

# Measuring the Availability and Response Times of Public Encrypted DNS Resolvers

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# Contributions

- We developed and released an open-source tool for measuring encrypted DNS performance to replicate and extend these results, and to support further research on DoH performance.
- We measure DoH response times a large list of resolvers, including both mainstream DoH resolvers that are included in major browser vendors and a large collection of non-mainstream resolvers.
- We study how the performance of various DoH resolvers differ based on vantage point.
- The first study of DoH performance measurements for non-mainstream resolvers, as well as the first comparison of DoH performance across a variety of vantage points, for a large number of resolvers.

# Context

| Browser | Cloudflare | Google | Quad9 | NextDNS | CleanBrowsing | OpenDNS |
|---------|------------|--------|-------|---------|---------------|---------|
| Chrome  | ✓          | ✓      |       | ✓       | ✓             | ✓       |
| Firefox | ✓          |        |       | ✓       |               |         |
| Edge    | ✓          | ✓      | ✓     | ✓       | ✓             | ✓       |
| Opera   | ✓          | ✓      |       |         |               |         |
| Brave   | ✓          | ✓      | ✓     | ✓       | ✓             | ✓       |

- Modern browsers provide only a few choices for encrypted DNS resolver, which we define as mainstream resolvers.

# Metrics

- **Availability:** Which DoH resolvers are active and responding to queries?
- **Latency:** What is the round-trip latency to each server?
- **DNS query response time:** What is the end- to-end time it takes for a client to initiate a query and receive a response?

# Experiment Setup

- **Vantage Points:** Three global vantage points in Amazon EC2
  - Ohio, United States (North America)
  - Seoul, North Korea (Asia)
  - Frankfurt, Germany (Europe)
- **Queries:** google.com, netflix.com
- **Resolvers**

- <https://dns.google/dns-query>
- <https://dns.aa.net.uk/dns-query>
- <https://adfree.usableprivacy.net/dns-query>
- <https://dns.adguard.com/dns-query>
- <https://dns-family.adguard.com/dns-query>
- <https://doh.in.ahadns.net/dns-query>
- <https://doh.la.ahadns.net/dns-query>
- <https://doh.nl.ahadns.net/dns-query>
- <https://dns.alidns.com/dns-query>
- <https://dnsnl-noads.alekberg.net/dns-query>
- <https://dnsnl.alekberg.net/dns-query>

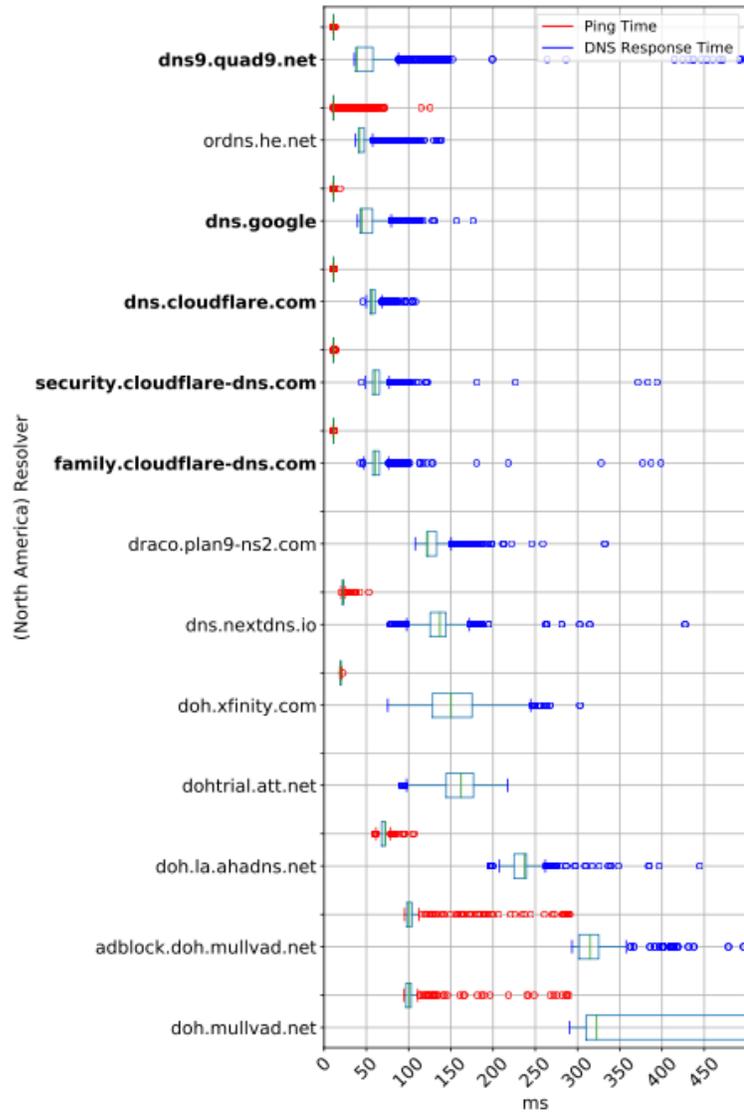
- <https://dns.arapurayil.com/dns-query>
- <https://dohtrial.att.net/dns-query>
- <https://dnses.alekberg.net/dns-query>
- <https://doh.bortzmeyer.fr/dns-query>
- <https://dns.circl.lu/dns-query>
- <https://doh.opendns.com/dns-query>
- <https://dns.cloudflare.com/dns-query>
- <https://family.cloudflare-dns.com/dns-query>
- <https://security.cloudflare-dns.com/dns-query>
- <https://odvr.nic.cz/dns-query>
- <https://dns.digitale-gesellschaft.ch/dns-query>
- <https://dns.digitale-gesellschaft.ch/dns-query>

- <https://dns1.ryan-palmer.com/dns-query>
- <https://doh.sb/dns-query>
- <https://dns.therifleman.name/dns-query>
- <https://dns1.dnscrypt.ca/dns-query>
- <https://dns2.dnscrypt.ca/dns-query>
- <https://dns-doh.dnsforfamily.com/dns-query>
- <https://dns-doh-no-safe-search.dnsforfamily.com/dns-query>
- <https://dnsforge.de/dns-query>
- <https://dns.dnshome.de/dns-query>
- <https://doh.pub/dns-query>
- <https://doh-ch.blahdns.com/dns-query>

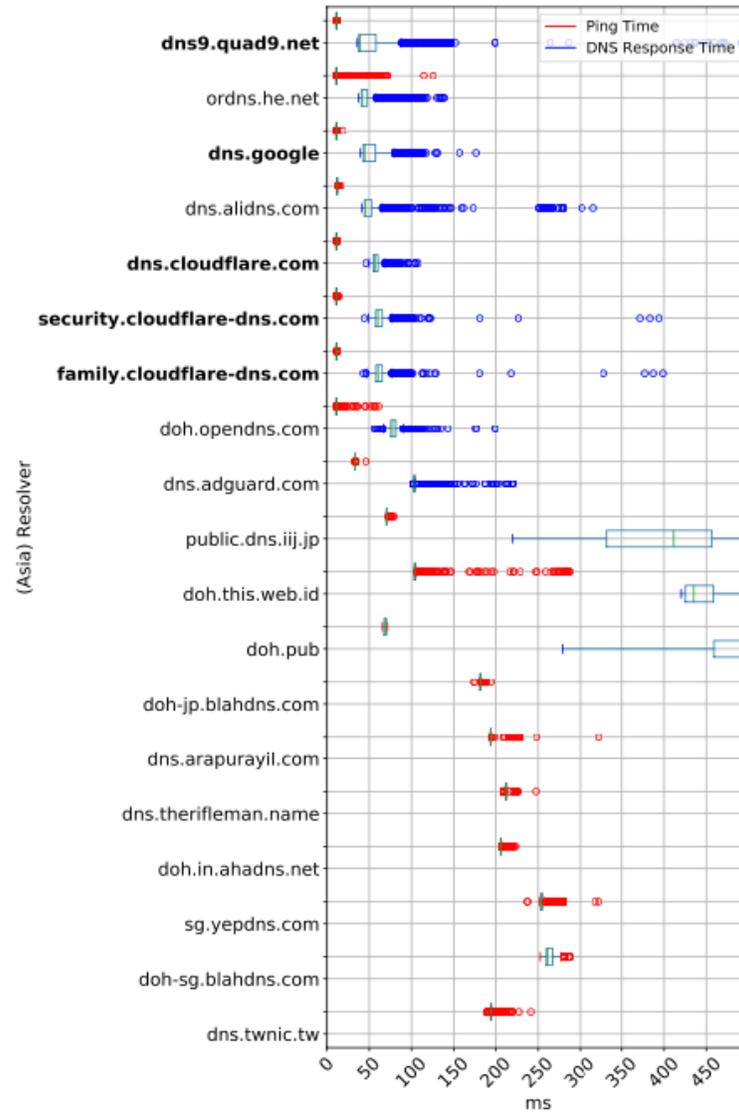
# Are Non-Mainstream Resolvers Available?

| <b>Error</b>                                | <b>Count % of All Responses</b> |              |
|---|---------------------------------|--------------|
| Couldn't Connect to Server                  | 47,377                          | 7%           |
| HTTP Error Status                           | 38,475                          | 5.7%         |
| Couldn't Decode Response                    | 26,686                          | 4%           |
| SSL Connect Error                           | 17,720                          | 2.6%         |
| Couldn't Resolve the Resolver's Domain Name | 8,864                           | 1.3%         |
| SSL Certificate Error                       | 4,465                           | 0.7%         |
| Other Error                                 | 234                             | < 1%         |
| SSL Timeout                                 | 27                              | < 1%         |
| Error in the HTTP/2 Framing Layer           | 2                               | < 1%         |
| <b>Successful Responses</b>                 | <b>531,528</b>                  | <b>78.7%</b> |
| <b>All Errors</b>                           | <b>143,848</b>                  | <b>21.3%</b> |

# How Do Non-Mainstream Resolvers Perform?



(a) North America (Local).

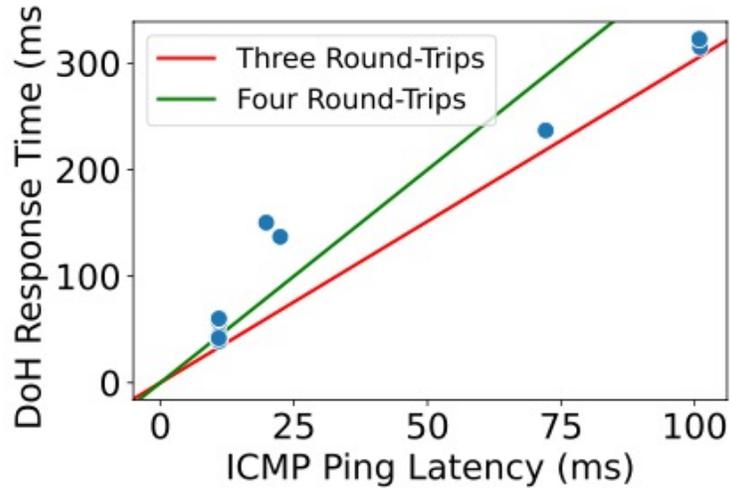


(b) Asia.

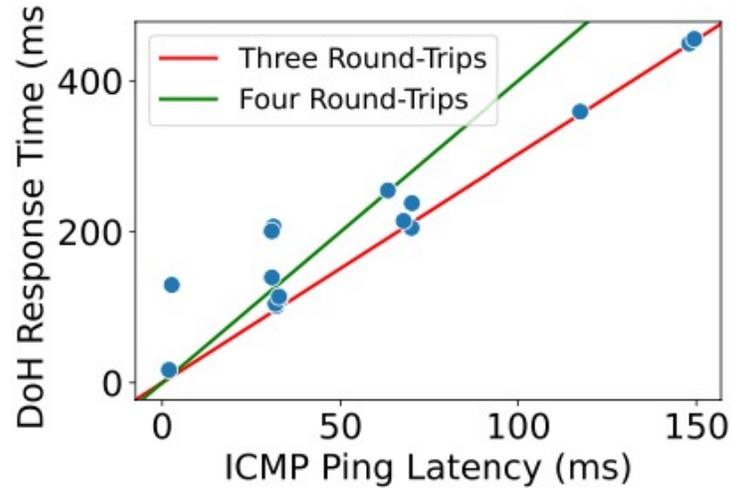


(c) Europe.

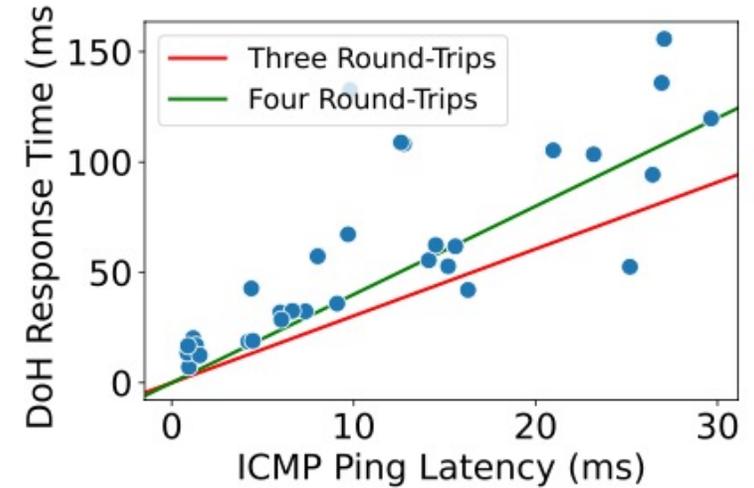
# Median DoH Query Response Times vs. Latency



(a) Ohio (Local).



(b) Seoul (Local).



(c) Frankfurt (Local).

# Conclusion

- Non-mainstream resolvers have higher median response times than mainstream ones, particularly if the resolvers are not local to the region.
- Most mainstream resolvers appear to be replicated and provide better response times across different geographic regions
- A local non-mainstream resolver can exhibit equivalent performance as compared mainstream resolvers (e.g., ordns.he.net in North America, dns.alldns.com in Europe, and doh.libredns.gr in Europe).
- There is an opportunity to invest in deploying and maintaining reliable, performant, global encrypted DNS infrastructure operated by a greater diversity of organizations