What If Everyone Did It?

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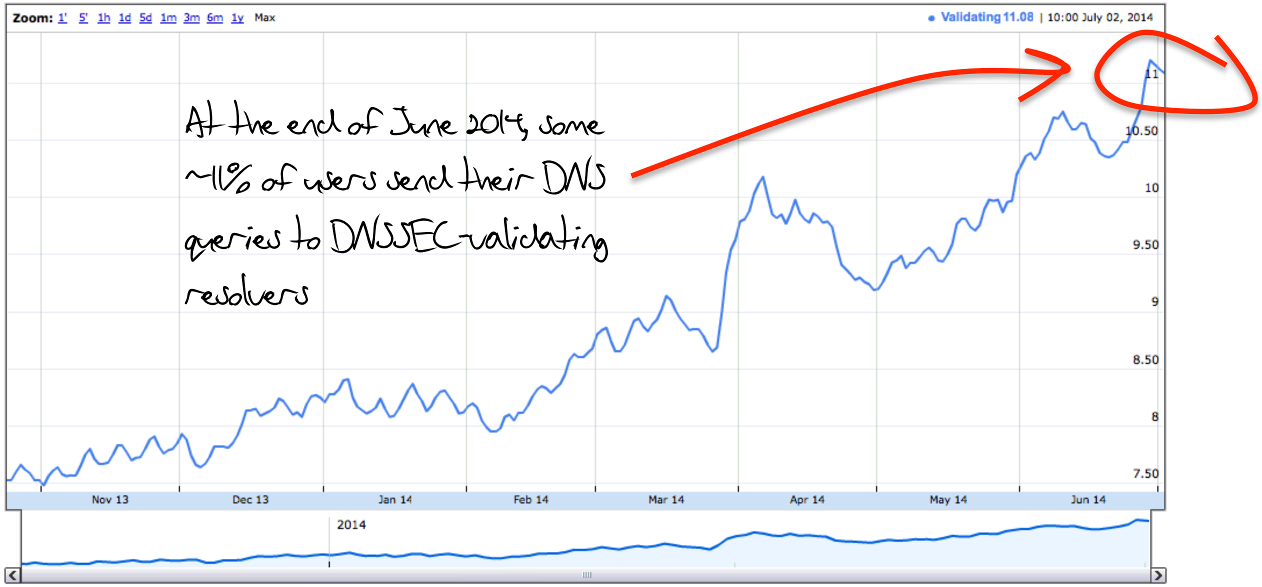
DNS Security

- Setting the AD bit in a recursive resolver response seems like a rather unimpressive way of conveying a positive security outcome, and in the same manner, setting SERVFAIL seems like a rather poor way of conveying a failed security outcome
- Various approaches to securing the channel between the client and the recursive resolver have been suggested, as well as an approach that eschews mediated security altogether and places the onus for validating a DNSSEC response back to the client who initiated the query
- Which is fine, but will this approach scale?
  - What can we say about a DNS environment where everyone performs their own DNSSEC validation?

DNSSEC today

- A small, but growing, fraction of all domain names are signed using DNSSEC
- A larger, but still small, fraction of users use DNS resolvers that perform DNSSEC validation



At the end of June 2014, some ~11% of users send their DNS queries to DNSSEC-validating resolvers

Zoom: 1' 5' 1h 1d 5d 1m 3m 6m 1y Max
● Validating 11.08 | 10:00 July 02, 2014
11
10.50
10
9.50
9
8.50
8
7.50
Nov 13
Dec 13
Jan 14
Feb 14
Mar 14
Apr 14
May 14
Jun 14
2014

What if everyone did it?

What if:

every resolver performed DNSSEC validation?

or even if:

every end device performed DNSSEC validation?

What difference in traffic loads and query rates would we see at an authoritative name server between serving an unsigned domain name and serving the signed equivalent of the domain name?

The Experiment

- We serve an online Ad with 3 embedded URLs that the user’s browser is tasked to fetch. The URLs use unique domain names that are:
  - Unsigned
  - Signed (good)
  - Signed (bad)

- We are looking for behaviours where we see the browser perform
  - Queries for the DS and DNSKEY RRs for both of the the signed domains, and
  - Fetch the signed (good) but not the signed (bad) URLs

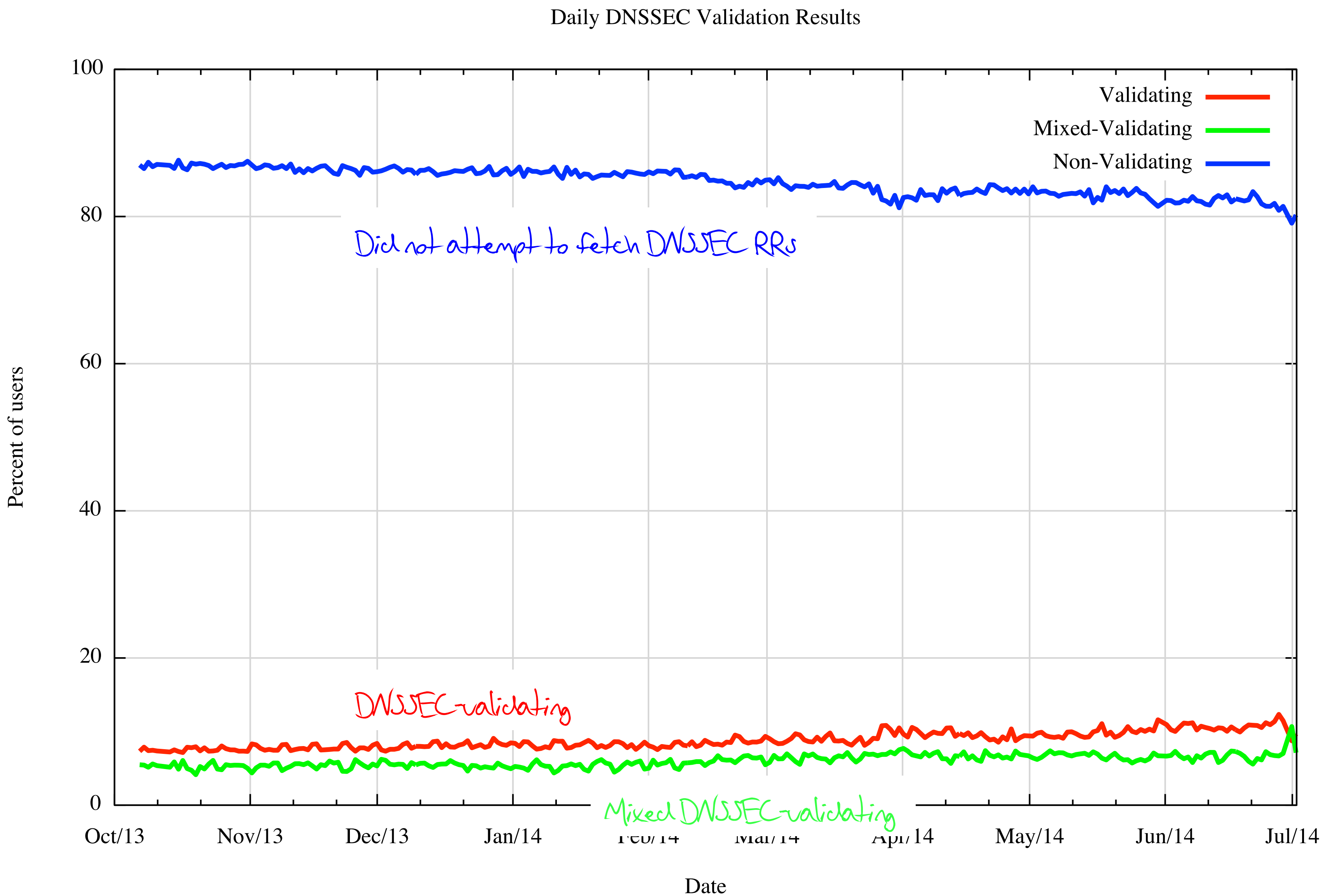
What we saw

- Users who exclusively used DNSSEC-validating resolvers
- Users who used a mix of validating and non-validating resolvers

  (typically, we saw the SERVFAIL response on a badly signed domain name cause the user to repeat the query to a resolver that did not perform DNSSEC validation)

- Users who exclusively used non-validating resolvers

What we saw



Did not attempt to fetch DNSSEC RRs

DNSSEC-validating

Mixed DNSSEC-validating

If your resolver validates DNS responses…

- Then the resolver will need to fetch the DNSKEY and DS RRs for the zone, and recurse upward to the root
- If these RRs are not cached, then at a minimum there are at least two additional DNS queries that are performed as part of the validation process

If your resolver validates DNS responses…

More queries, longer resolution time

Dual Stack client - query for unsigned domain name

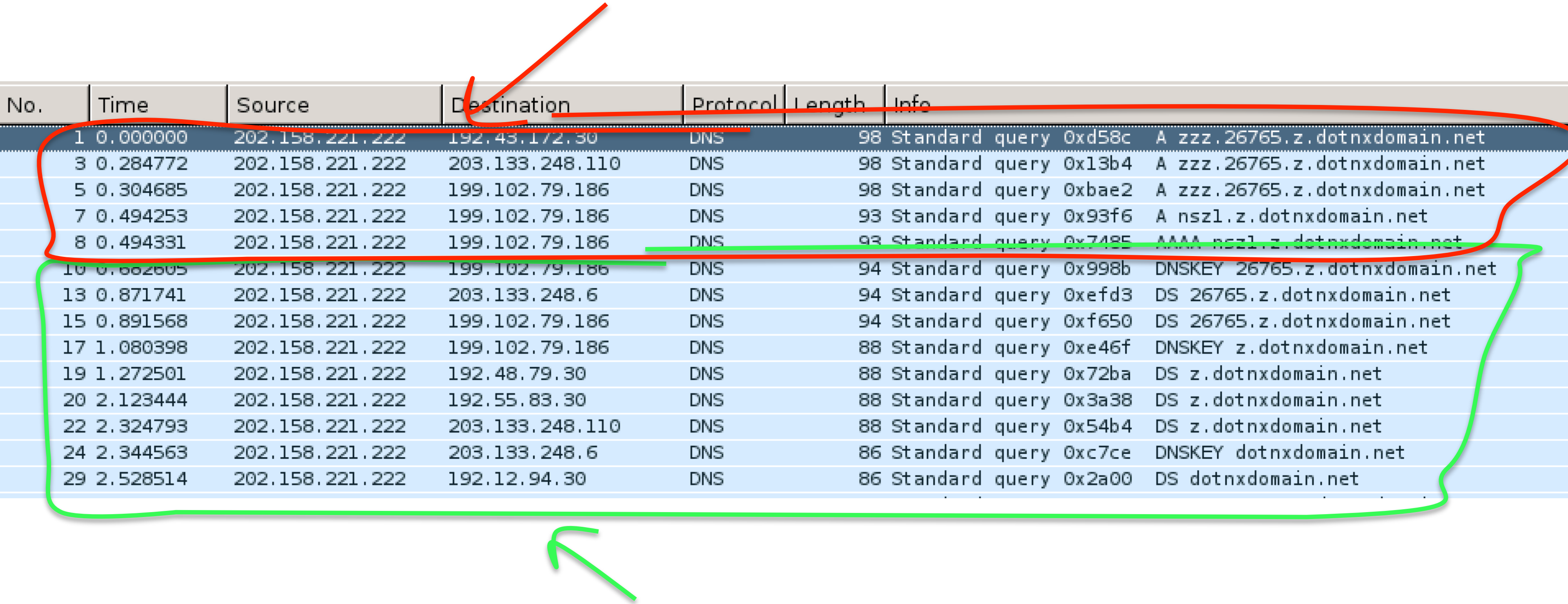
```
20:36:40.288 query: unsigned.example.com IN AAAA -ED (199.102.79.186)
20:36:41.028 query: unsigned.example.com IN A    -ED (199.102.79.186)
```

Dual Stack client - query for signed domain name

```
20:36:41.749 query: signed.example.com IN A      -ED (199.102.79.186)
20:36:41.758 query: signed.example.com IN AAAA   -ED (199.102.79.186)
20:36:41.876 query: signed.example.com IN DS     -ED (199.102.79.186)
20:36:41.993 query: signed.example.com IN DNSKEY -ED (199.102.79.186)
```

Validation Time

Validation - DNS Queries

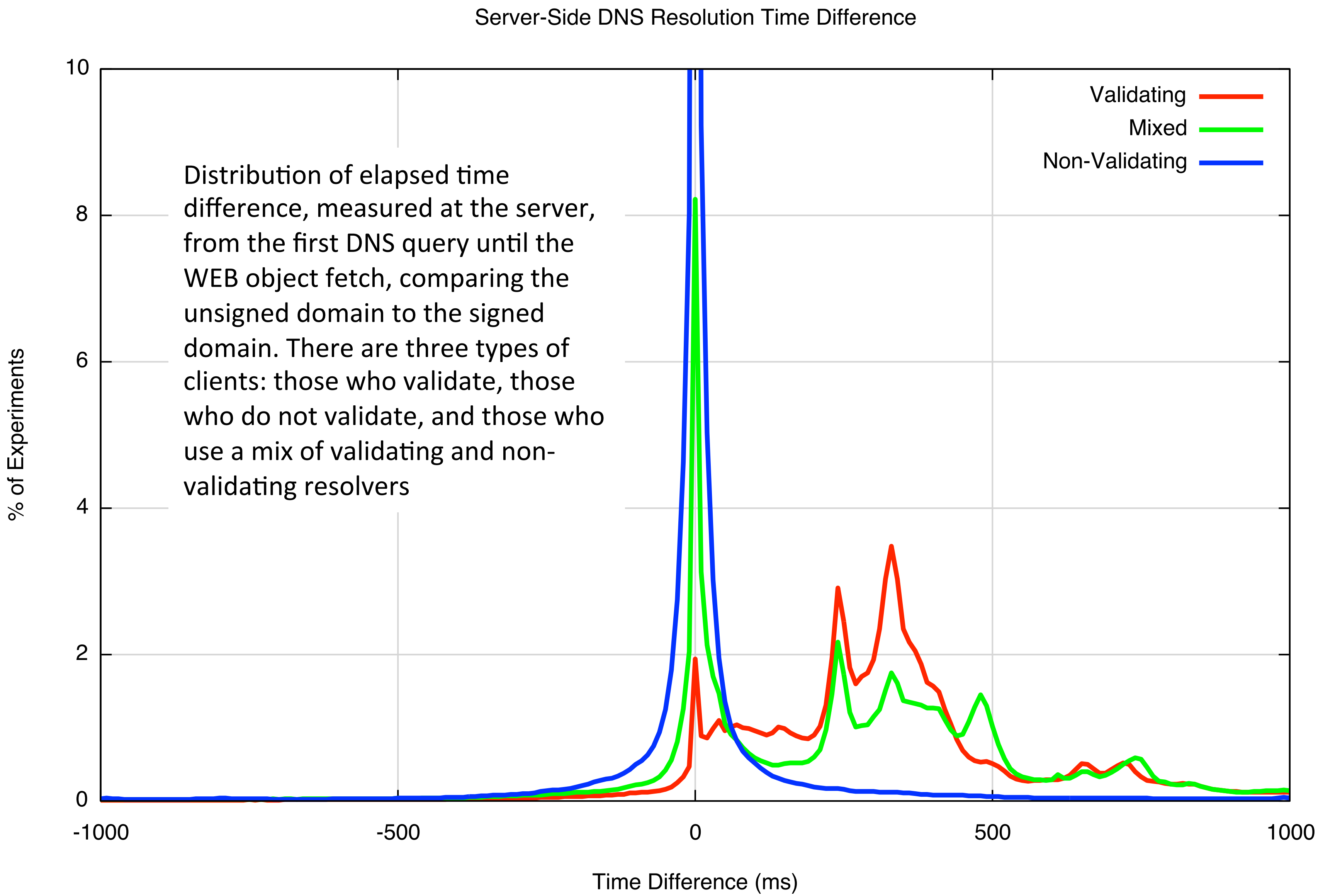


```
No.  Time      Source           Destination      Protocol Length Info
   1 0.000000  202.158.221.222  192.43.172.30    DNS        98 Standard query 0xd58c  A zzz.26765.z.dotnxdomain.net
   3 0.284772  202.158.221.222  203.133.248.110  DNS        98 Standard query 0x13b4  A zzz.26765.z.dotnxdomain.net
   5 0.304685  202.158.221.222  199.102.79.186   DNS        98 Standard query 0xbae2  A zzz.26765.z.dotnxdomain.net
   7 0.494253  202.158.221.222  199.102.79.186   DNS        93 Standard query 0x93f6  A nsz1.z.dotnxdomain.net
   8 0.494331  202.158.221.222  199.102.79.186   DNS        93 Standard query 0x7485  AAAA nsz1.z.dotnxdomain.net
  10 0.682605  202.158.221.222  199.102.79.186   DNS        94 Standard query 0x998b  DNSKEY 26765.z.dotnxdomain.net
  13 0.871741  202.158.221.222  203.133.248.6    DNS        94 Standard query 0xefd3  DS 26765.z.dotnxdomain.net
  15 0.891568  202.158.221.222  199.102.79.186   DNS        94 Standard query 0xf650  DS 26765.z.dotnxdomain.net
  17 1.080398  202.158.221.222  199.102.79.186   DNS        88 Standard query 0xe46f  DNSKEY z.dotnxdomain.net
  19 1.272501  202.158.221.222  192.48.79.30     DNS        88 Standard query 0x72ba  DS z.dotnxdomain.net
  20 2.123444  202.158.221.222  192.55.83.30     DNS        88 Standard query 0x3a38  DS z.dotnxdomain.net
  22 2.324793  202.158.221.222  203.133.248.110  DNS        88 Standard query 0x54b4  DS z.dotnxdomain.net
  24 2.344563  202.158.221.222  203.133.248.6    DNS        86 Standard query 0xc7ce  DNSKEY dotnxdomain.net
  29 2.528514  202.158.221.222  192.12.94.30     DNS        86 Standard query 0x2a00  DS dotnxdomain.net
```

DNS queries

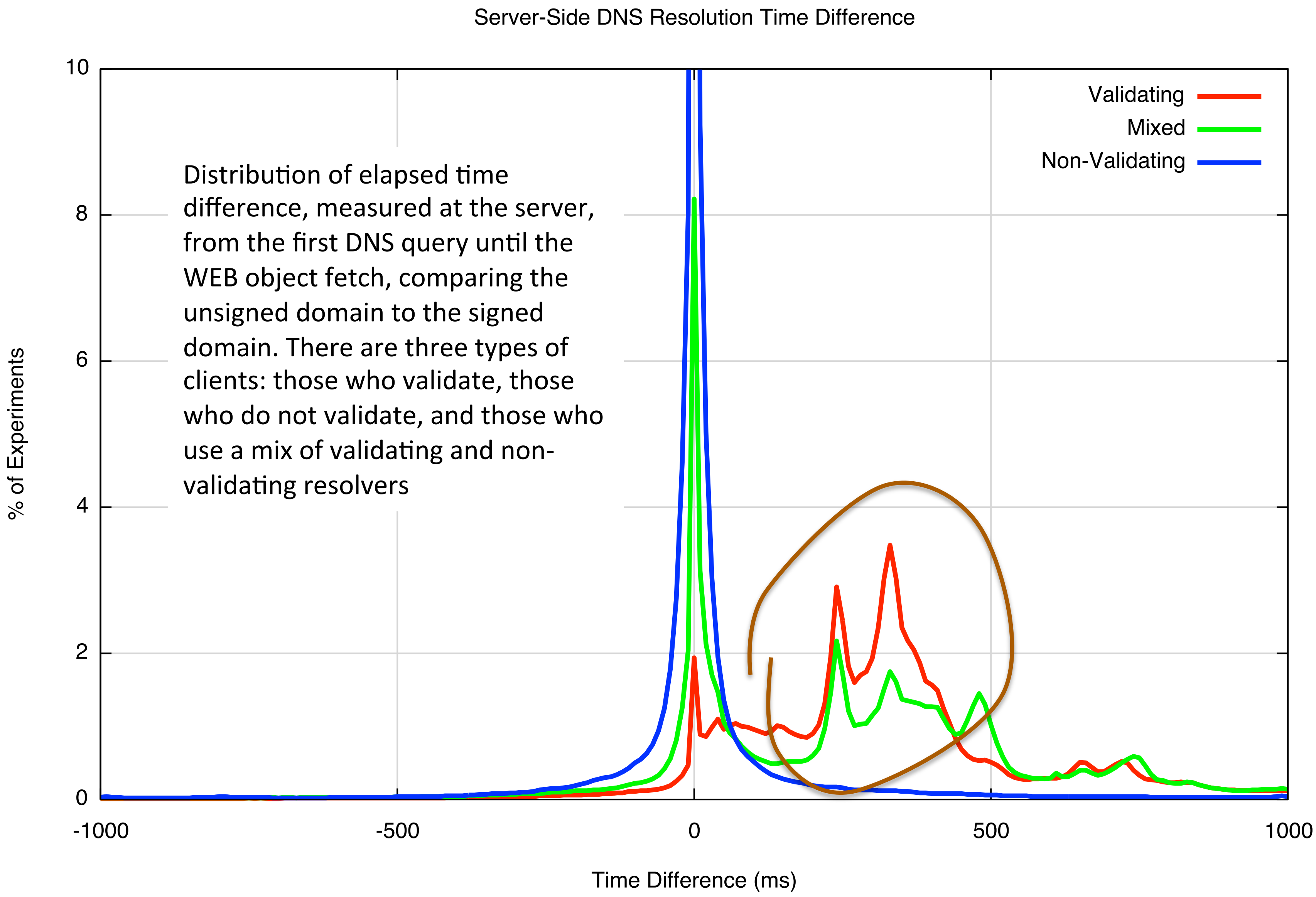
Validation Queries

Time Cost



Distribution of elapsed time difference, measured at the server, from the first DNS query until the WEB object fetch, comparing the unsigned domain to the signed domain. There are three types of clients: those who validate, those who do not validate, and those who use a mix of validating and non-validating resolvers

Time Cost



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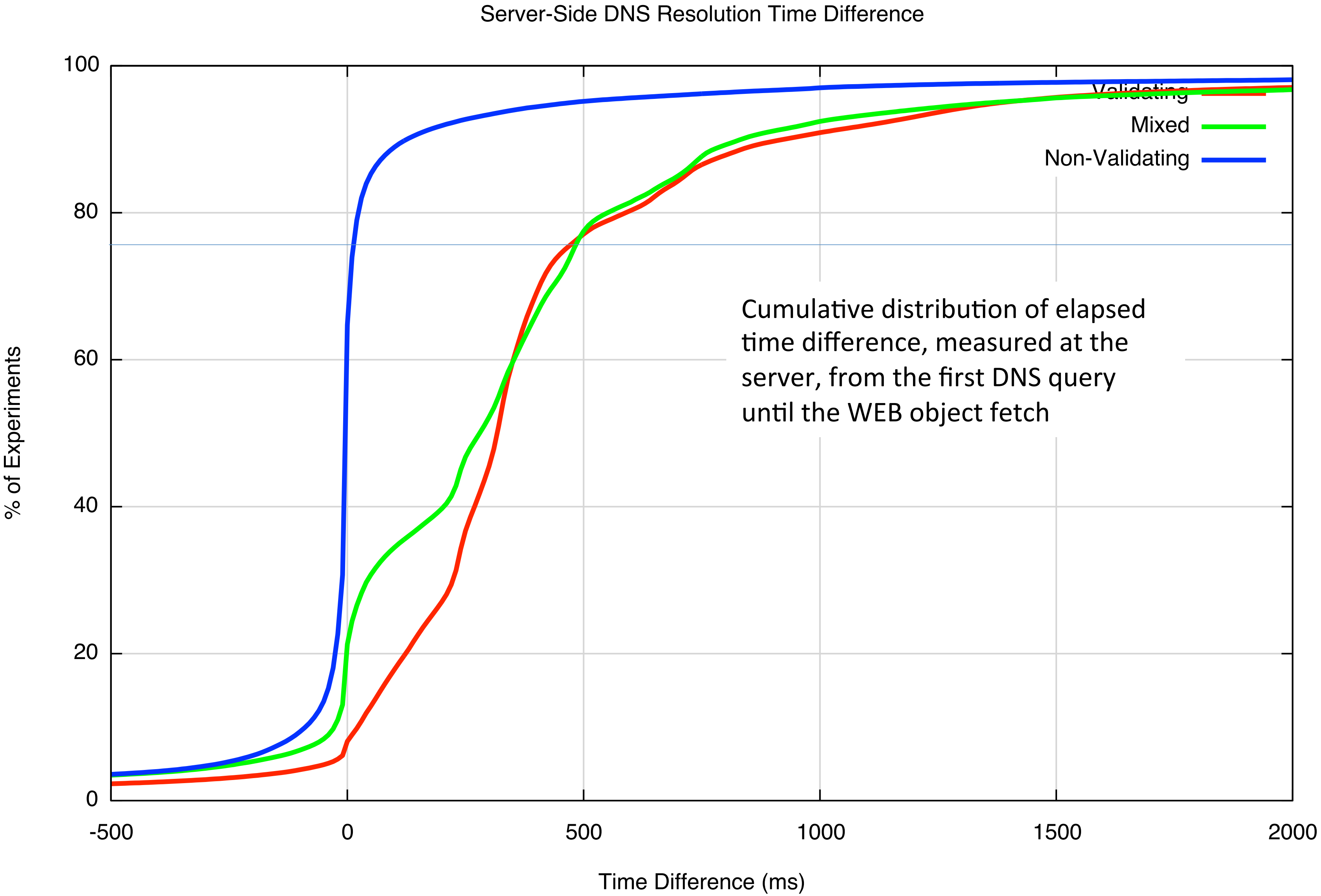
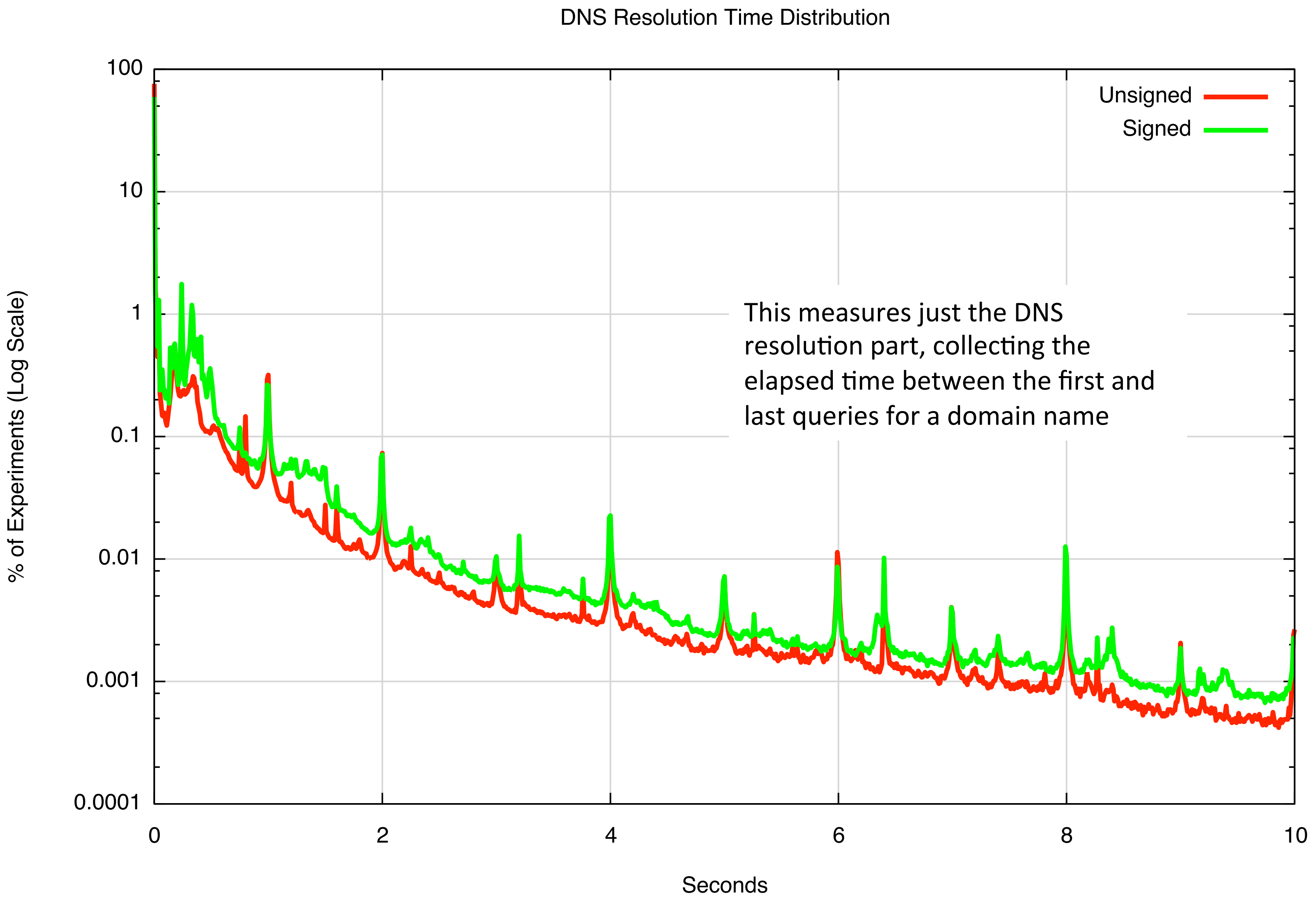
Time Cost



Cumulative distribution of elapsed time difference, measured at the server, from the first DNS query until the WEB object fetch

DNS Resolution Time



This measures just the DNS resolution part, collecting the elapsed time between the first and last queries for a domain name

Unsigned/Non-Validating vs Signed/Validating

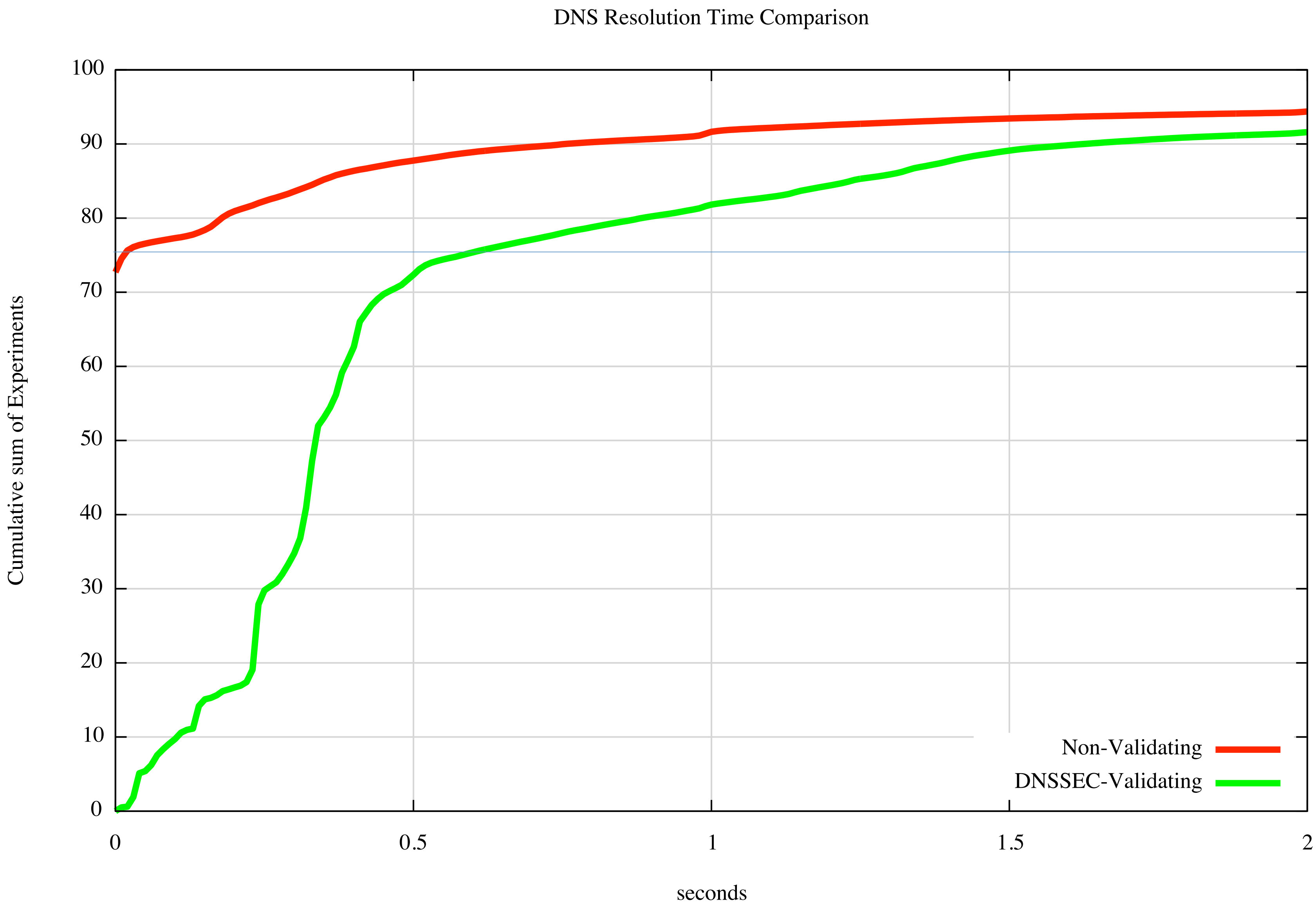
- The previous distribution is skewed by the observation that 80% of the trigger condition that caused queries for the validly signed name were initiated on hosts who exclusively used non-validating resolvers
- Can we remove that factor from the data?

- Let’s try a slightly different comparison, and compare the total DNS query time between
  – Non-validating users querying an unsigned name

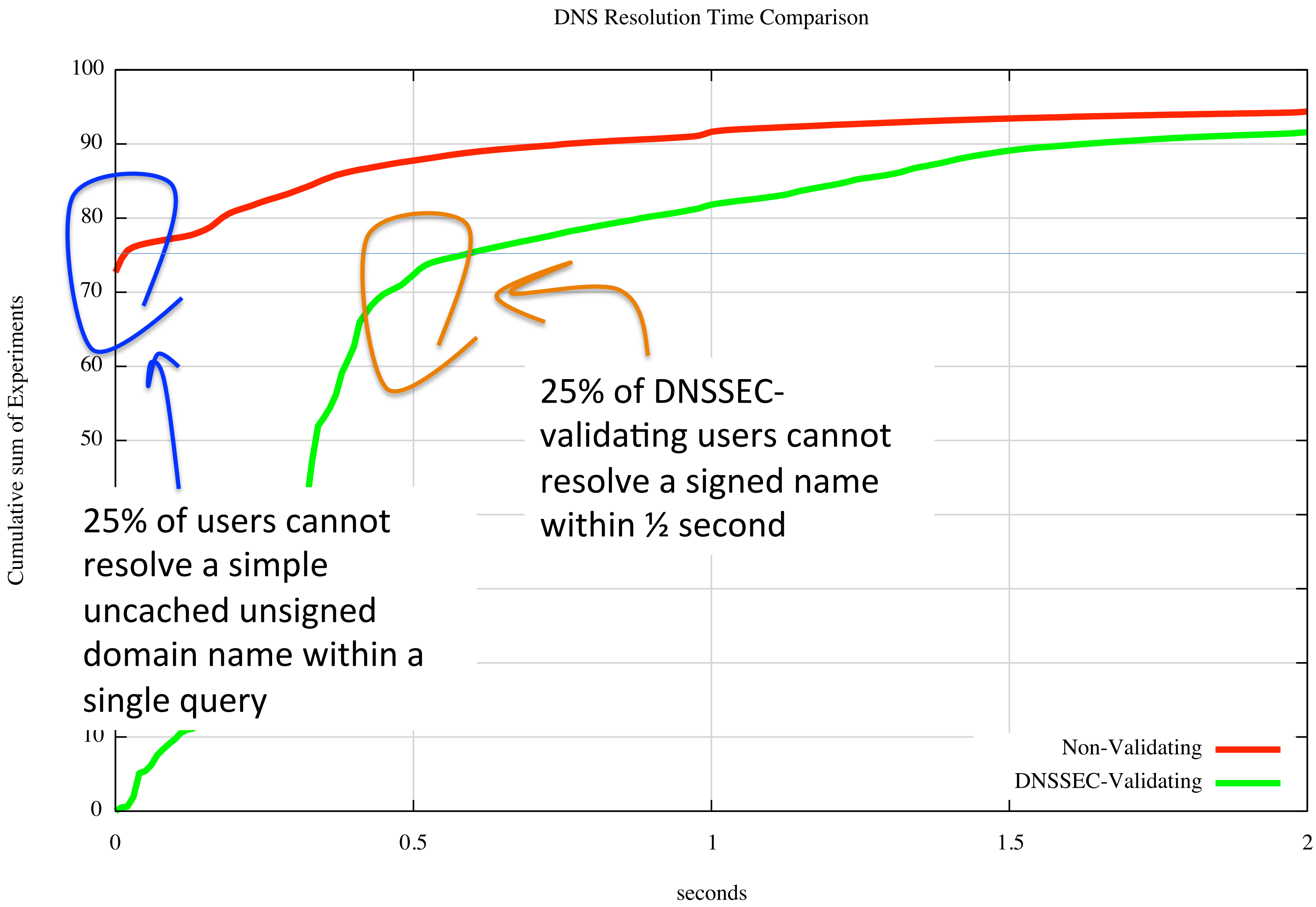
  and

  – Validating users querying for a signed name

like-to-like: unsigned vs signed



like-to-like: unsigned vs signed



25% of DNSSEC-validating users cannot resolve a signed name within ½ second

25% of users cannot resolve a simple uncached unsigned domain name within a single query

Validation Time

- When resolving a previously unseen domain name most clients will experience up to 500ms additional time spent in validation
  - This is a non-cached response - caching mitigates this considerably for commonly queried domain names

It could be faster…

- Most resolvers appear to perform the validation path check using serial fetches. Parallel fetches of the DNSSEC validation path RRs would improve this situation

Authoritative Server Measurements

- The following analysis attempts to answer the question:
  - What increase in queries and traffic should I expect to see if the unsigned zone I currently serve is DNSSEC signed, and everyone is using DNSSEC validating resolvers?

If you serve a signed Domain Name:

You will generate larger responses:

Dual Stack client – query for unsigned domain name, no EDNS0

Query: 117 Bytes
Response: 168 bytes

Dual Stack client – query for signed domain name, EDNS0

Query: (A) 127 Bytes
Response: (A) 1168 bytes

Query: (DS) 80 Bytes
Response: (DS) 341 bytes

Query: (DNSKEY) 80 Bytes
Response: (DNSKEY) 742 bytes

Total: Query 287 bytes
Response: 2,251 bytes

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The DS query is directed to the parent zone, so you may or may not see this query at the authoritative server. In our case we are serving the parent zone as well

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You will generate larger responses:

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Query: 117 Bytes
Response: 168 bytes

Dual Stack client – query for signed domain name, EDNS0

Query: (A) 127 Bytes
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Query: (DS) 80 Bytes
Response: (DS) 341 bytes

Query: (DNSKEY) 80 Bytes
Response: (DNSKEY) 742 bytes

Total: Query 287 bytes
Response: 2,251 bytes

That's an increase of 13x in terms of outbound traffic volume

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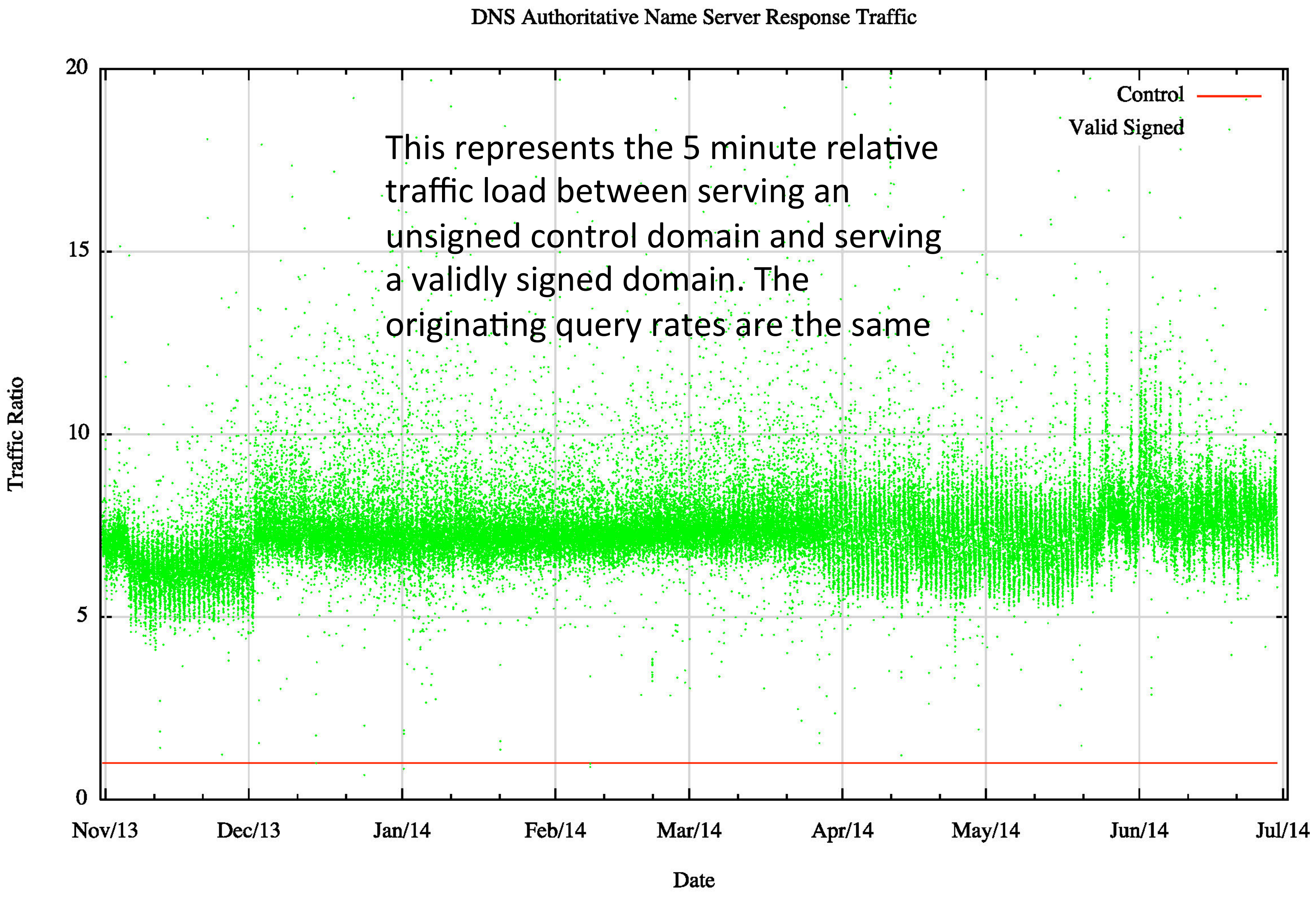
Server Traffic Load



This represents the 5 minute relative traffic load between serving an unsigned control domain and serving a validly signed domain. The originating query rates are the same

Server Traffic Load

- Serving a DNSSEC-signed name appears to generate 7.5x the traffic load, as compared to serving an unsigned name
  - But 20% of clients are performing validation, and hence 20% of the clients generate 13x more traffic
  - The theory would expect to see a 3.4x increase in traffic.
  - Why is this observed result double the prediction?

Server Traffic Load

- Use of the EDNS DNSSEC-OK flag is far higher than the level of DNSSEC validation
  - 84% of queries have the EDNS0 DNSSEC-OK flag set
  - And this query generates a response of 1168 bytes (i.e. 7x the size of a null EDNS response)
  - So 64% of clients set EDNS0 DNSSEC-OK, and 20% of clients also ask for DS and DNSKEY RRs
  - The theory predicts that this would result in 7.25x the traffic over an unsigned domain
  - Which is (roughly) what we see

Server Traffic Load

- What is the traffic load difference between serving an unsigned zone and serving a signed zone if **every** client performed DNSSEC validation?
  - The difference from the current levels of DNSSEC traffic lies predominately in the additional DNSKEY and DS responses
  - You should expect approximately **15x** the traffic load for response traffic

Server Query Load

If you serve a signed Domain Name:

You'll receive 2-3 times as many queries:

```
Dual Stack client – query for unsigned domain name, no EDNS0

    Query: 117 Bytes
    Response: 168 bytes

Dual Stack client – query for signed domain name, EDNS0

    Query: (A) 127 Bytes
    Response: (A) 1168 bytes

    Query: (DS) 80 Bytes
    Response: (DS) 341 bytes

    Query: (DNSKEY) 80 Bytes
    Response: (DNSKEY) 742 bytes
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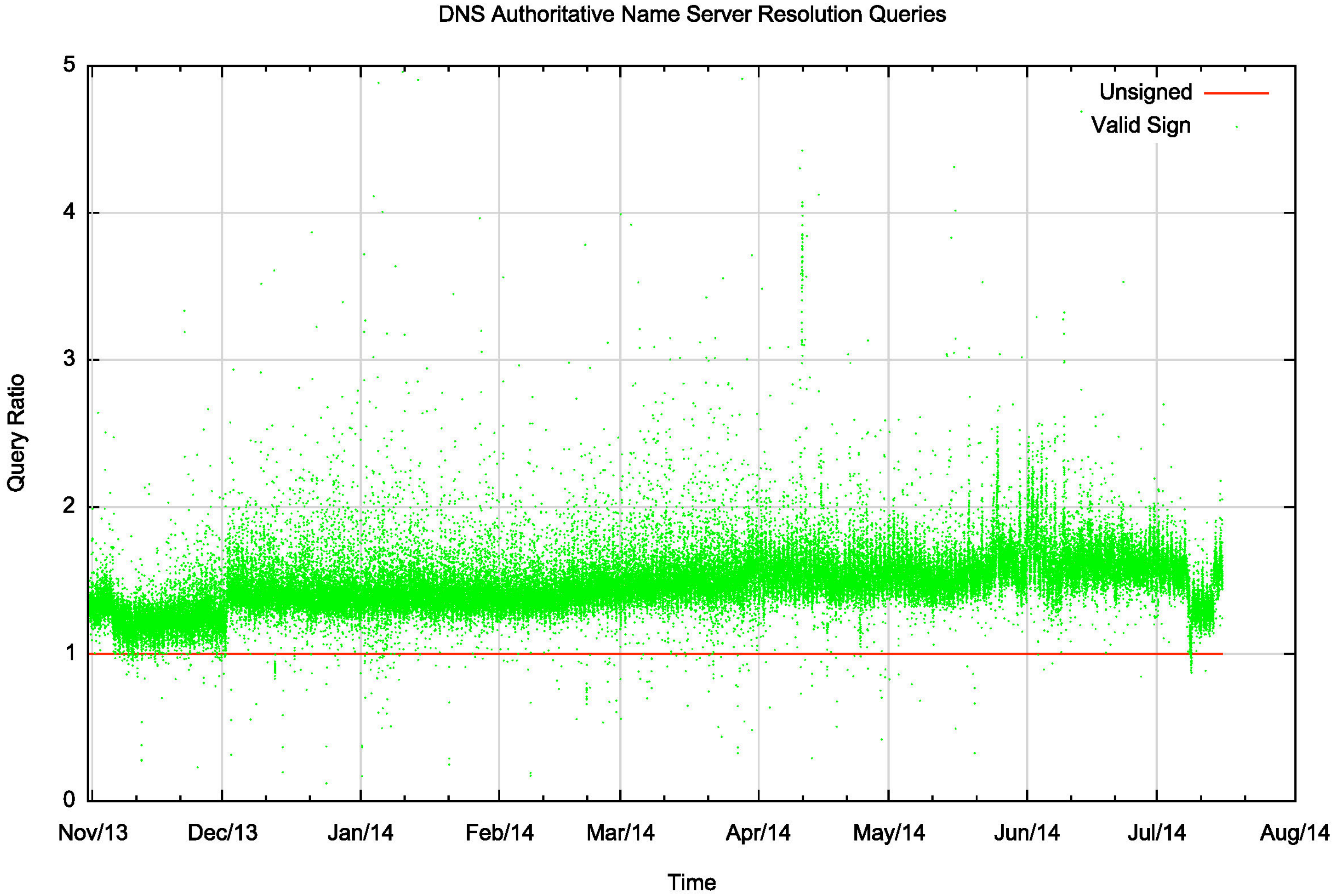
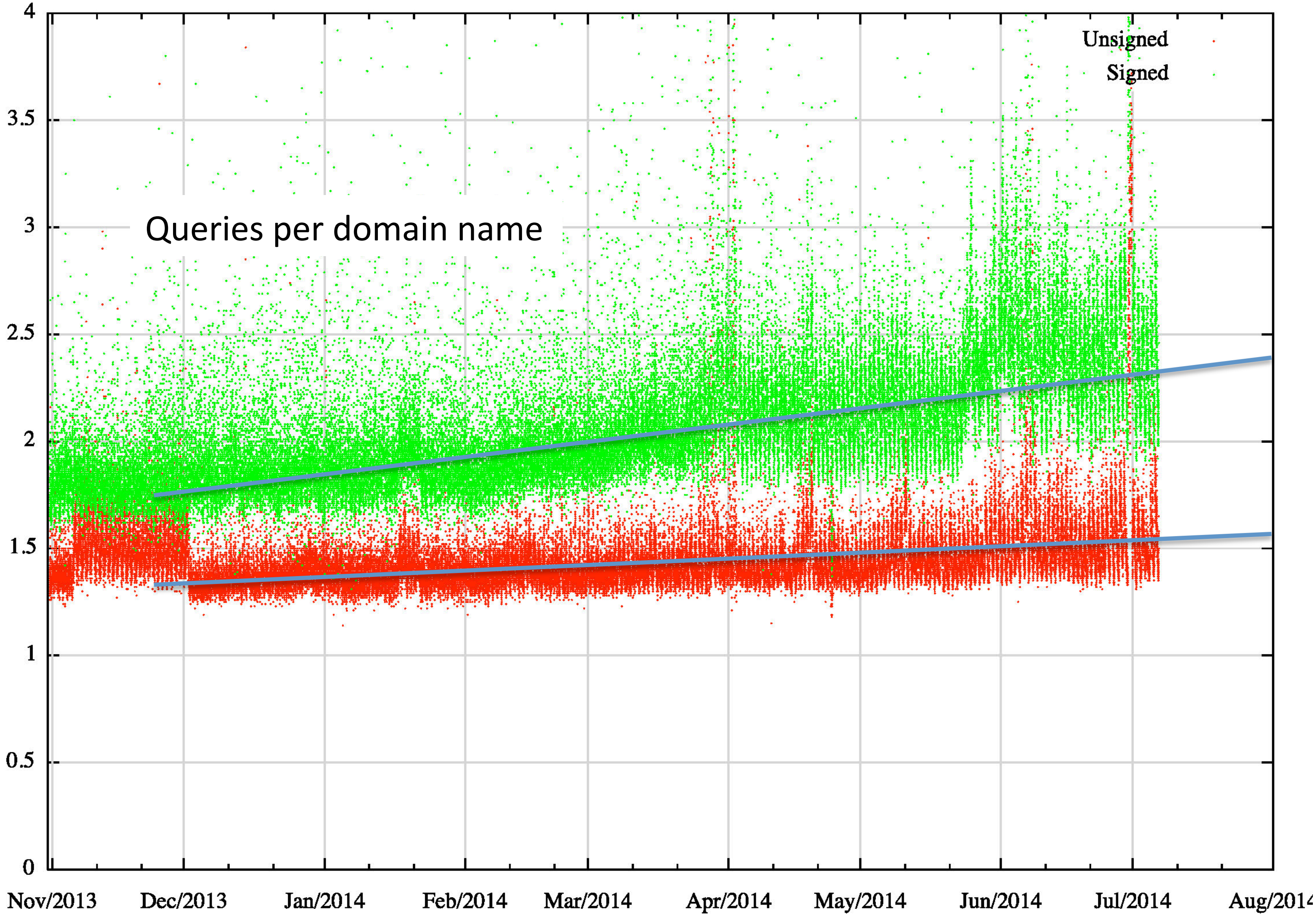


Server Query Load

- 20% of clients use validating resolvers, so the signed domain query load should be 1.4x that of the unsigned domain
- But we are observing an increase in the query load of 1.6x the unsigned domain.
- Why?

Repeat queries are rising



Query duplication

We are seeing a noticeable level of query duplication from anycast DNS server farms

The same query is being received from multiple slave resolvers within a short period of time

```
Domain              Time         Query source                Query

0a62f.z.example.com 02:05:31.998 74.125.41.81  port: 52065  q: DNSKEY?
0a62f.z.example.com 02:05:32.000 74.125.41.19  port: 53887  q: DNSKEY?
0a62f.z.example.com 02:05:32.005 74.125.41.146 port: 52189  q: DNSKEY?
0a62f.z.example.com 02:05:32.008 74.125.16.213 port: 42079  q: DNSKEY?
```

This is rising over time

Setting Expectations

For a validly signed zone an authoritative server may anticipate about **4x the query load** and **15x the traffic load** as compared to serving an equivalent unsigned zone, if everyone performed DNSSEC validation *

(* if you served the parent zone as well)

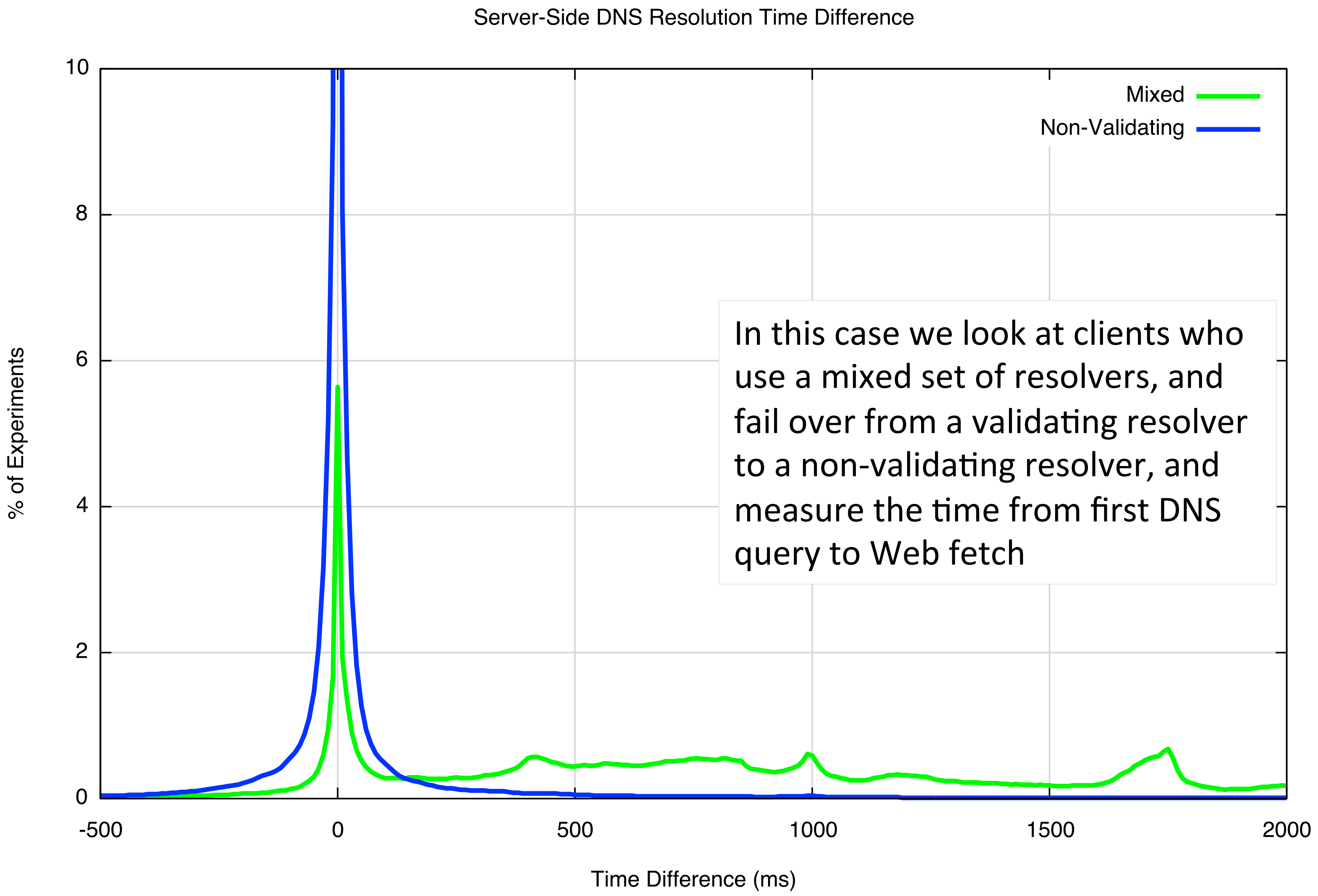
The Worst Case

But things get worse when the DNSSEC signatures are invalid:

- The response from a DNSSEC-validating recursive resolver upon DNSSEC validation failure is SERVFAIL, which prompts clients of this resolver to re-query using an alternative resolver
- The recursive resolver may re-query the name using alternative servers, on the assumption that the validation failure is due to a secondary server falling out of sync with the current zone data

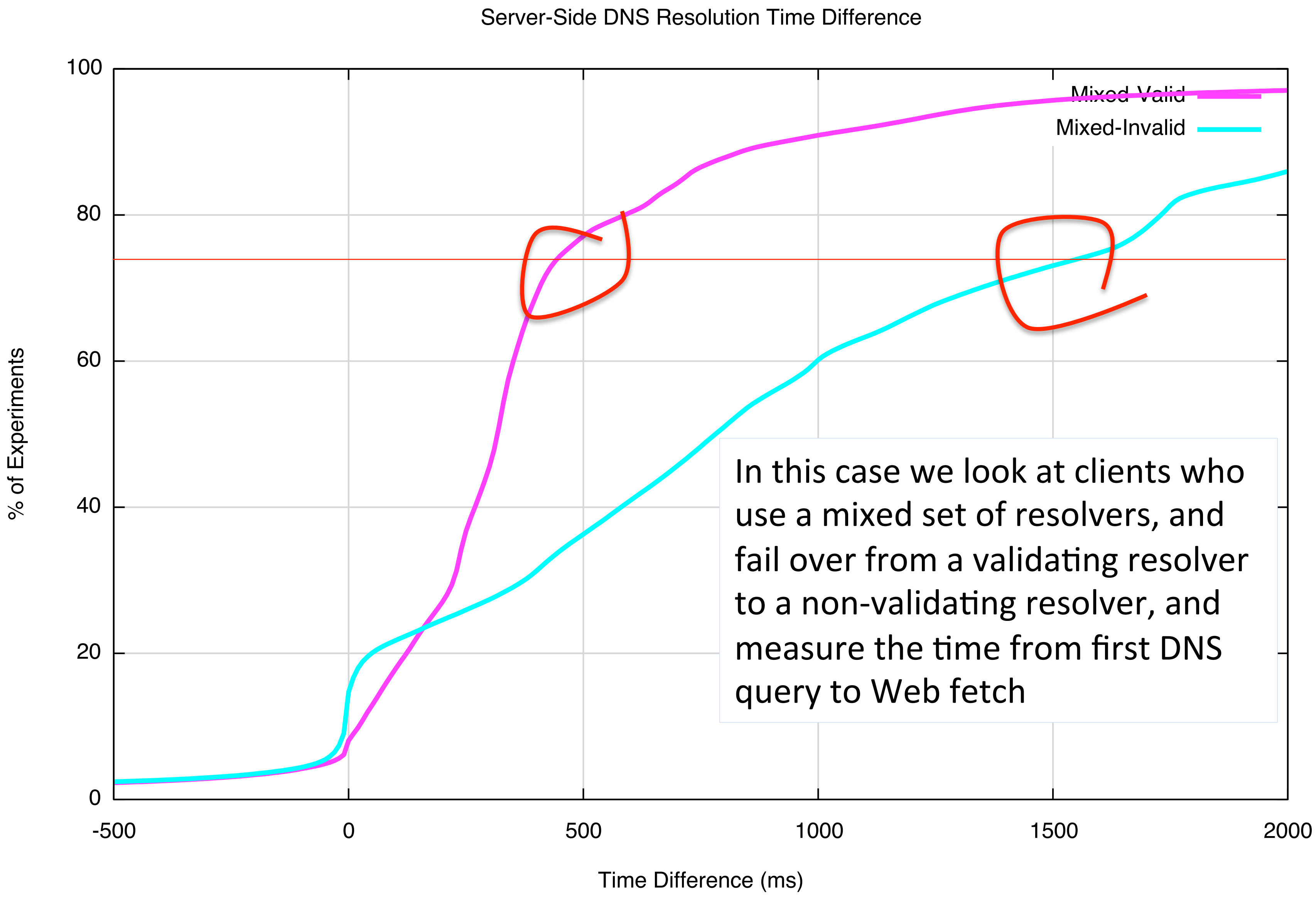
How much worse does it get?

DNS Resolution Time Difference



In this case we look at clients who use a mixed set of resolvers, and fail over from a validating resolver to a non-validating resolver, and measure the time from first DNS query to Web fetch

DNS Resolution Time Difference



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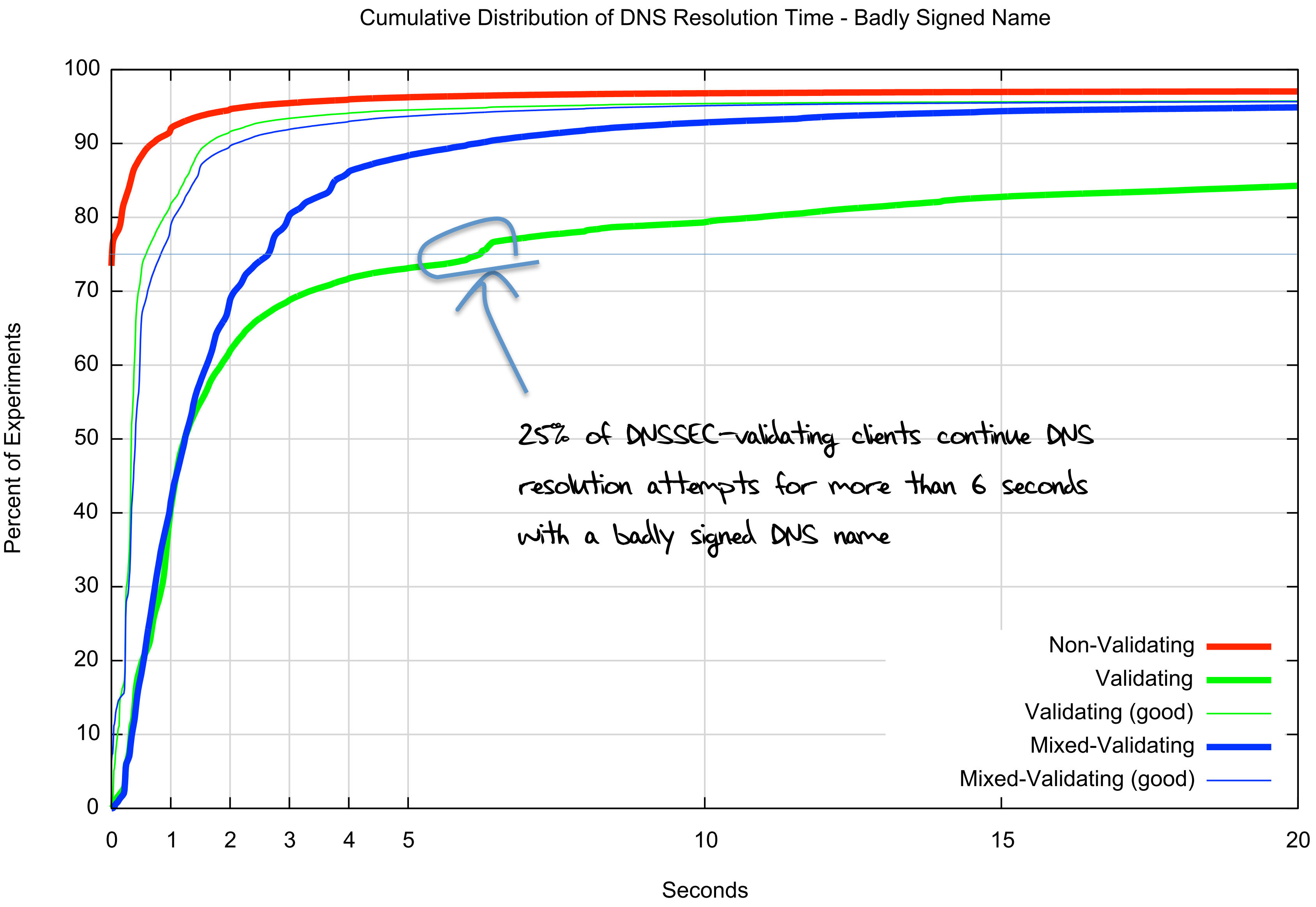
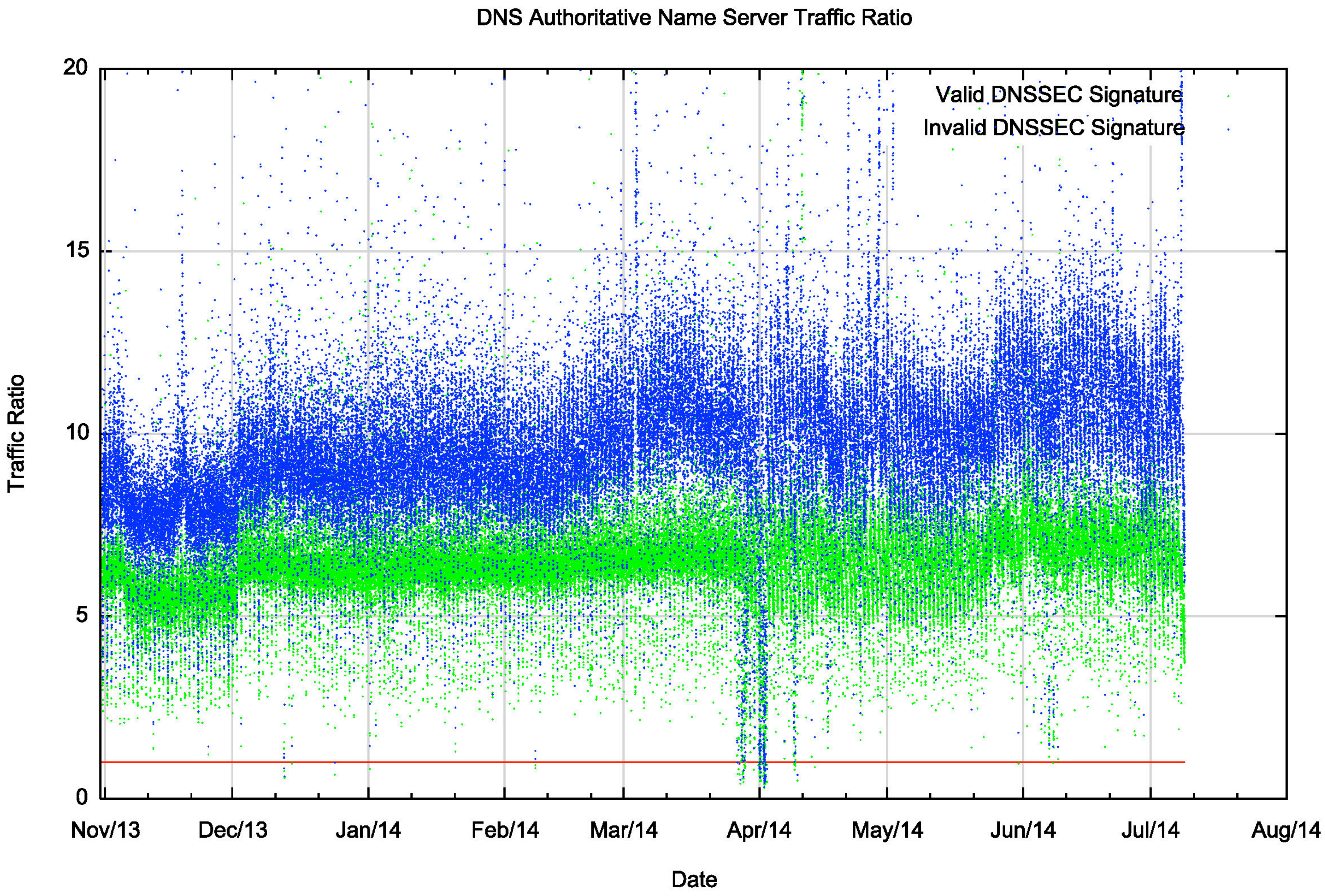
DNS Resolution Times



25% of DNSSEC-validating clients continue DNS resolution attempts for more than 6 seconds with a badly signed DNS name

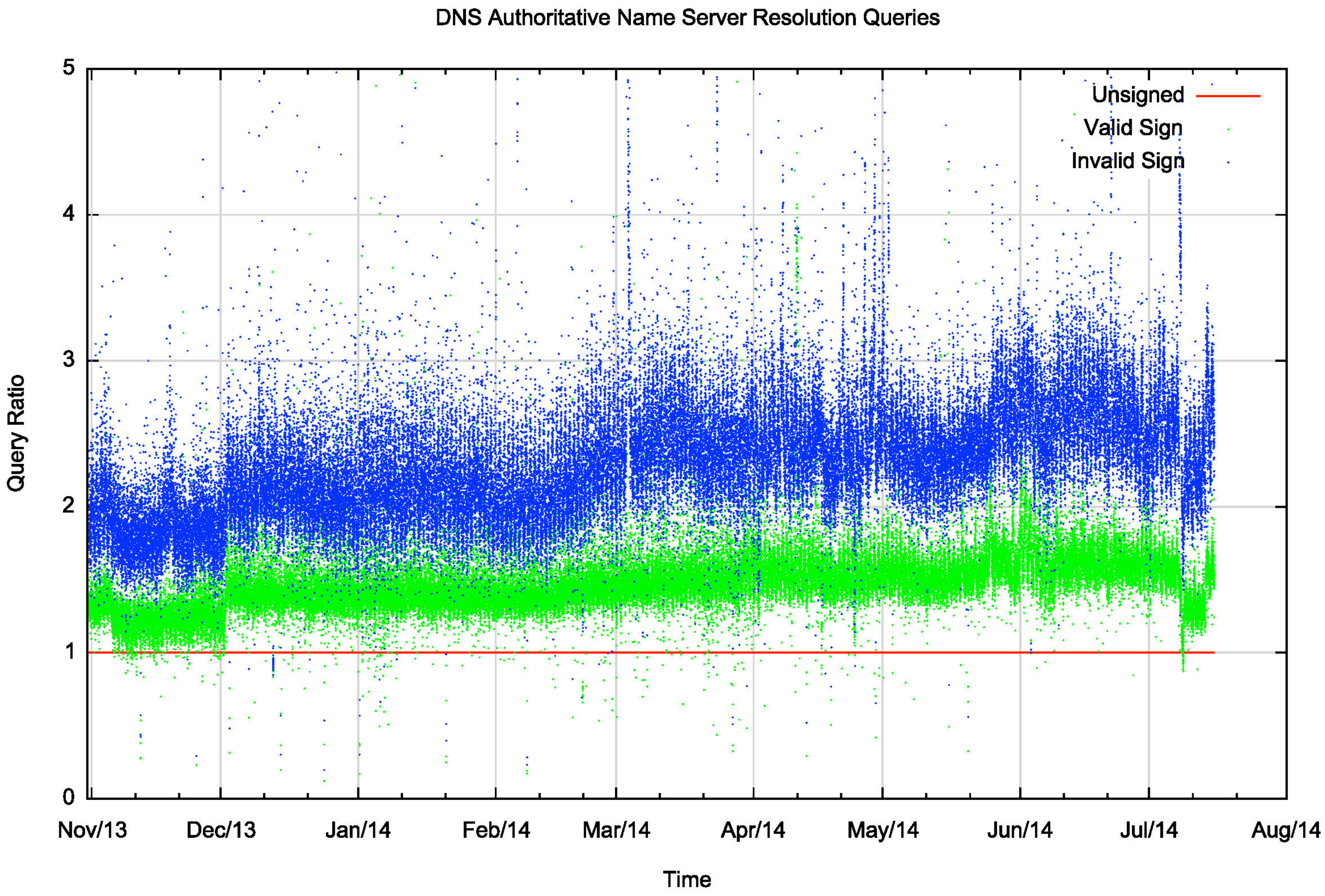
Relative Traffic Profile



Traffic Profile

- The traffic load for a badly signed domain name is around 10x the load for an unsigned domain
- If everyone were to use validating resolvers then the load profile would rise to around 26x the load of an unsigned domain

Query Profile



Setting Expectations

For a validly signed zone an authoritative server may anticipate about **4x the query load** and **15x the traffic load** as compared to serving an equivalent unsigned zone, if everyone performed DNSSEC validation *

But if you serve a badly signed zone, expect **8x the query load** and around **26x the traffic load** *

(* if you served the parent zone as well)