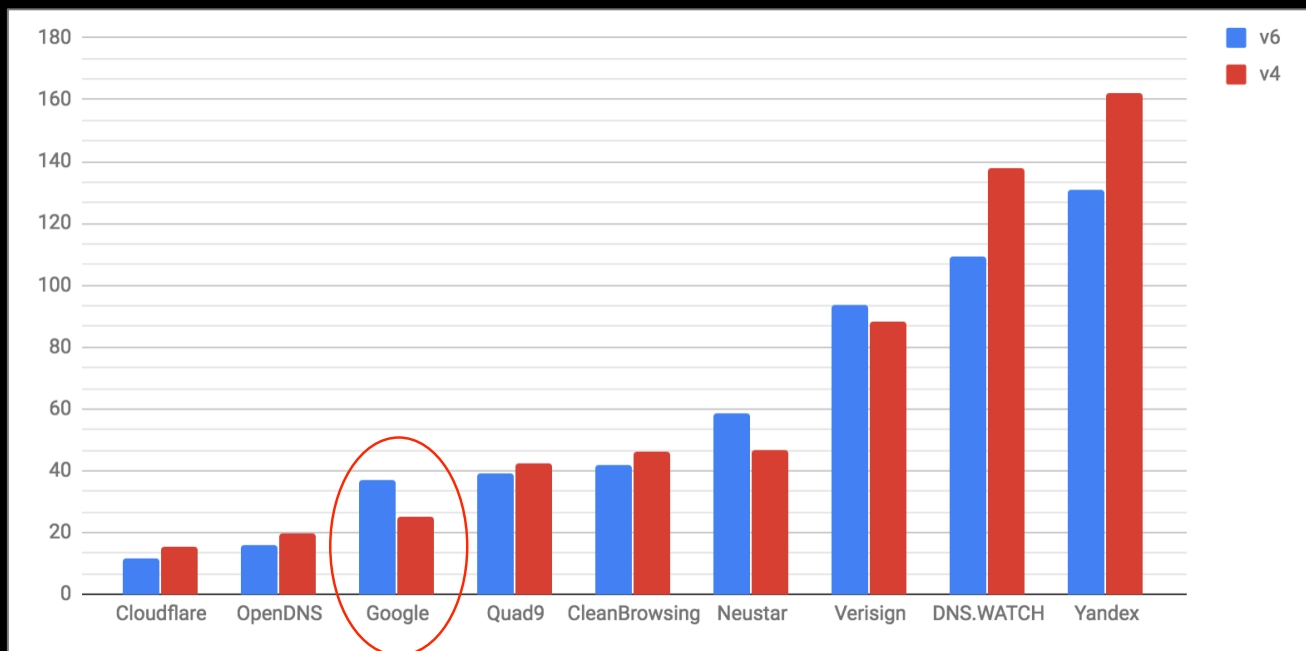


	Mean	Standard Deviation	Minimum	25th Percentile	Median	75th Percentile	Maximum
Cloudflare	11.93	44.69	0	0	1	7	1745
OpenDNS	15.82	29.23	0	1	7	16	536
Google	36.88	45.93	0	9	18	38	426

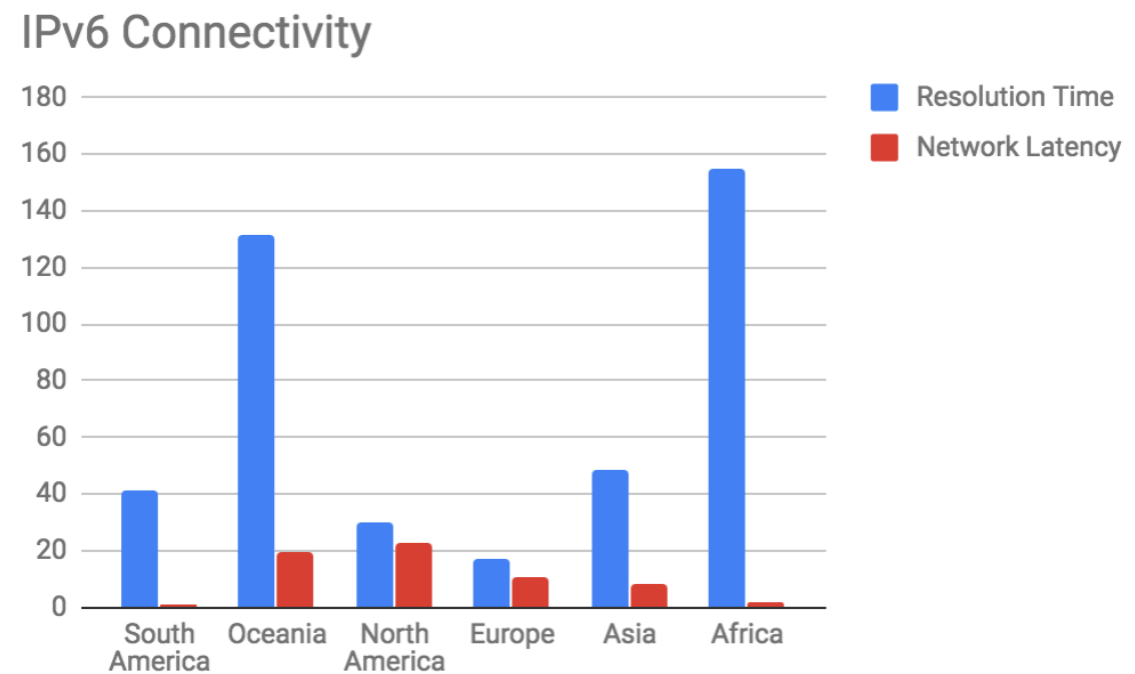
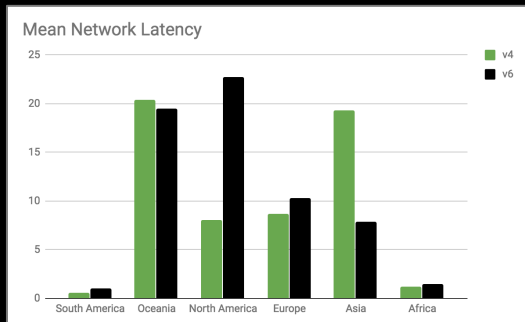
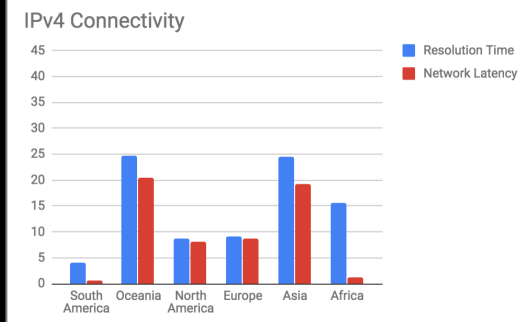
Google not as fast but consistent over time versus newcomer Cloudflare

IPv6 is On-par or Faster than IPv4

Top providers have embraced a multi-family approach, with v6 performance as good or better than v4 —with a notable exception.

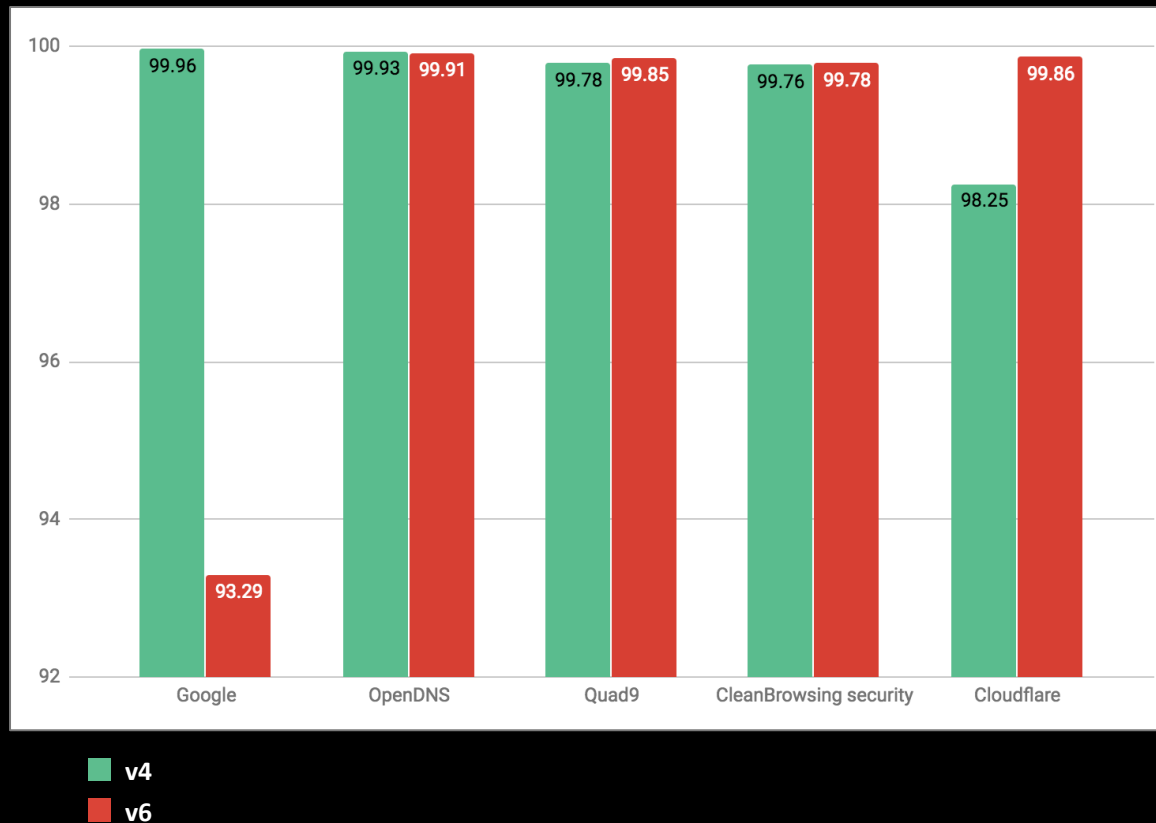


Notable Exception: Google



What About Availability?

High Availability, but Anomalies Exist



- ISPs and outlier issues can impact availability
- >99% availability, except...
- Cloudflare's IPv4 DNS service
- Google's IPv6 DNS service

Cloudflare Availability Issue

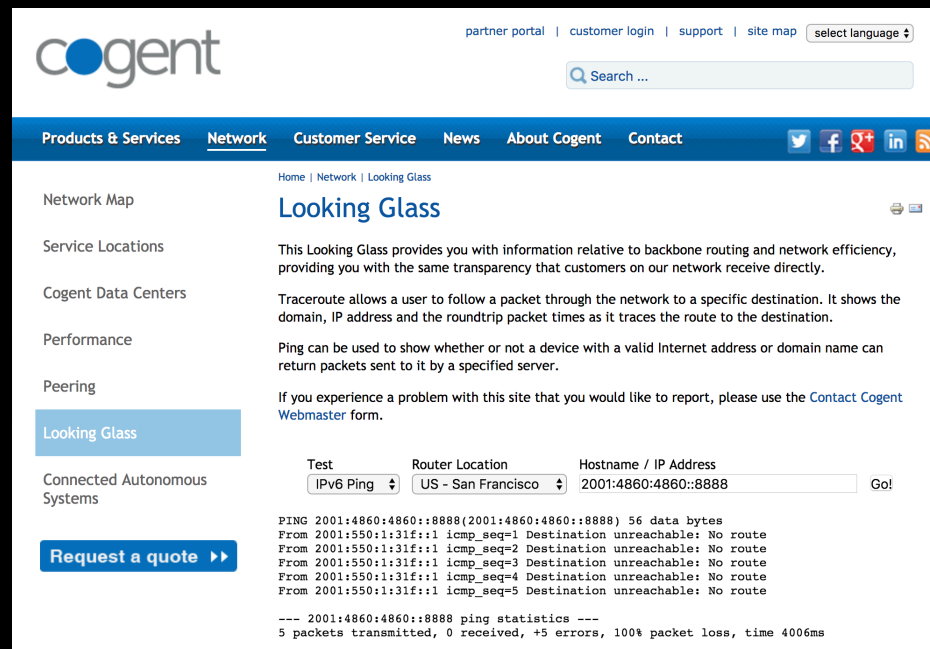
- Previously unassigned IP space was handed to Cloudflare for its DNS resolver
- ISP/vendor misuse of 1.1.1.1 address prevents DNS requests from reaching Cloudflare
- Cloudflare still working to address availability issues
- Use 1.0.0.1 if 1.1.1.1 is broken

```
Path trace from Guadalajara, Mexico (143.255.57.237) to 1.1.1.1
1 143-255-57-193.static.hostdime.com (143.255.57.193) 0 ms
2 189-209-200-21.static.axtel.net (189.209.200.21) 0 ms
3 dial-148-240-205-1.zone-1.ip.static-ftth.axtel.net.mx (148.240.205.1) 16 ms
4 *
5 *
6 *
7 *
8 *
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17 *
18 *
19 *
20 *
21 *
22 *
23 *
24 *
25 *
26 *
27 *
28 *
29 *
30 *
```

```
Path trace from Guadalajara, Mexico (143.255.57.237) to 1.0.0.1
1 *
2 189-209-200-21.static.axtel.net (189.209.200.21) 1 ms
3 dial-148-240-205-1.zone-1.ip.static-ftth.axtel.net.mx (148.240.205.1) 15 ms
4 *
5 one.one.one.one (1.0.0.1) 30 ms
```

Google DNS Affected by Routing Issues

- Tier 1 ISP Cogent doesn't maintain routes to Google's IPv6 DNS addresses
- All packets routed through Cogent from vantage points were dropped



The screenshot shows the Cogent Network Looking Glass interface. The left sidebar contains links to Network Map, Service Locations, Cogent Data Centers, Performance, Peering, Looking Glass (selected), and Connected Autonomous Systems. The main content area is titled 'Looking Glass' and provides information about backbone routing and network efficiency. It includes a Traceroute section and a Ping section. The Ping section shows a test result for 'IPv6 Ping' from 'US - San Francisco' to '2001:4860:4860::8888'. The test result shows 56 data bytes and 5 packets transmitted, but all 5 packets were dropped, resulting in 100% packet loss and a time of 4006ms.

Test Router Location Hostname / IP Address
IPv6 Ping US - San Francisco 2001:4860:4860::8888 Go!

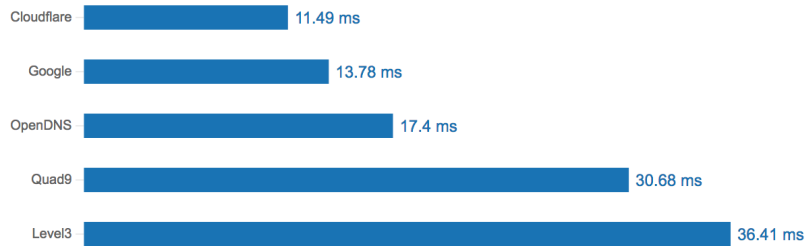
PING 2001:4860:4860::8888(2001:4860:4860::8888) 56 data bytes
From 2001:550:1:31f::1 icmp_seq=1 Destination unreachable: No route
From 2001:550:1:31f::1 icmp_seq=2 Destination unreachable: No route
From 2001:550:1:31f::1 icmp_seq=3 Destination unreachable: No route
From 2001:550:1:31f::1 icmp_seq=4 Destination unreachable: No route
From 2001:550:1:31f::1 icmp_seq=5 Destination unreachable: No route

--- 2001:4860:4860::8888 ping statistics ---
5 packets transmitted, 0 received, +5 errors, 100% packet loss, time 4006ms

Summary Results

Overall Rankings: Global Top 5

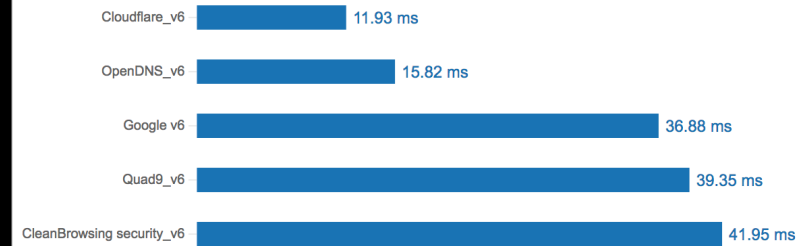
Top Providers – v4



Regional Highlights

- United States: Google
- Canada: Cloudflare
- United Kingdom: Level 3
- Japan: Cloudflare

Top Providers – v6



Regional Highlights

- United States: Cloudflare
- Canada: OpenDNS
- United Kingdom: OpenDNS
- Japan: Cloudflare

Wrap Up

- Global DNS Performance Report
 - Covers Public Resolvers, Managed Providers, Root servers
 - Releasing 10/10/18
- Questions? Feedback? Requests?
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 - @bitprints