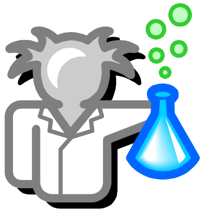
A Question of Protocol

Geoff Huston
APNIC



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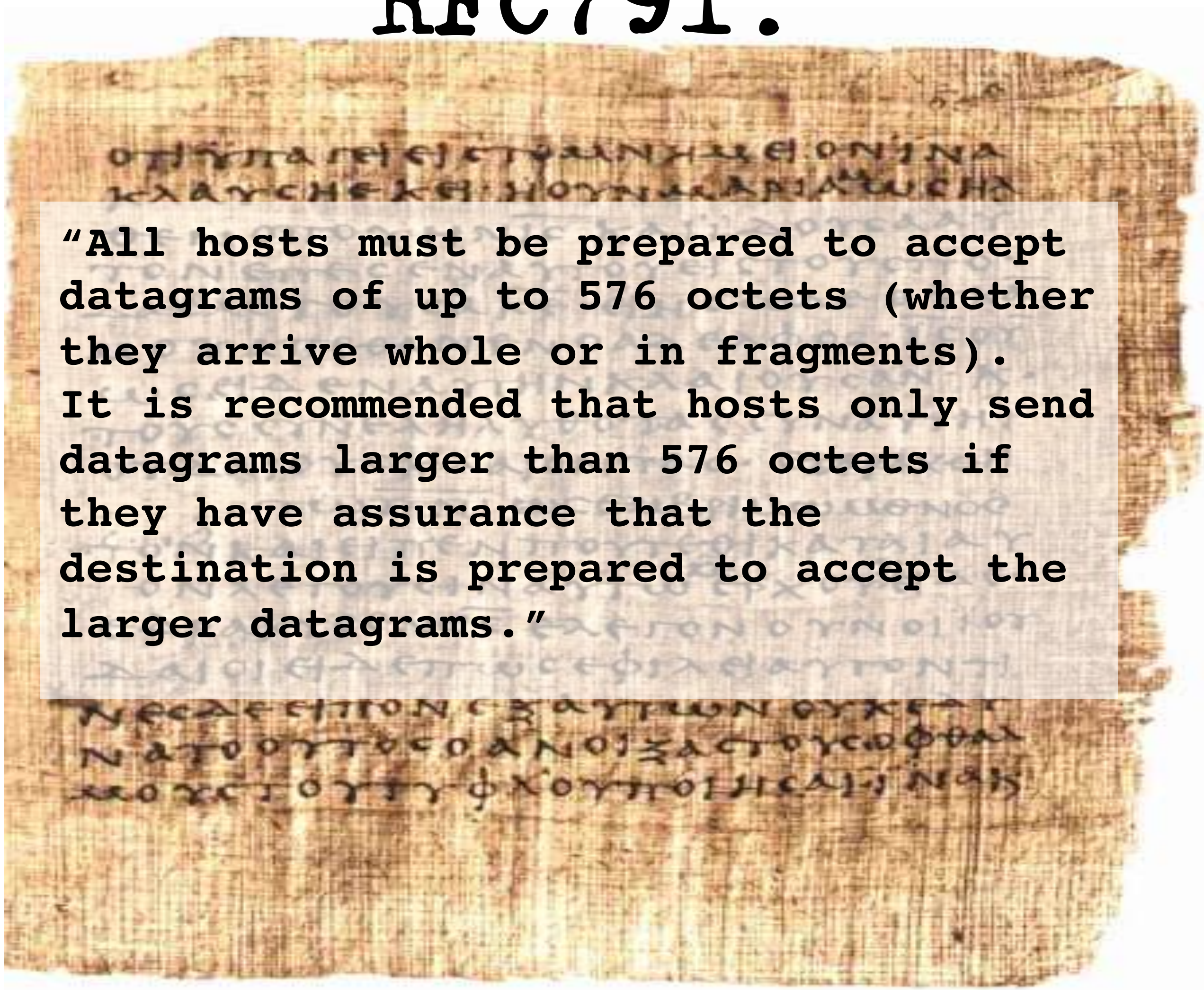
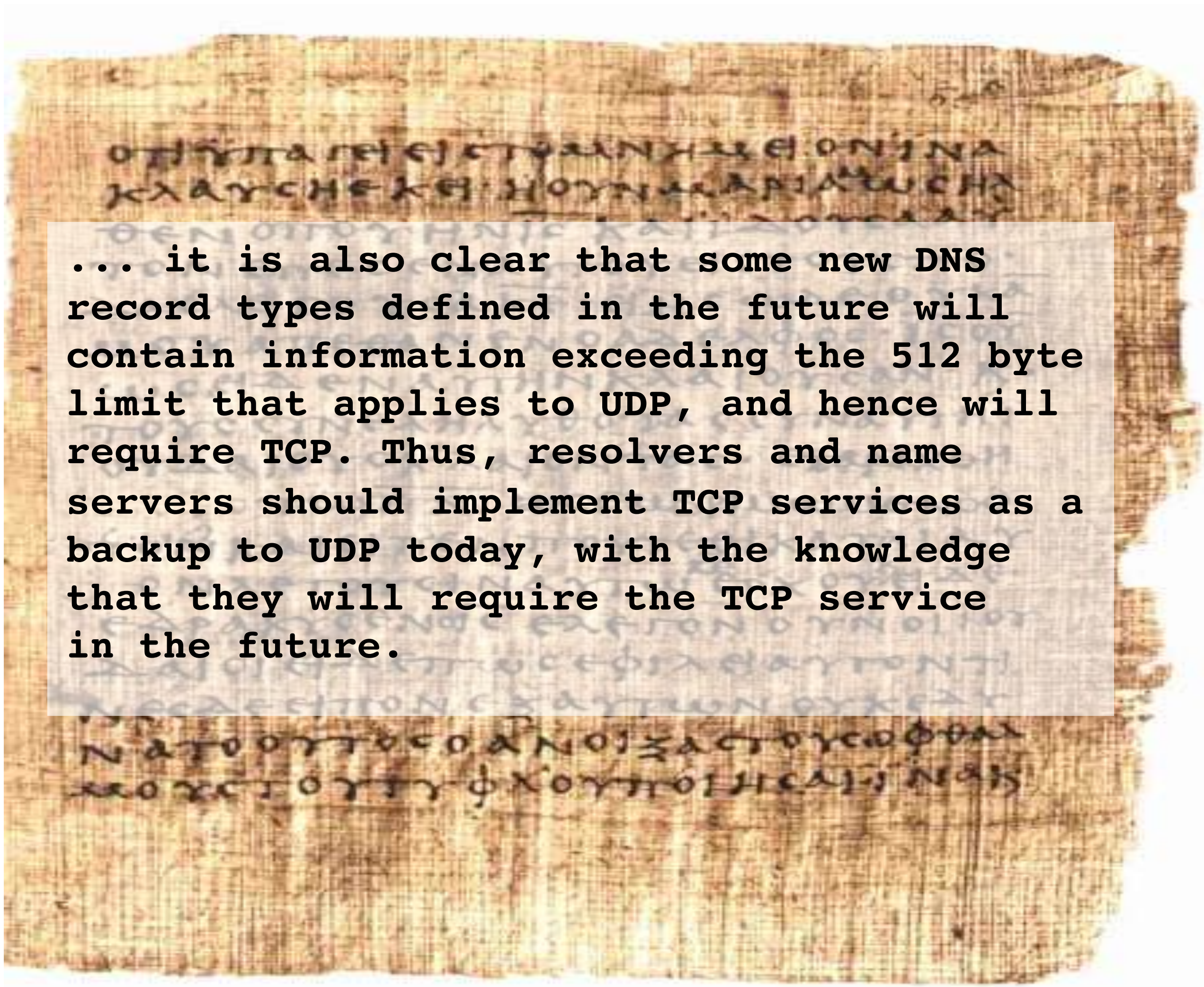


"All hosts must be prepared to accept datagrams of up to 576 octets (whether they arrive whole or in fragments). It is recommended that hosts only send datagrams larger than 576 octets if they have assurance that the destination is prepared to accept the larger datagrams."

Then came RFC1123:



... it is also clear that some new DNS record types defined in the future will contain information exceeding the 512 byte limit that applies to UDP, and hence will require TCP. Thus, resolvers and name servers should implement TCP services as a backup to UDP today, with the knowledge that they will require the TCP service in the future.

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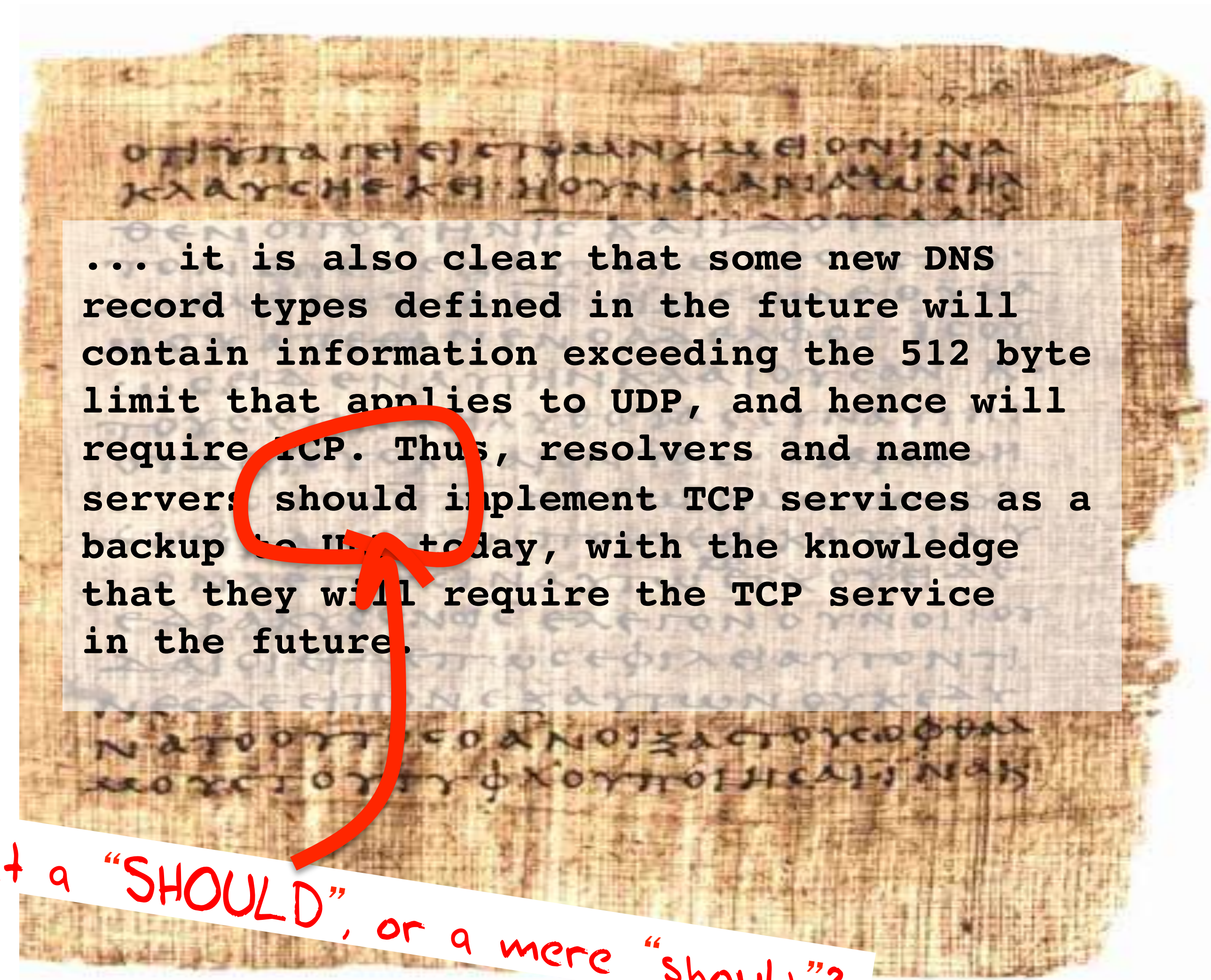

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is that a "SHOULD", or a mere "should"?

Hang on…

RFC 791 said 576 octets, yet RFC 1123 reduces this even further to 512 bytes

What's going on?

- An IPv4 UDP packet contains:
  - 20 bytes of IP header
  - <= 40 bytes of IP options
  - 8 bytes of UDP header
  - payload
- The IP header is between 28 and 68 bytes

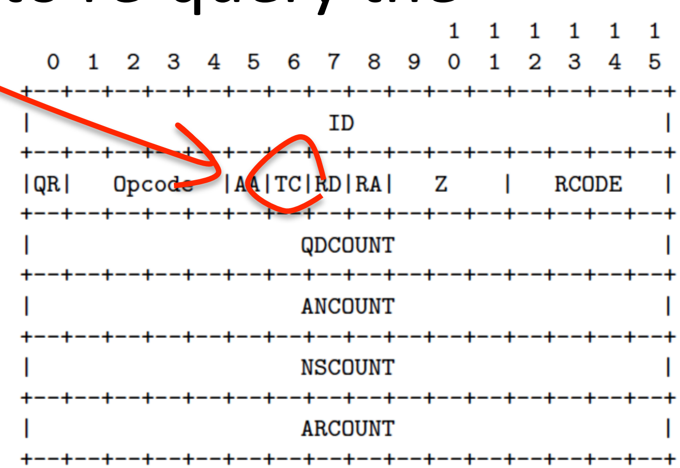
All IPv4 hosts must accept a 576 byte IP packet, which implies that the maximum UDP payload that all hosts will accept is 512 bytes

The original DNS model

If the reply is <= 512 bytes, send a response over UDP

If the reply is > 512 bytes, send a response over UDP, but set the TRUNCATED bit in the DNS payload

– Which should trigger the client to re-query the server using TCP



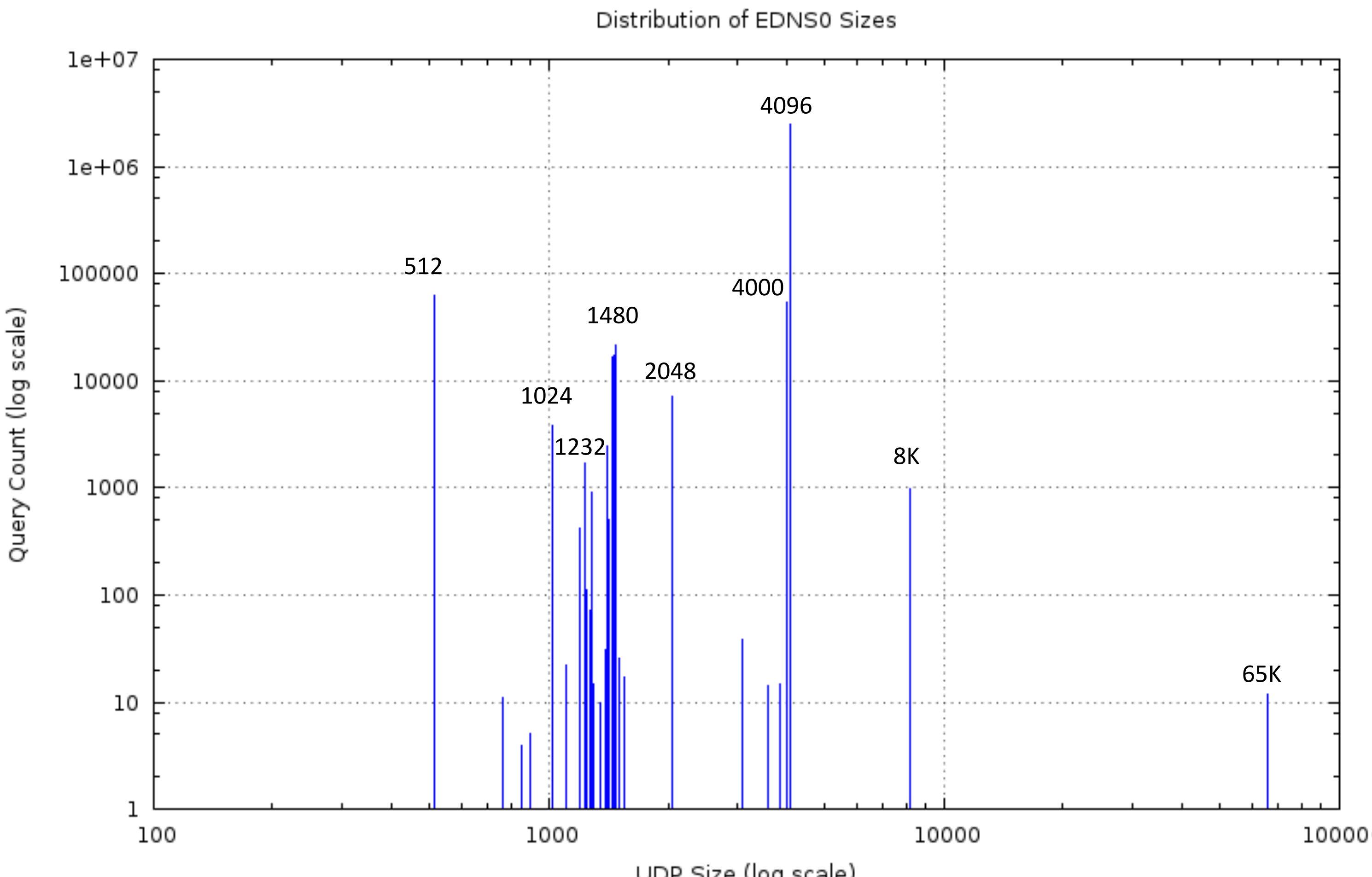
Then came EDNS0

RFC2671:

```
4.5. The sender's UDP payload size (which OPT stores in the RR CLASS
     field) is the number of octets of the largest UDP payload that can
     be reassembled and delivered in the sender's network stack.  Note
     that path MTU, with or without fragmentation, may be smaller than
     this.
```

The sender can say to the resolver: “It’s ok to send me DNS responses using UDP up to size <xxx>. I can handle packet reassembly.”

Aside: Offered EDNS0 Size Distribution



Aside: Offered EDNS0 Size Distribution

512	62977
768	11
850	4
900	5
1024	3857
1100	22
1200	416
1232	1706
1252	112
1272	71
1280	906
1300	15
1352	10
1392	31
1400	2431
1410	1291
1412	209
1420	513
1440	10443
1450	16332
1452	3605
1460	17387
1472	1933
1480	21225
1500	26
1550	17
2048	6984
3072	38
3584	14
3839	15
4000	54492
4096	2500352
8192	981
65535	12

1280 ← ?? iPv6

1452 ← iPv6?? 1500 - 48

1480 ← ?? 1500 -20

4096 ← RFC6891

What if…

One were to send a small query in UDP to a DNS resolver with:

- EDNS0 packet size set to a large value
- The IP address of the intended victim as the source address of the UDP query
- A query that generates a large response in UDP
  - ISC.ORG IN ANY, for example

You get a 10x – 100x gain!

Mix and repeat with a combination of a bot army and the published set of open recursive resolvers (of which there are currently some 28 million!)

Which leads to…

Possible Mitigations…?

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So lets look at 2) & 3):

This would then force the query into TCP

And the TCP handshake does not admit source address spoofing

Could this work?

How many customers use DNS resolvers that support TCP queries?

- Lets find out with an experiment:
  - Turn down the EDNS0 size limit on an authoritative server to 512 bytes
  - Enlist a large number of clients to fetch a collection of URLs:
    - Short DNS name, unsigned   (fits in a 512 byte UDP response)
    - Short DNS name, DNSSEC-signed
    - Long DNS name, unsigned
    - Long DNS name, DNSSEC-signed

Results

DNS Name	UDP Queries	Truncated UDP Responses	TCP responses	Truncated UDP to TCP Fail
Short, unsigned	2,029,725	2	6	0
Short, signed	2,037,563	1,699,935 83.4%	1,660,754 81.5%	39,101 1.9%
Long, unsigned	2,023,205	2,021,212 99.9%	1,968,927 97.3%	52,285 2.6%
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Results

To get to the long name with a >512 byte response we used *cnames*:

4a9c317f.4f1e706a.6567c55c.0be33b7b.2b51341.a35a853f.59c4df1d.3b069e4e.87ea53bc.2b4cfb4f.987d5318.
fc0f8f61.3cbe5065.8d9a9ec4.1ddfa1c2.4fee4676.1ffb7fcc.ace02a11.a3277bf4.2252b9ed.9b15950d.db03a738.
dde1f863.3b0bf729.04f95.z.dotnxdomain.net.
CNAME
33d23a33.3b7acf35.9bd5b553.3ad4aa35.09207c36.a095a7ae.1dc33700.103ad556.3a564678.16395067.
a12ec545.6183d935.c68cebfb.41a4008e.4f291b87.479c6f9e.5ea48f86.7d1187f1.7572d59a.9d7d4ac3.
06b70413.1706f018.0754fa29.9d24b07c.04f95.z.dotnxdomain.net

33d23a33.3b7acf35.9bd5b553.3ad4aa35.09207c36.a095a7ae.1dc33700.103ad556.3a564678.16395067.
a12ec545.6183d935.c68cebfb.41a4008e.4f291b87.479c6f9e.5ea48f86.7d1187f1.7572d59a.9d7d4ac3.
06b70413.1706f018.0754fa29.9d24b07c.04f95.z.dotnxdomain.net. A 199.102.79.187,

Results

To get to the long name with a >512 byte response we used *cnames*

Are these *cnames* causing a higher dropout rate?

We re-ran the experiment with a mangled DNS authoritative name server that had a lowered max UDP response size of 275 bytes, which allowed us to dispense with the *cname* construct

Results (2)

DNS Name	UDP Queries	Truncated UDP Responses	TCP responses	Truncated UDP to TCP Fail
Short, unsigned	936,007	0	3	3
Short, signed	936,116	935,990 100.0%	916,251 97.9%	19,739 2.1%
Long, unsigned	920,613	920,483 100.0%	896,953 97.4%	23,530 2.6%
Long, signed	934,446	934,330 100.0%	910,757 97.5%	23,573 2.5%

it looks like the cname construct is not influencing the results!

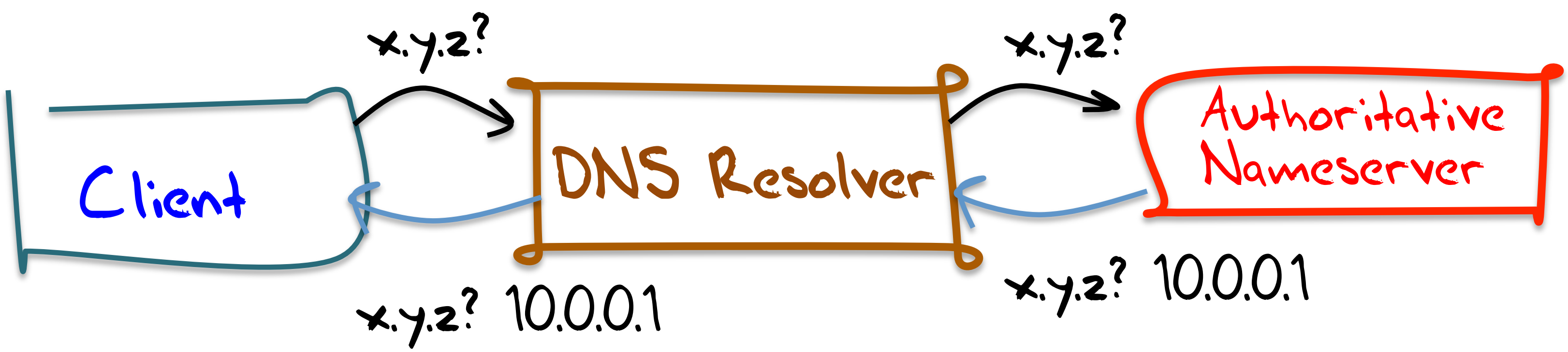
Results

2.6% of clients use a set of DNS resolvers that are incapable of reverting to TCP upon receipt of a truncated UDP response from an authoritative name server

(The failure here in terms of reverting to TCP refers to resolvers at the "end" of the client's DNS forwarder chain who are forming the query to the authoritative name server)

Aside: Understanding DNS Resolvers is "tricky"

What we would *like* to think happens in DNS resolution!



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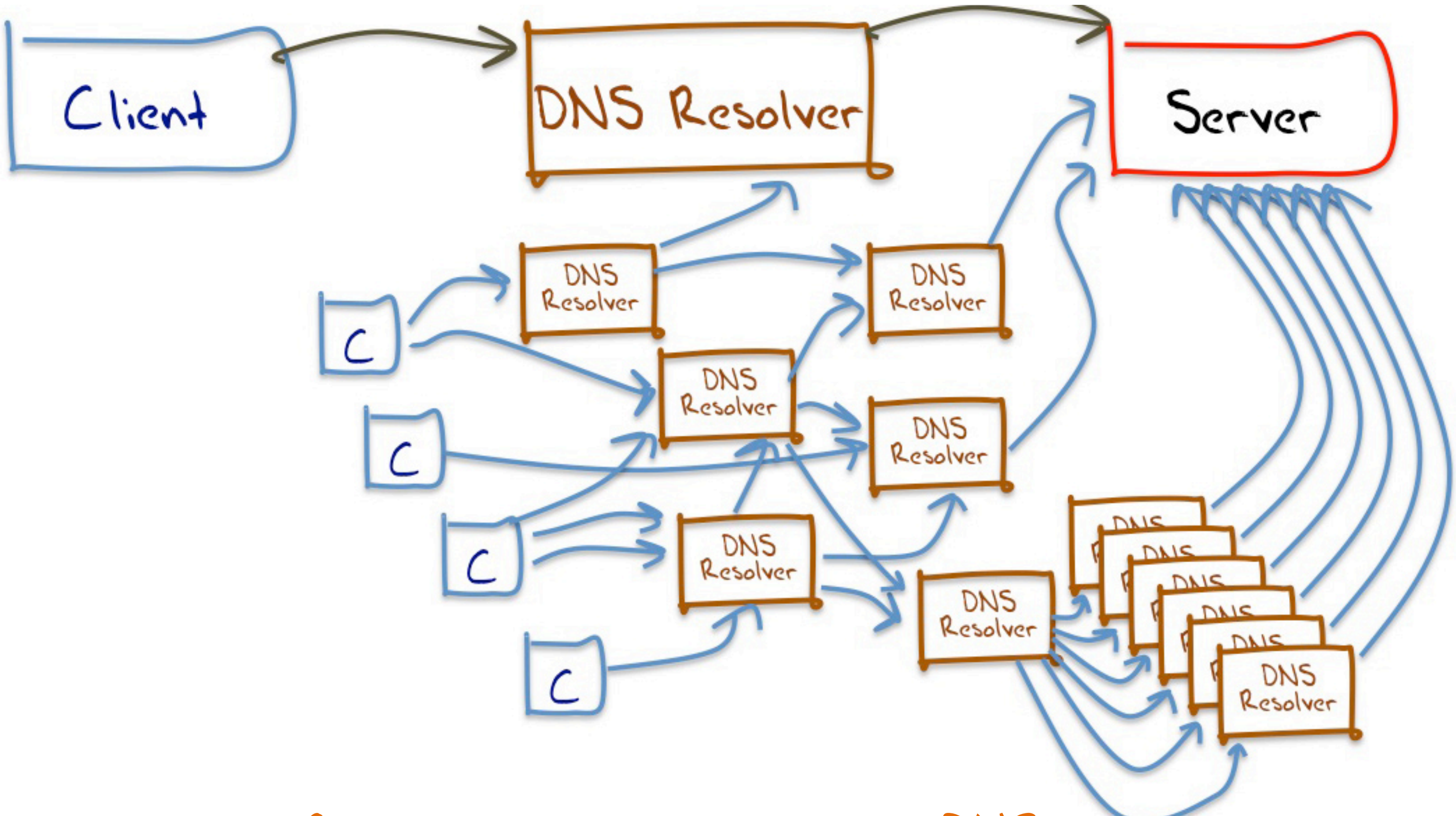

A small sample of what appears to happen in DNS resolution

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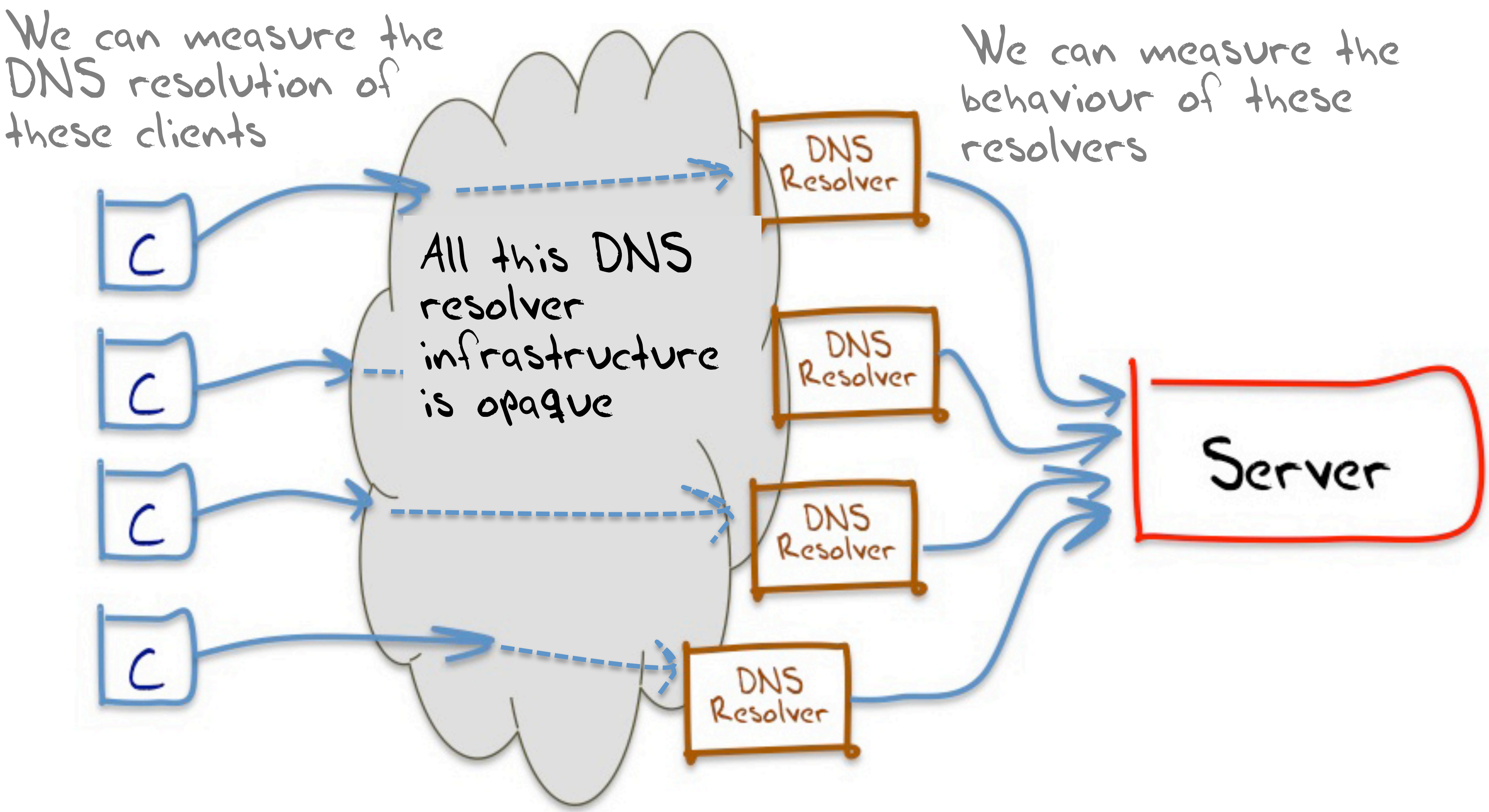

The best model we can use for DNS resolution in these experiments

Can we say anything about these "visible" resolvers?

Visible Resolvers

Total Seen: 80,505

UDP only: 13,483

17% of resolvers cannot ask a query in TCP following receipt of a truncated UDP response

6.4% of clients uses these resolvers

3.8% of them failover to use a resolver that can ask a TCP query

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What about DNS resolution performance?

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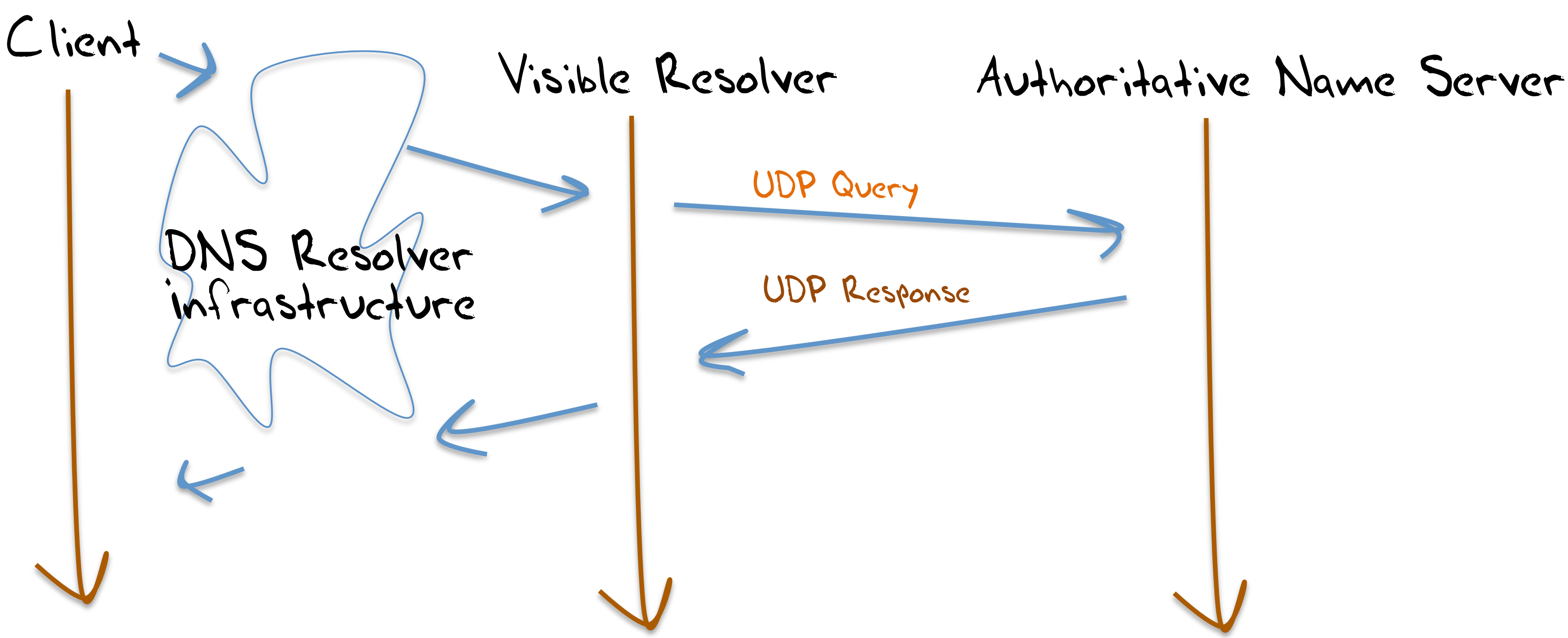

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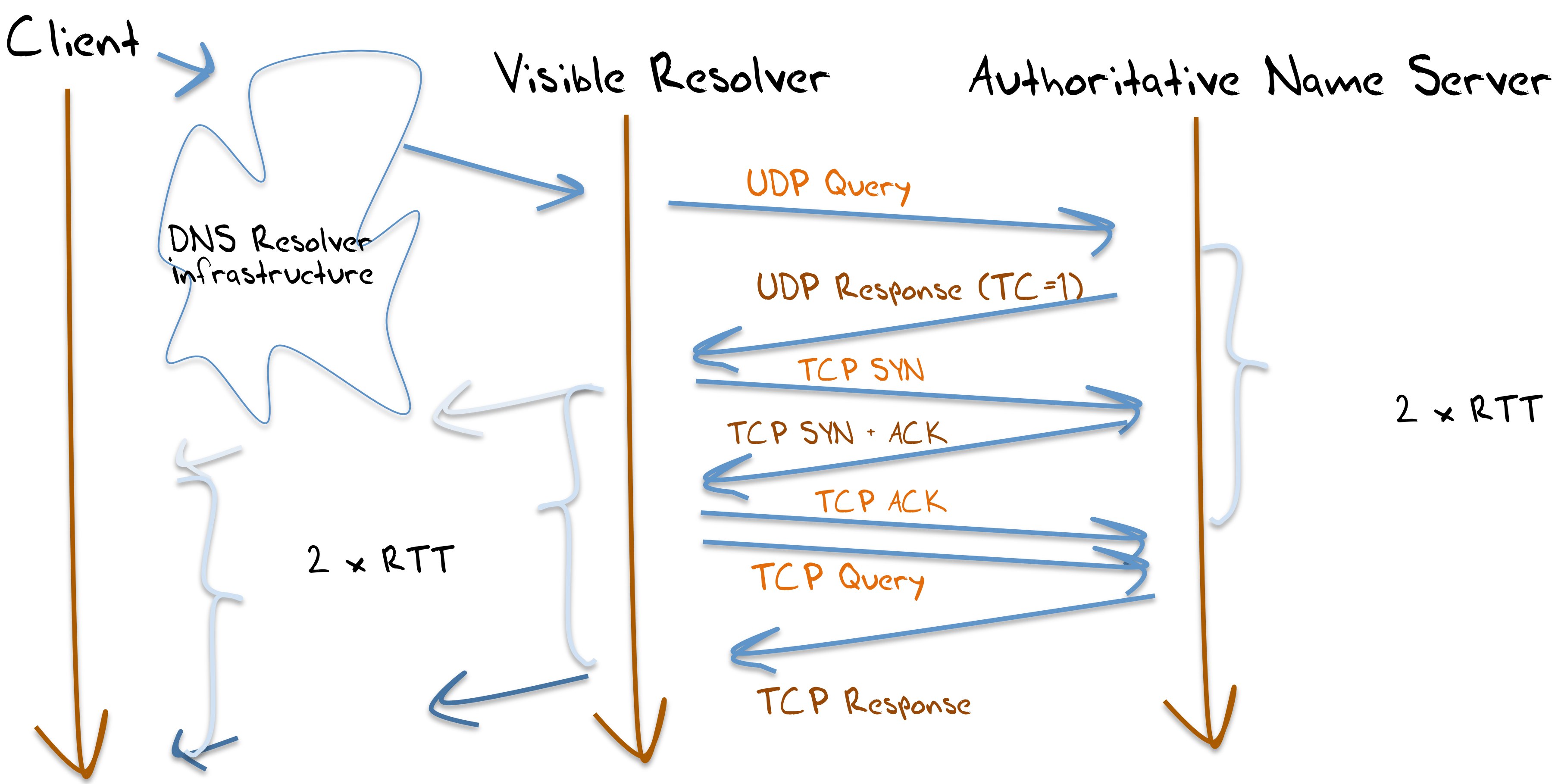
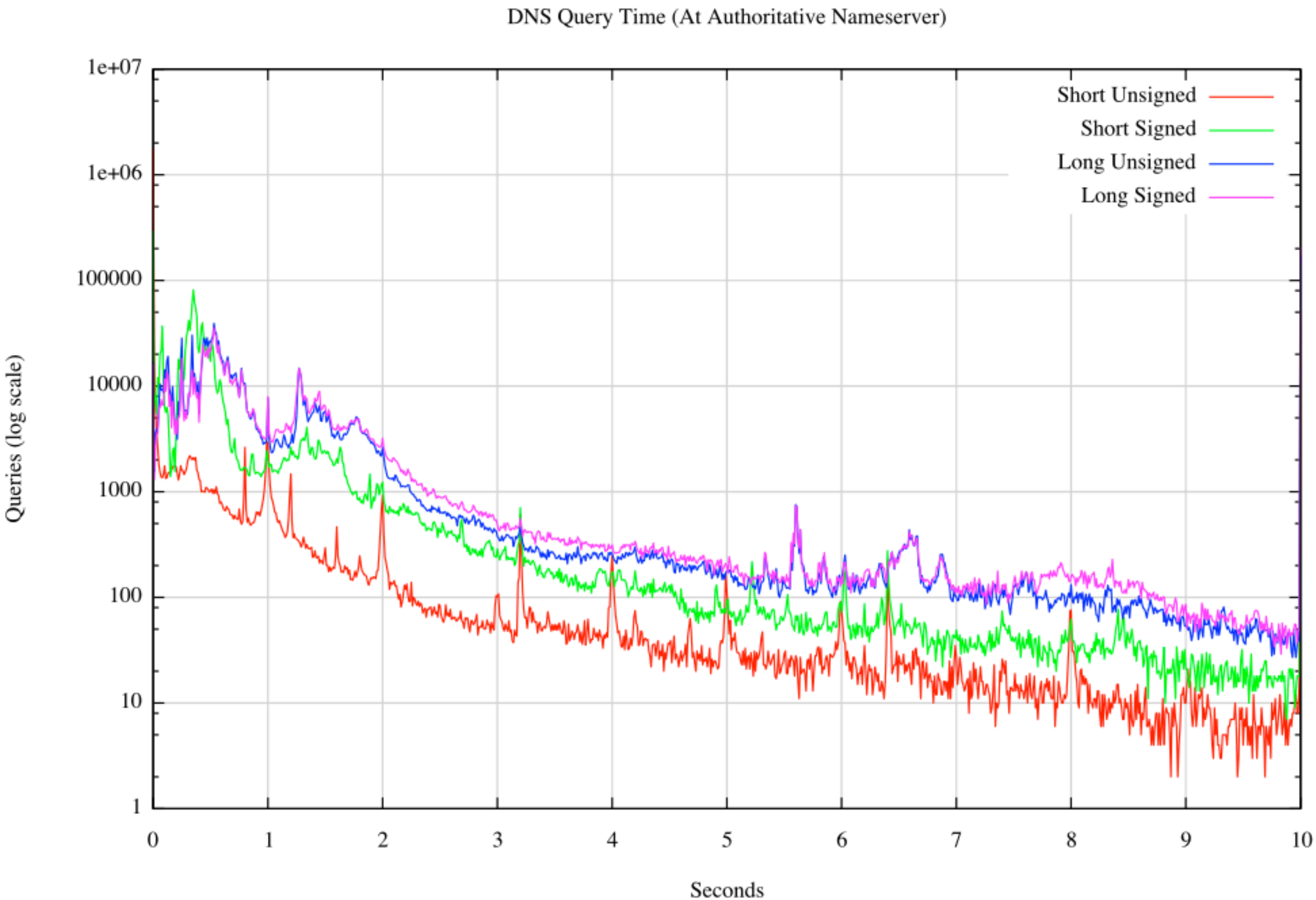


Time to resolve a name



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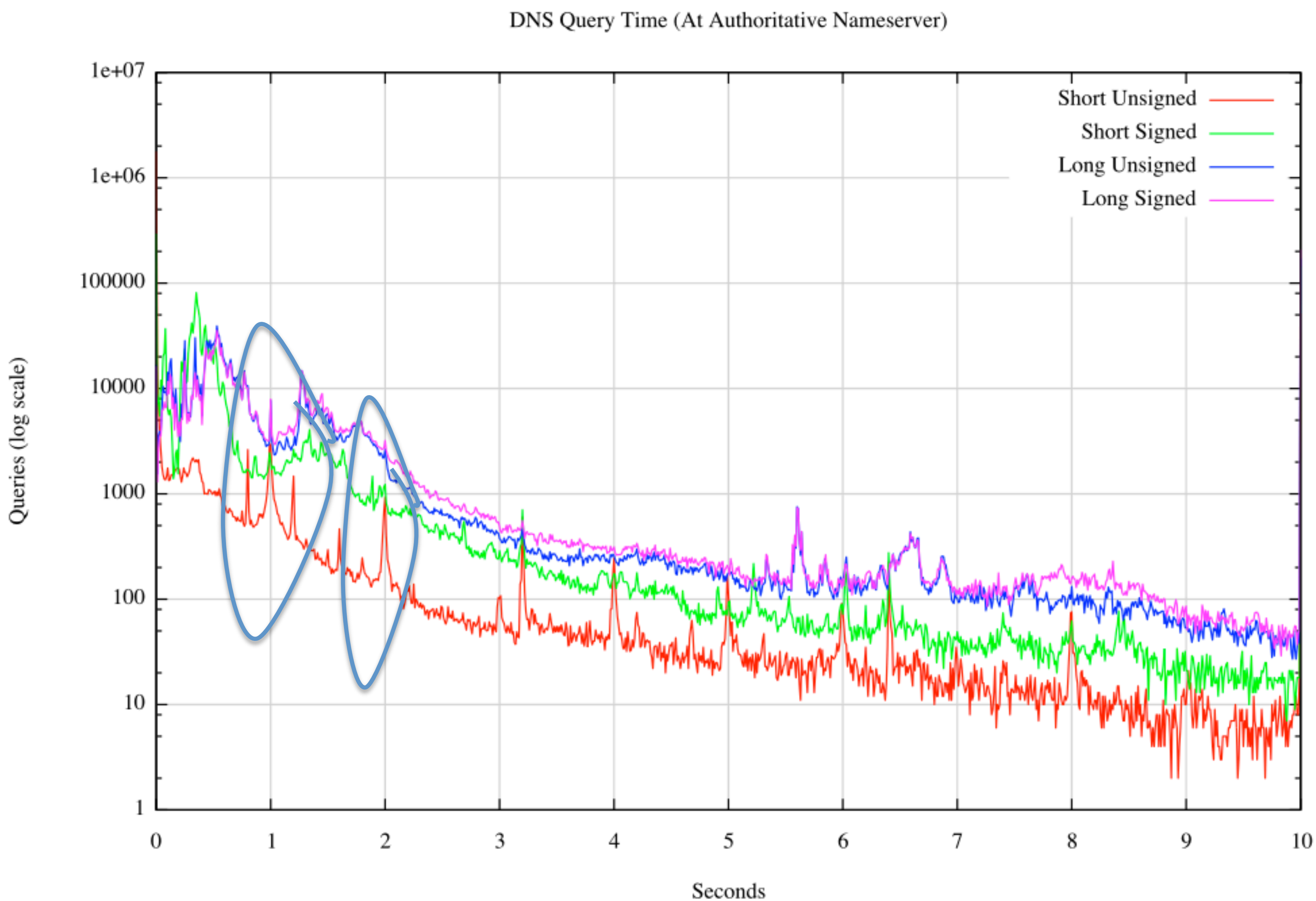

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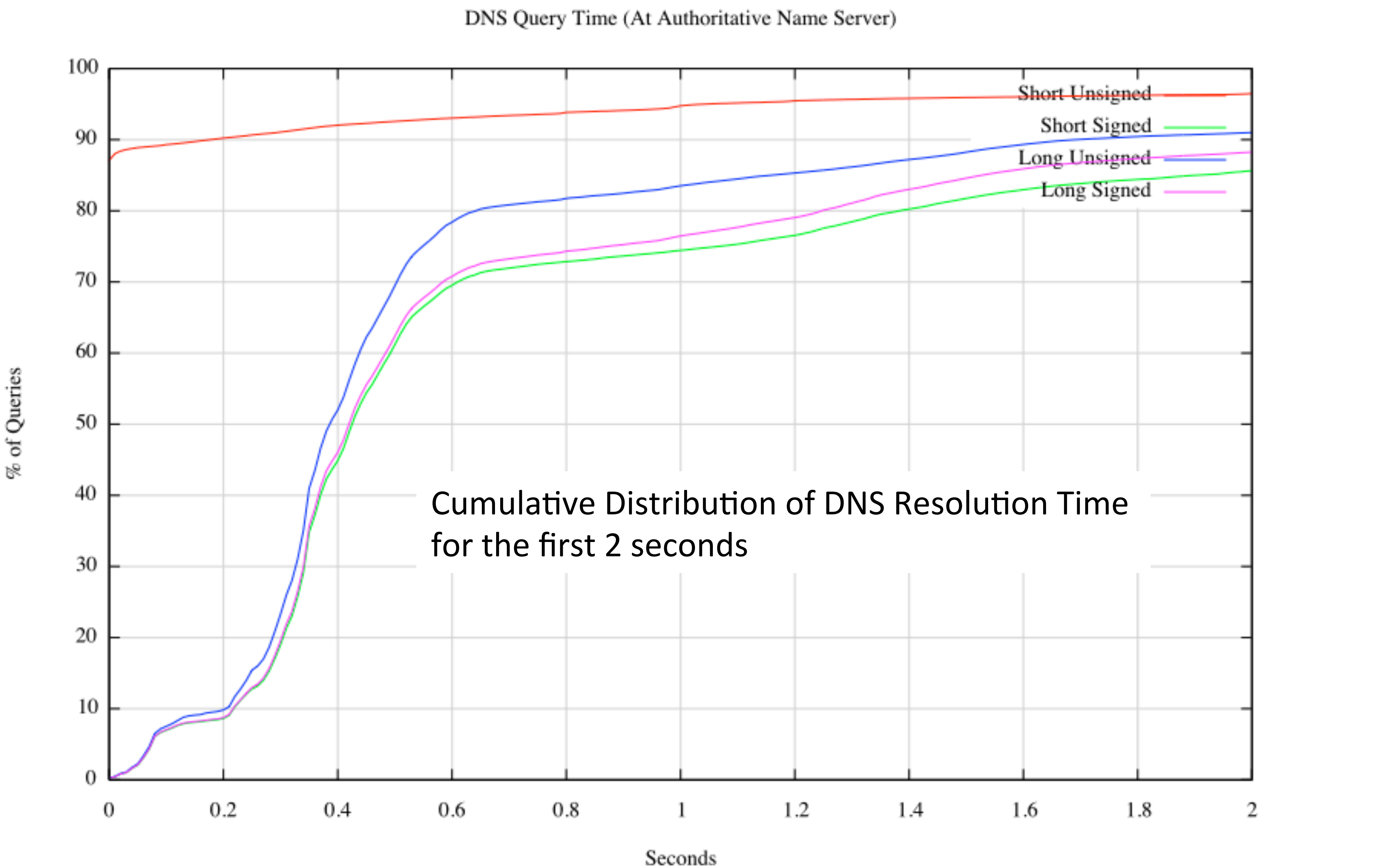

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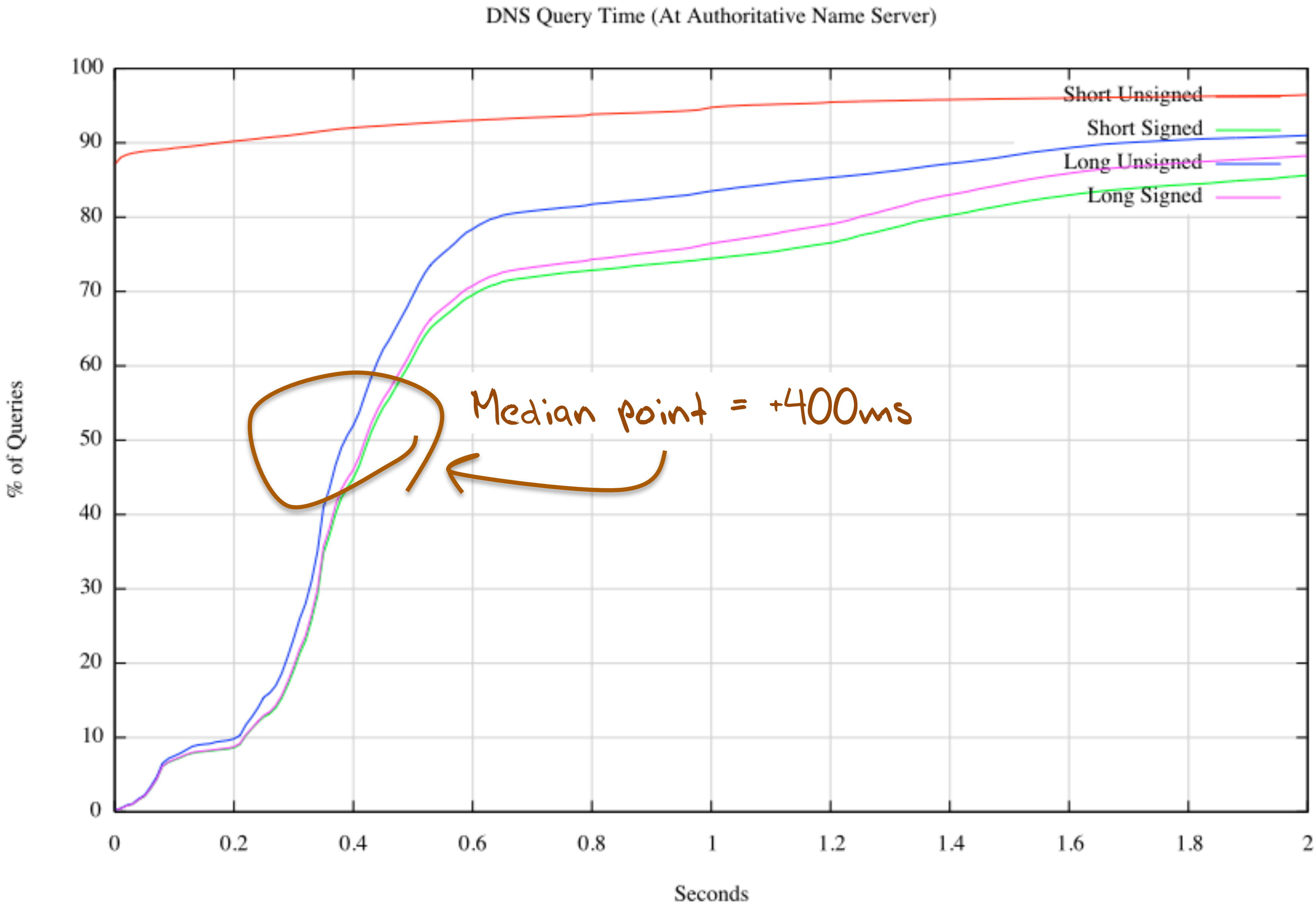

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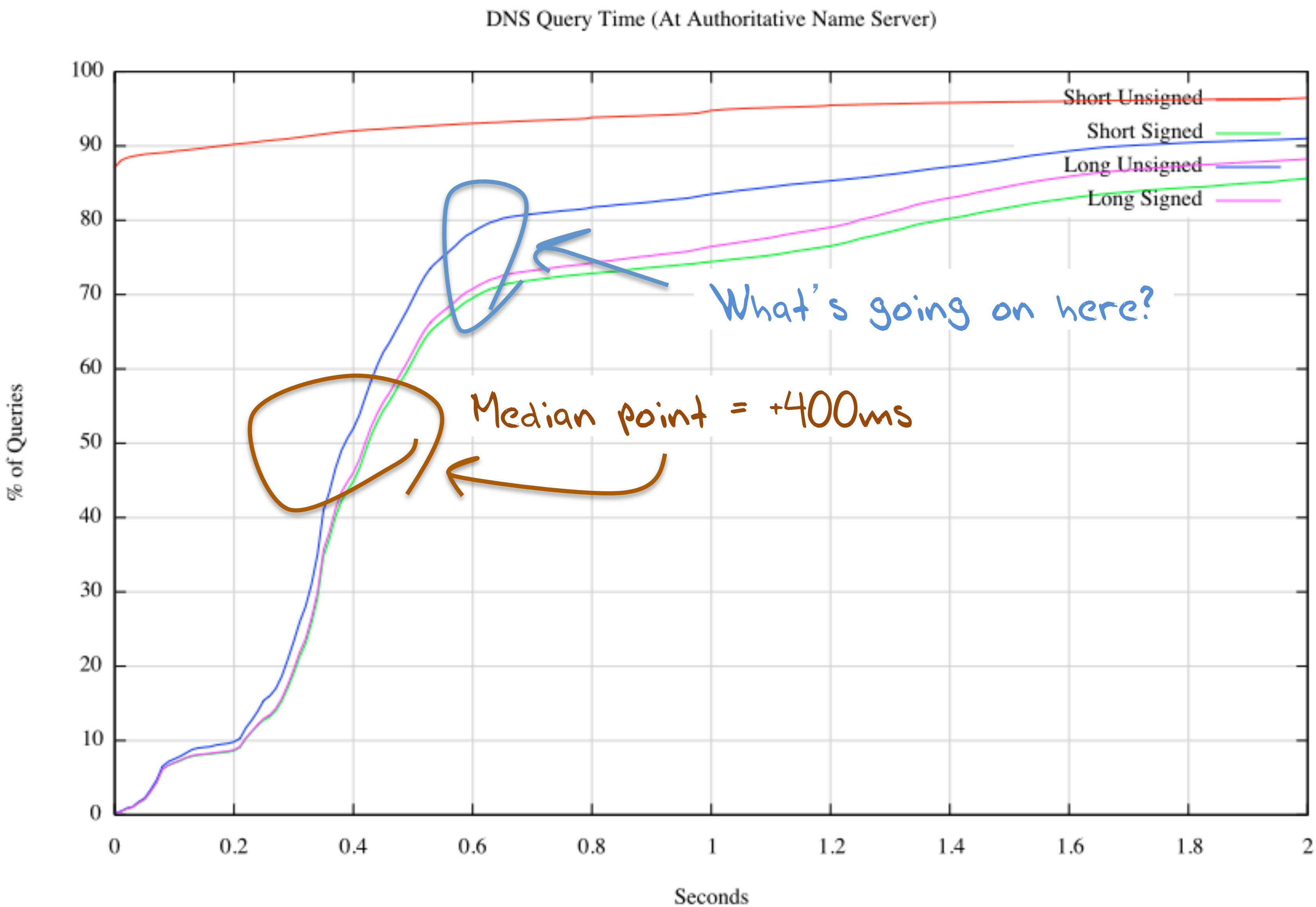


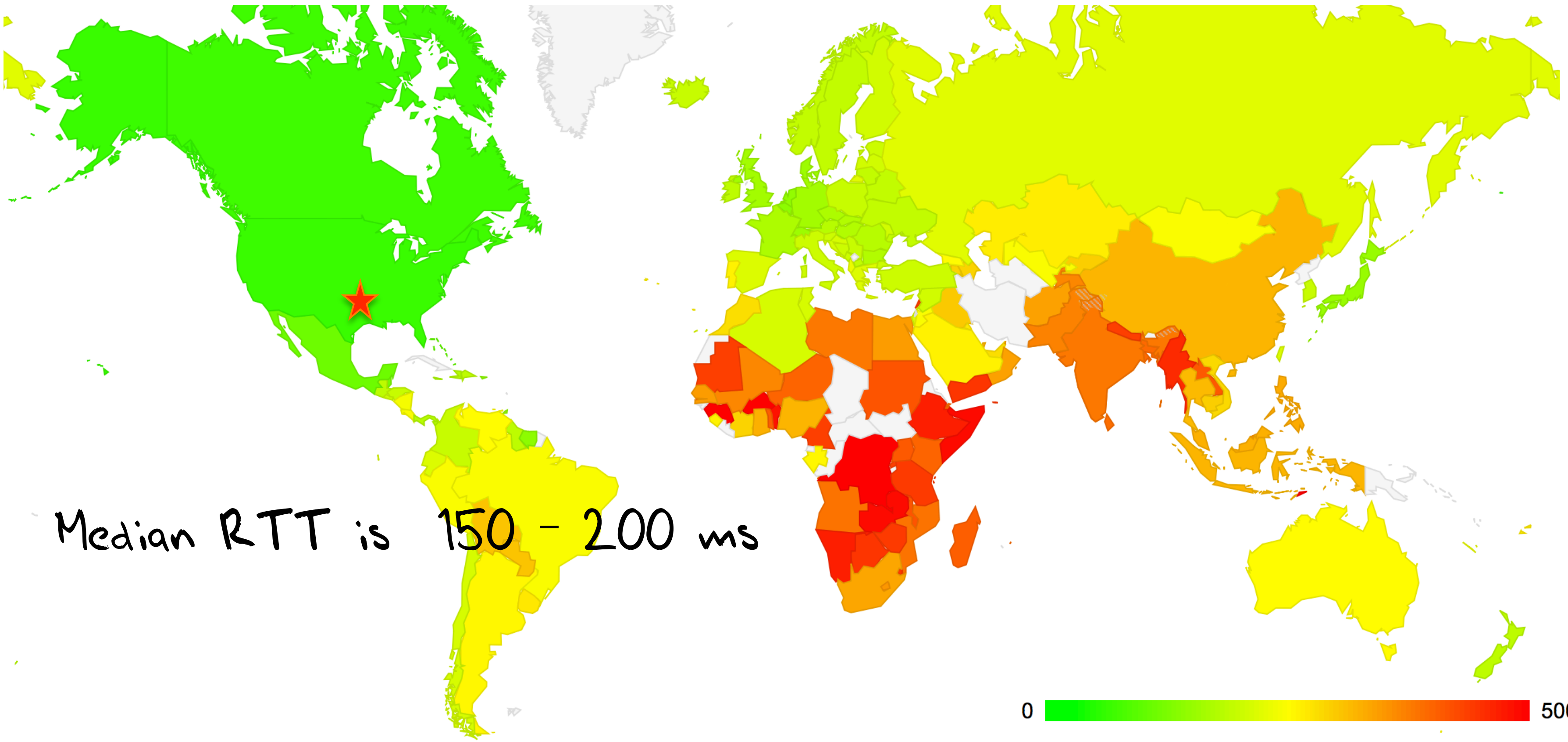
Time to resolve a name

How does this median value of 400ms relate to the RTT measurements to reach the authoritative name server?

The authoritative name server is located in Dallas, and the initial TCP SYN/ACK exchange can provide an RTT measurement sample

We can geo-locate the resolver IP addresses to get the following RTT distribution map

Measured RTT Distributions by Country



DNS over TCP

Around 70% of clients will experience an additional DNS resolution time penalty of 2 x RTT time intervals

However the other 30% experience a longer delay.

- 10% of clients experience a multi-query delay with a simple UDP query response
- 20% of clients experience this additional delay when the truncated UDP response forces their resolver to switch to TCP

If we really want to use DNS over TCP

Then maybe its port 53 that’s the problem for these 17% of resolvers and 20% of the clients

Why not go **all** the way?

- How about DNS over XML over HTTP over port 80 over TCP? 

Thanks!