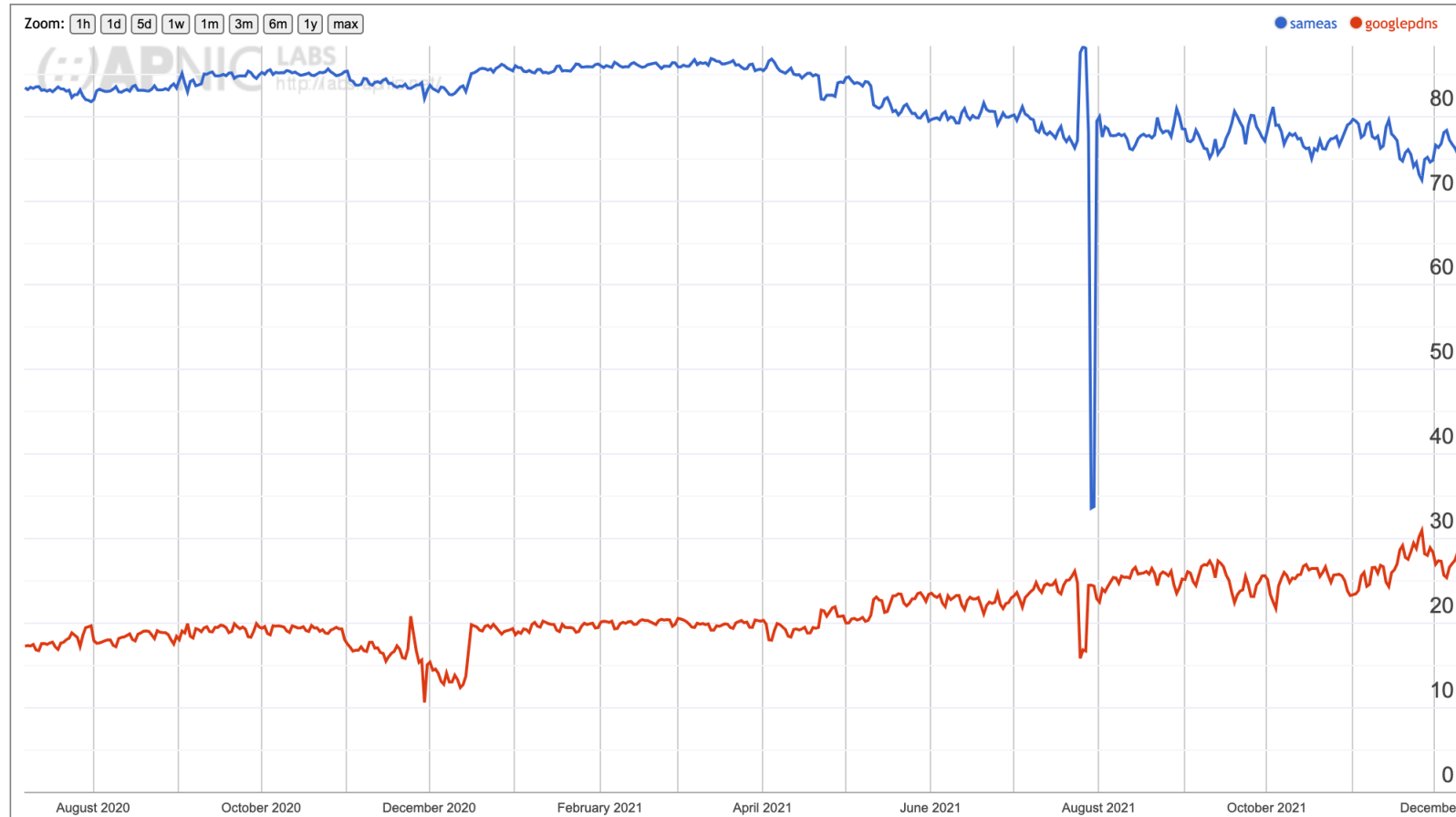


# DNS Centrality

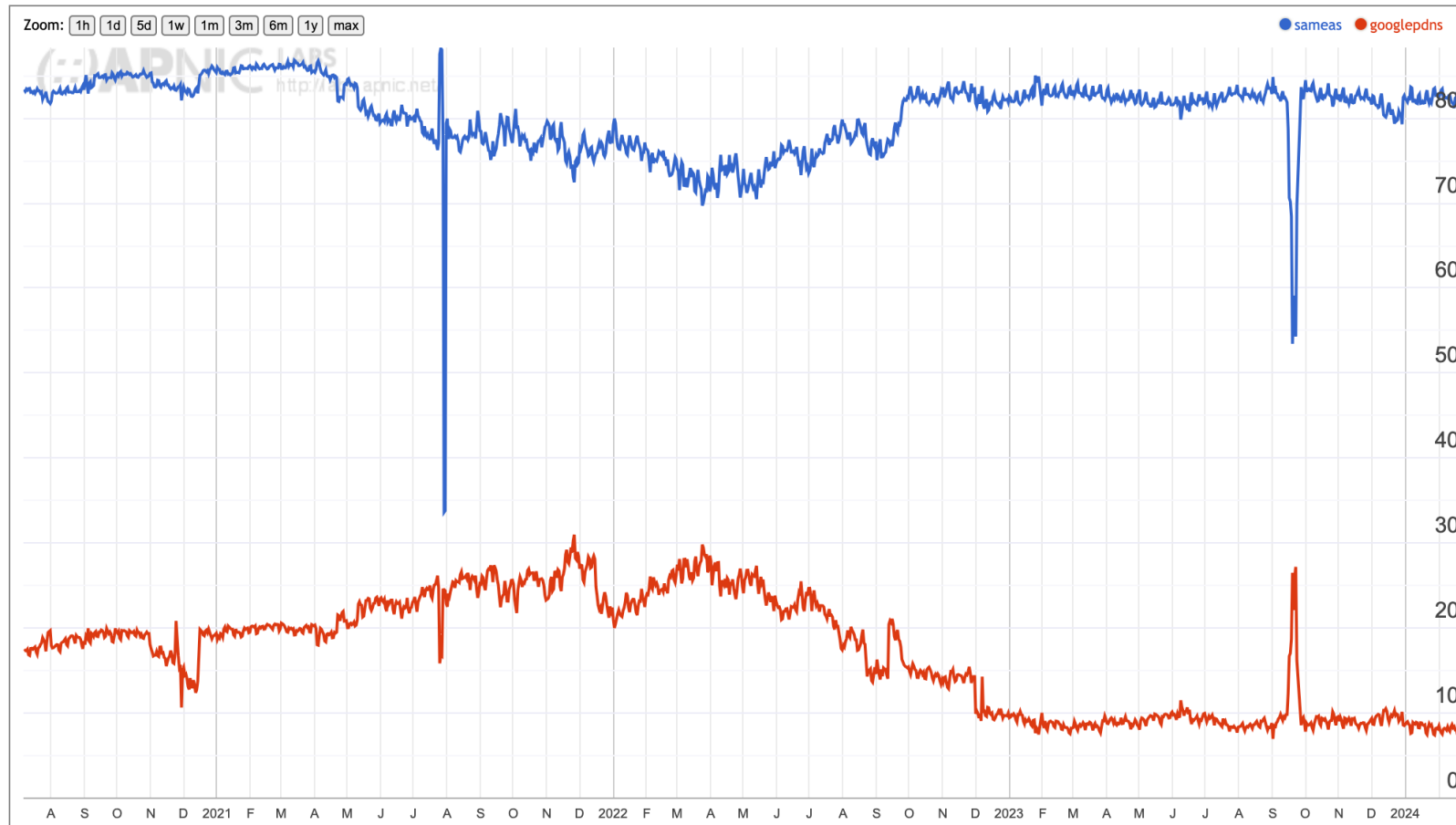
# The DNS...

- Is a massive distributed system with no central locus of control
- Both resolvers and servers are diverse and highly distributed
- So why should we worry about centrality and concentration in the DNS?

# Resolver Concentration in EU



# EU pressure on ISPs!



# Concentration Measurements

- Lets look at the “market” of DNS open resolvers using the “all resolvers” measurements
  - Single Entity Dominance:
    - Google has 68.7% of the open DNS resolver market
  - Four-Firm Concentration:
    - Google, Cloudflare, 114DNS and OpenDNS have 91.6% market share
  - HHI Index:
    - 49%
- So the open resolver market sector is **highly centralized**.
- But this open resolver activity represents only one third of the total resolution market, and the HHI Index of the open resolvers as a subset of the total resolution market is far lower, at 5%

# Authoritative Servers

- Data about the recursive-to-authoritative query set is hard to find
  - Recursive resolvers sit in a privileged position in the DNS as they are exposed to both the identity of the stub resolver (the ‘user’) and the DNS names that they are querying
  - So there are many caveats that apply to access to such data – and rightly so
- At APNIC we have limited access to the data relating to the use of the 1.1.1.1 recursive resolver
  - We don’t know who is querying, but we can see query names and query protocol
  - The market share of Cloudflare’s open resolver service is around 3% of users which is a non-trivial resolver in the open resolver set (ranked #2 in terms of market share)

# Centrality in Authoritative Servers?

- One way to measure this is to look at the **query-count weighted ranking** of the DNS authoritative server providers
- If an authoritative name server hosts a very popular domain name then it's likely that the query count will be high
- If a service operator hosts a large number of domains on its authoritative server infrastructure, then it's likely that the query count will be high
- So lets characterise the authoritative service hosting market by their query-based 'market share'

# Measurement Technique

- Obtain a data set of 24 hours of query name data from the 1.1.1.1 resolver system
- Group the query names
- Resolve the names to find the “lowest” authoritative name server for the query name using a local resolution environment
- Take the first name server name
- Discard the query names
- Resolve the name server names to IP address, and discard the name server names
- Map the IP addresses to AS numbers, and discard the IP addresses
- Group the query counts into AS numbers and rank by query share



# Data Set

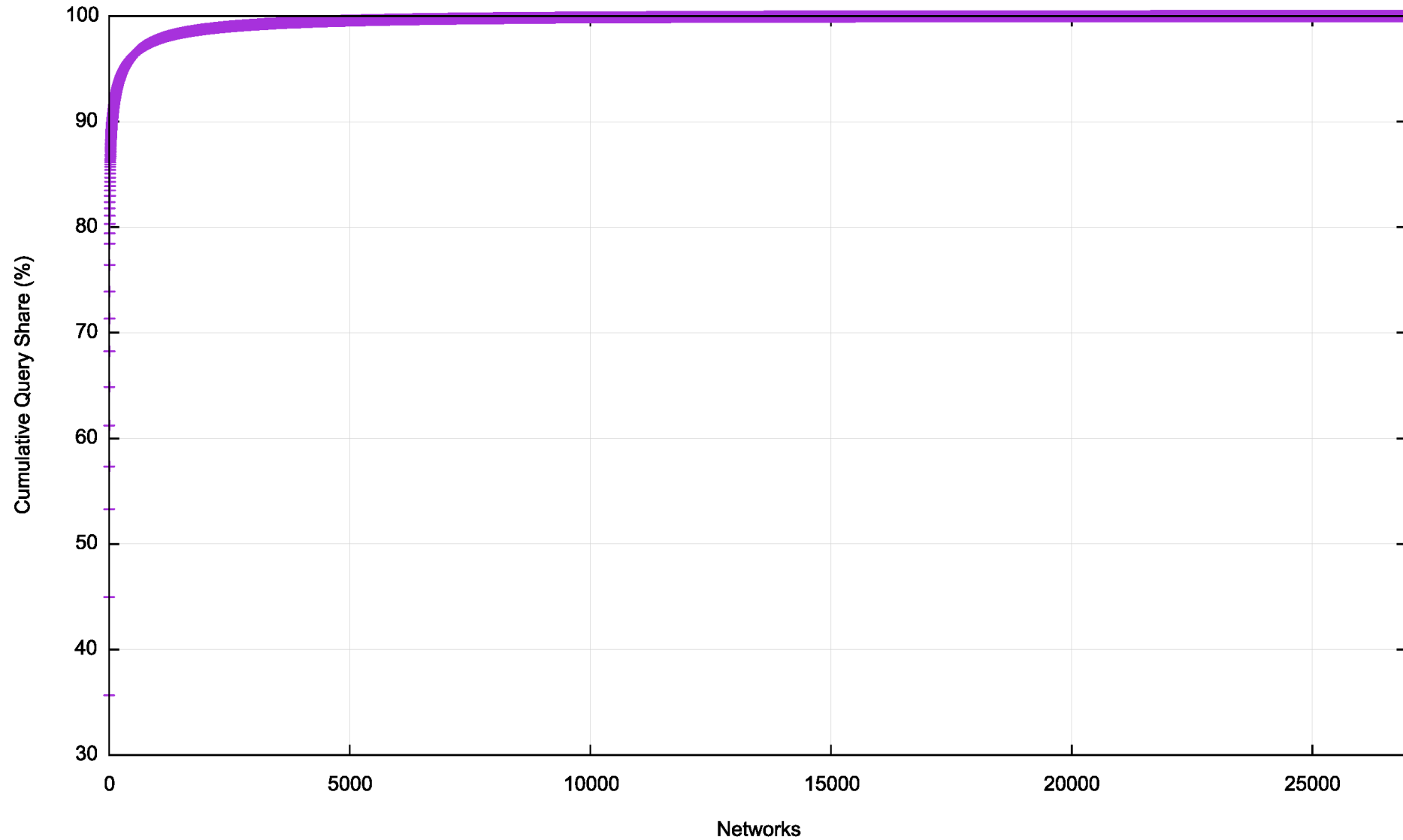
Rank	AS Number	Query Share	Cumulative Share	Name
56	31034	0.06%	89.64%	Aruba, IT
57	20446	0.06%	89.70%	Stackpath CDN, US
58	199524	0.06%	89.76%	Gcore, LU
59	60068	0.05%	89.82%	CDN77, GB

Here's an extract of the resultant data set

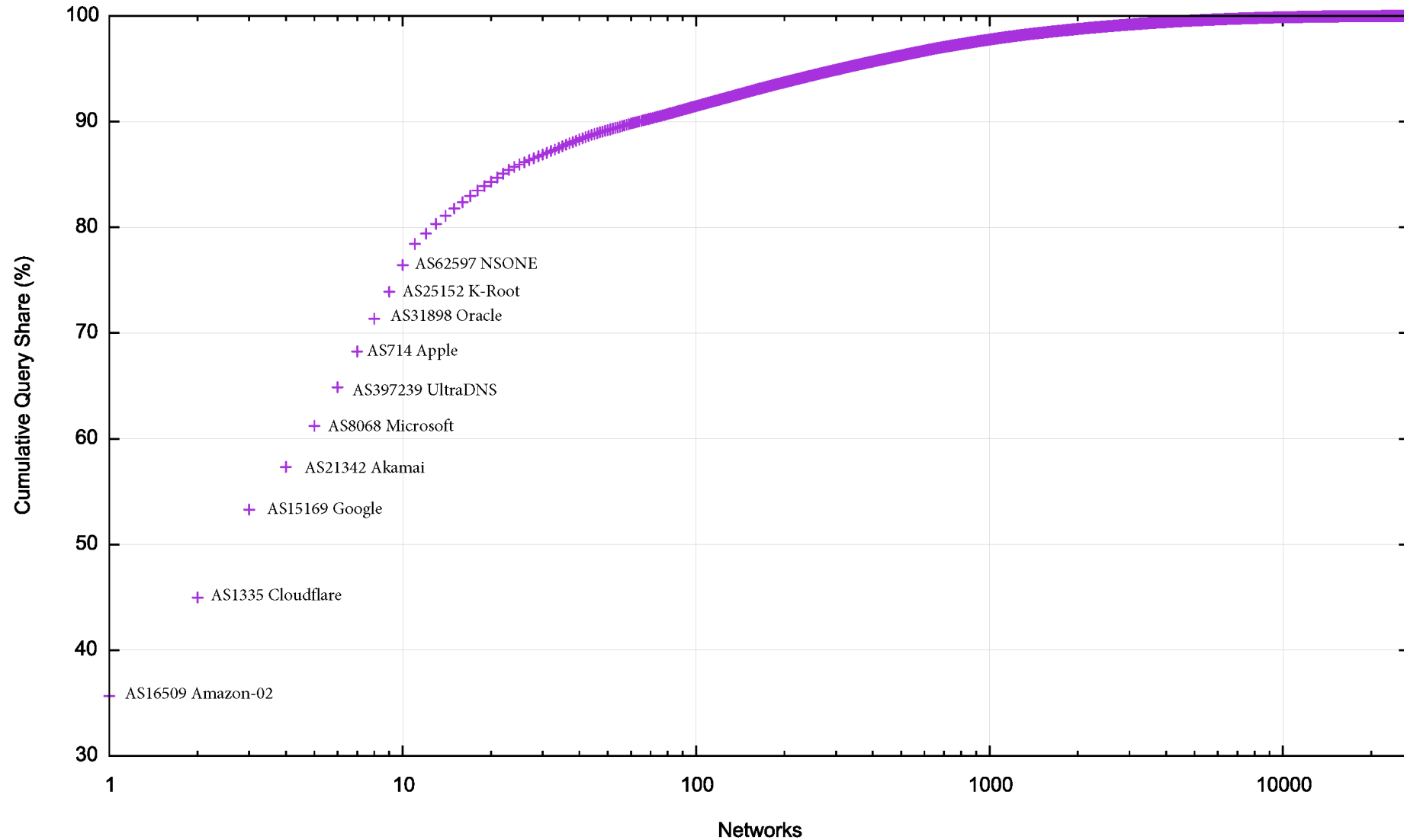
The 24 hour data capture identified 26,971 unique AS numbers (out of a total of 75,000 unique AS numbers in the routing table)

While approximately one third of networks host at least one queried authoritative name server the top 50 ASNs have 89.2% of the query share.

# Cumulative Distribution



# Cumulative Distribution



# Top 10 Auth Server Networks

Rank	AS Number	Query Share	Cumulative Share	Name
1	AS16509	35.7%	35.7%	Amazon-02, US
2	AS13335	9.3%	45.0%	Cloudflare, US
3	AS15169	8.3%	53.3%	Google, US
4	AS21342	4.0%	57.3%	Akamai – ASN2, US
5	AS8068	3.9%	61.2%	Microsoft, US
6	AS397239	3.7%	64.9%	UltraDNS, US
7	AS714	3.4%	68.3%	Apple, US
8	AS31898	3.1%	71.4%	Oracle, US
9	AS*	2.5%	73.9%	Root Server System
10	AS62597	2.5%	76.4%	NSONE, US

# Concentration Measurements

- Lets look at the “market” of DNS authoritative server providers using query-weighted ranking
  - Single Entity Dominance:
    - Amazon has 35.7% of the Authoritative Server market
  - Four-Firm Concentration:
    - Amazon, Cloudflare, Google, and Akamai have 57.3% market share
  - HHI Index:
    - 15%
- This appears to be a “**moderately concentrated**” market

# Geopolitical Centrality?

- There are 10 network entities who host the authoritative name servers that have a query share of three quarters of the recursive-to-authoritative DNS query volume
- All 10 networks are attributed to US entities