Cache Me If You Can: Effects of DNS Time-to-Live

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RIPE 79

Rotterdam, The Netherlands

2019-10-15

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Outline

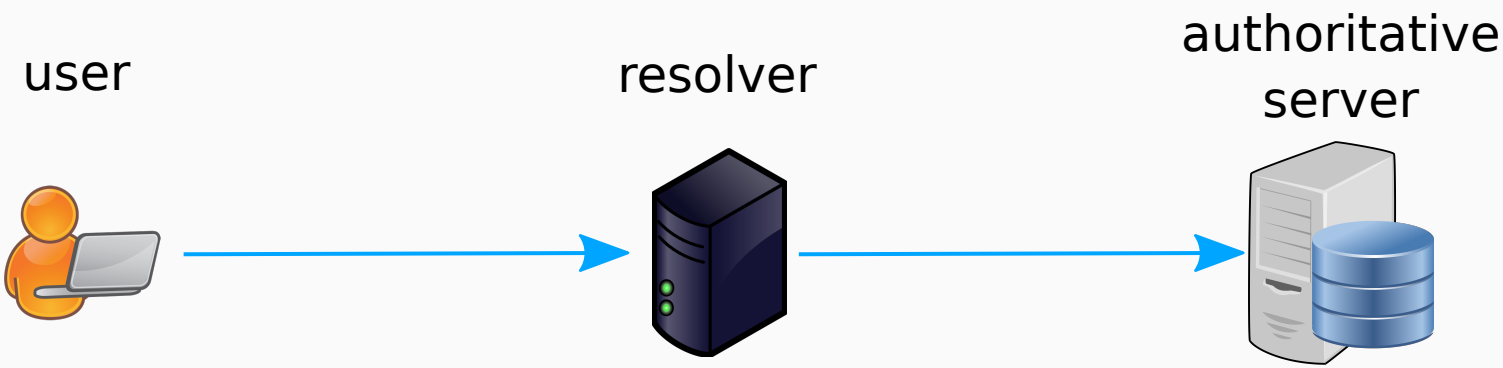
Our research on DNS over the last years

Our rearch on DNS security/stability:

- **Anycast and DDoS**: IMC 2016 [2]
- **Resolvers**: IMC 2017 [5]
- **Anycast Engineering**: IMC 2017 [1]
- **Caching and DDoS**: IMC 2018 [4]
- **Caching and TTL, and performance:** IMC 2019 [3]
  - (this paper)
  - IMC will be next week in Amsterdam

Introduction

The role of TTL



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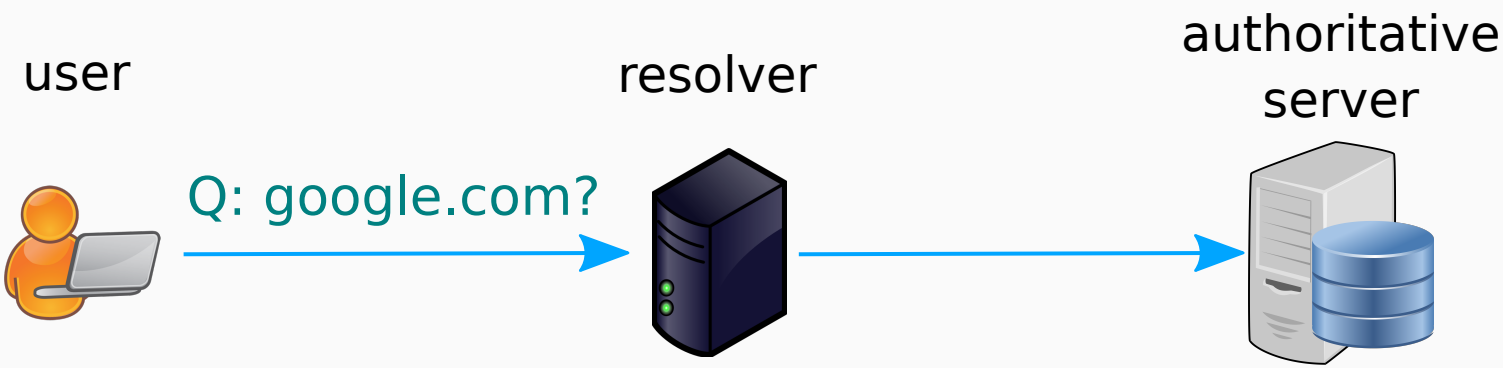

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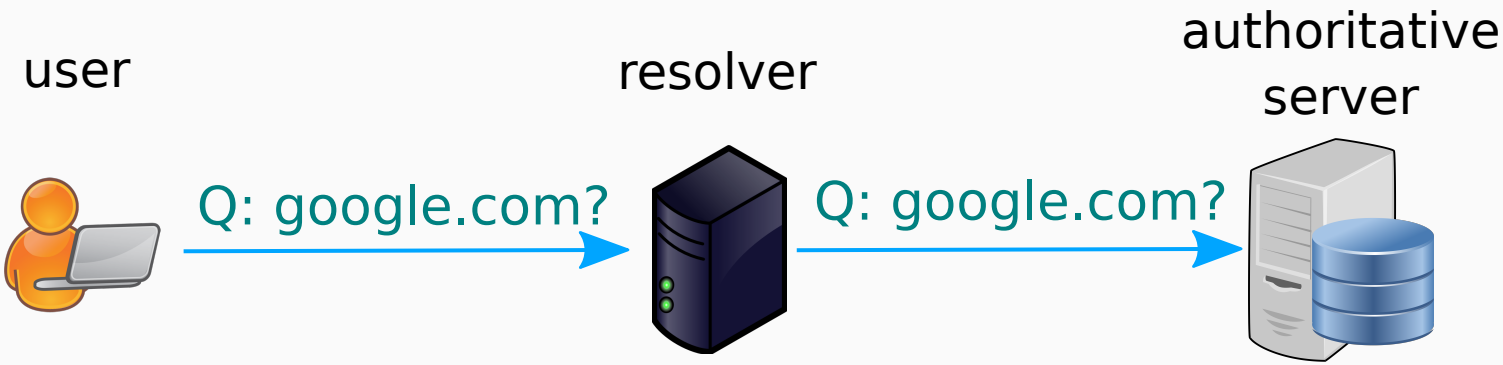

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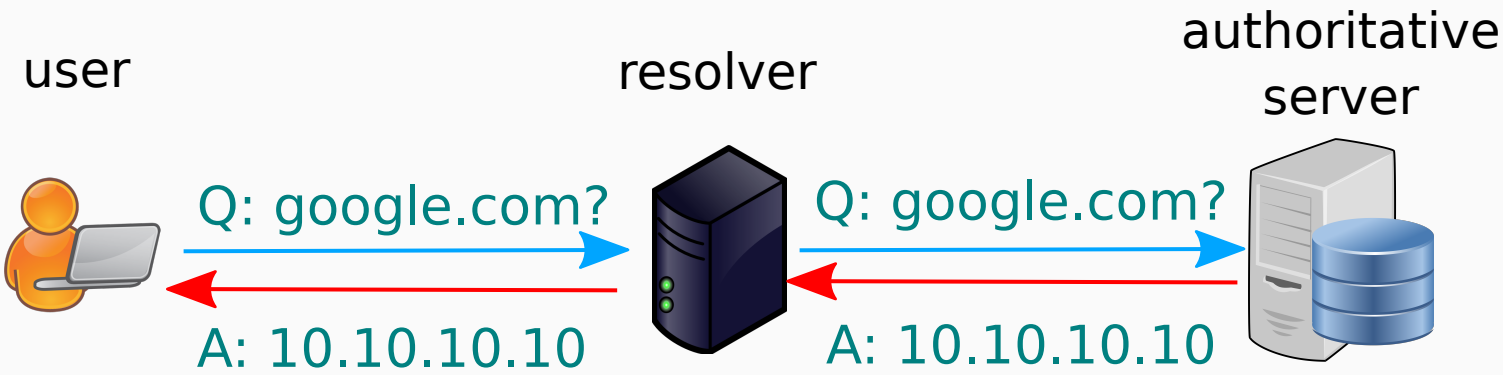

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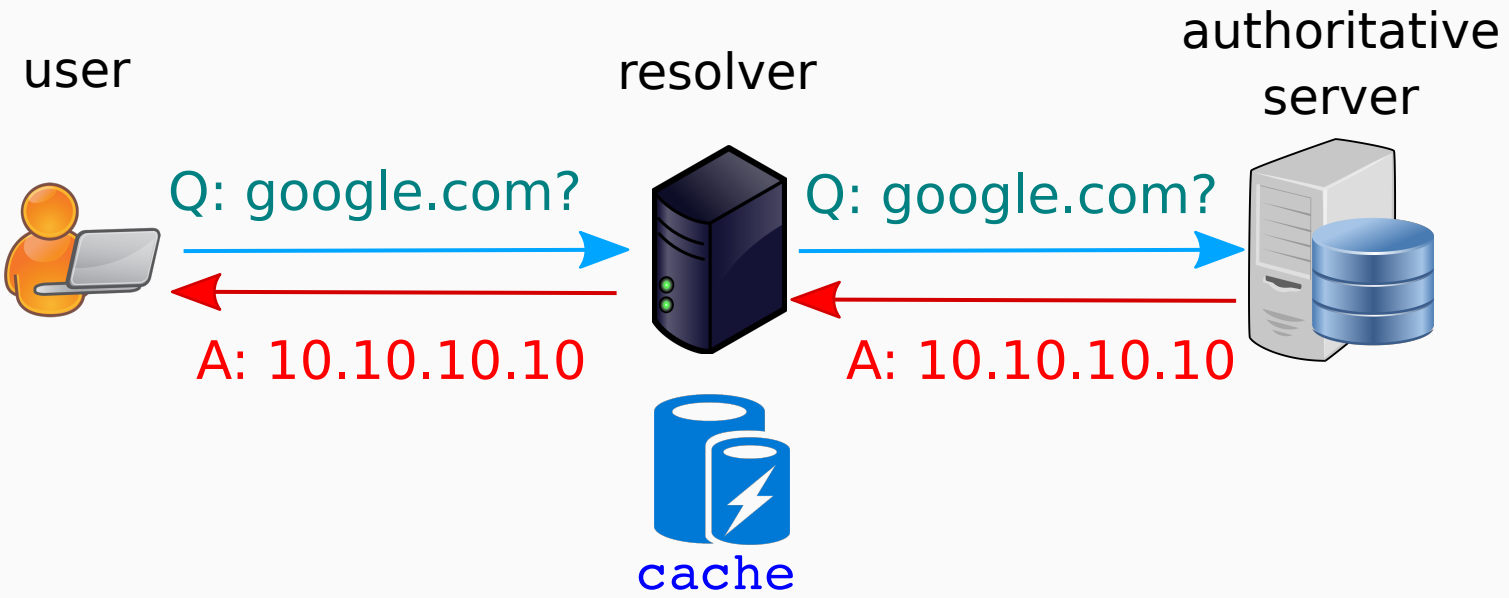

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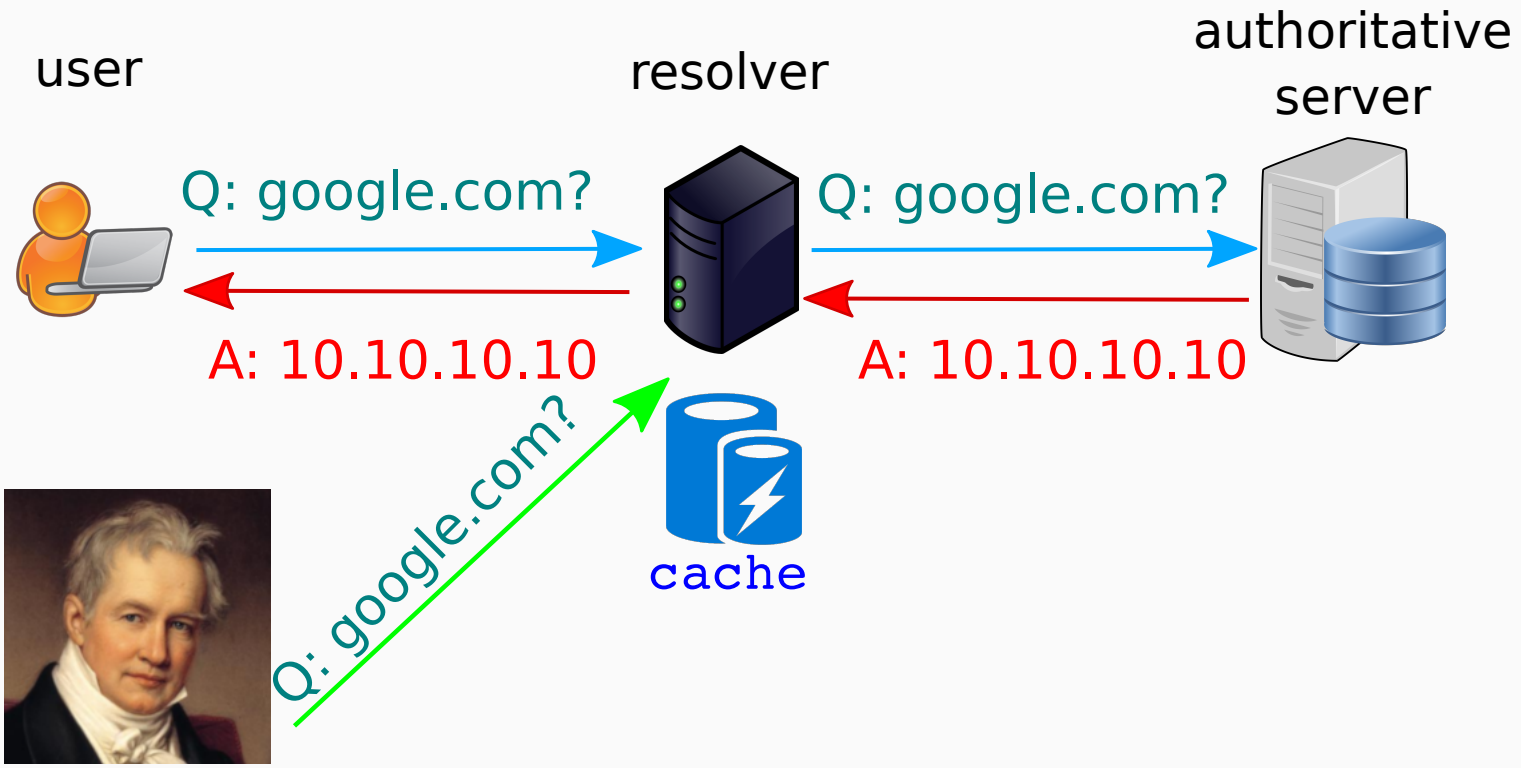

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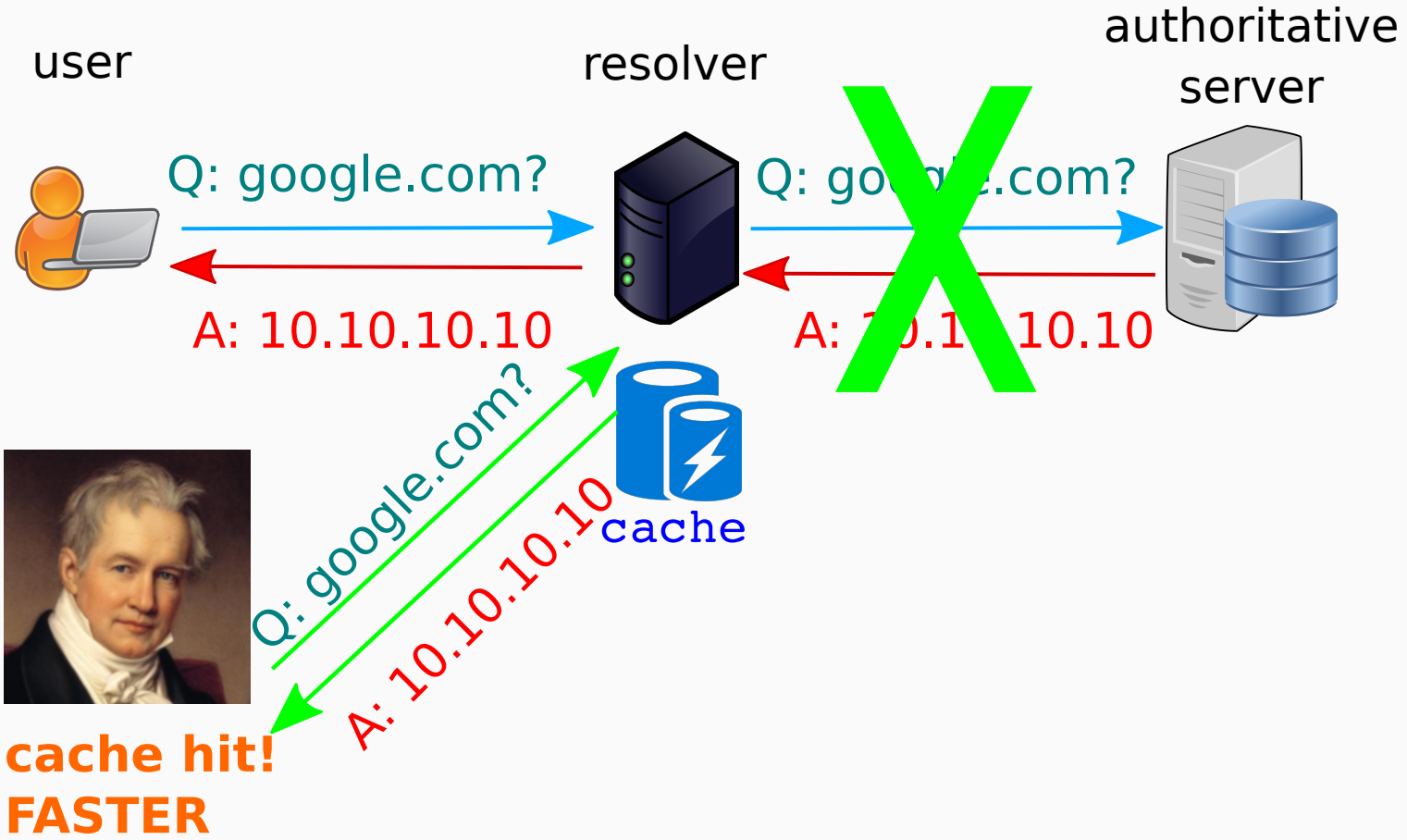

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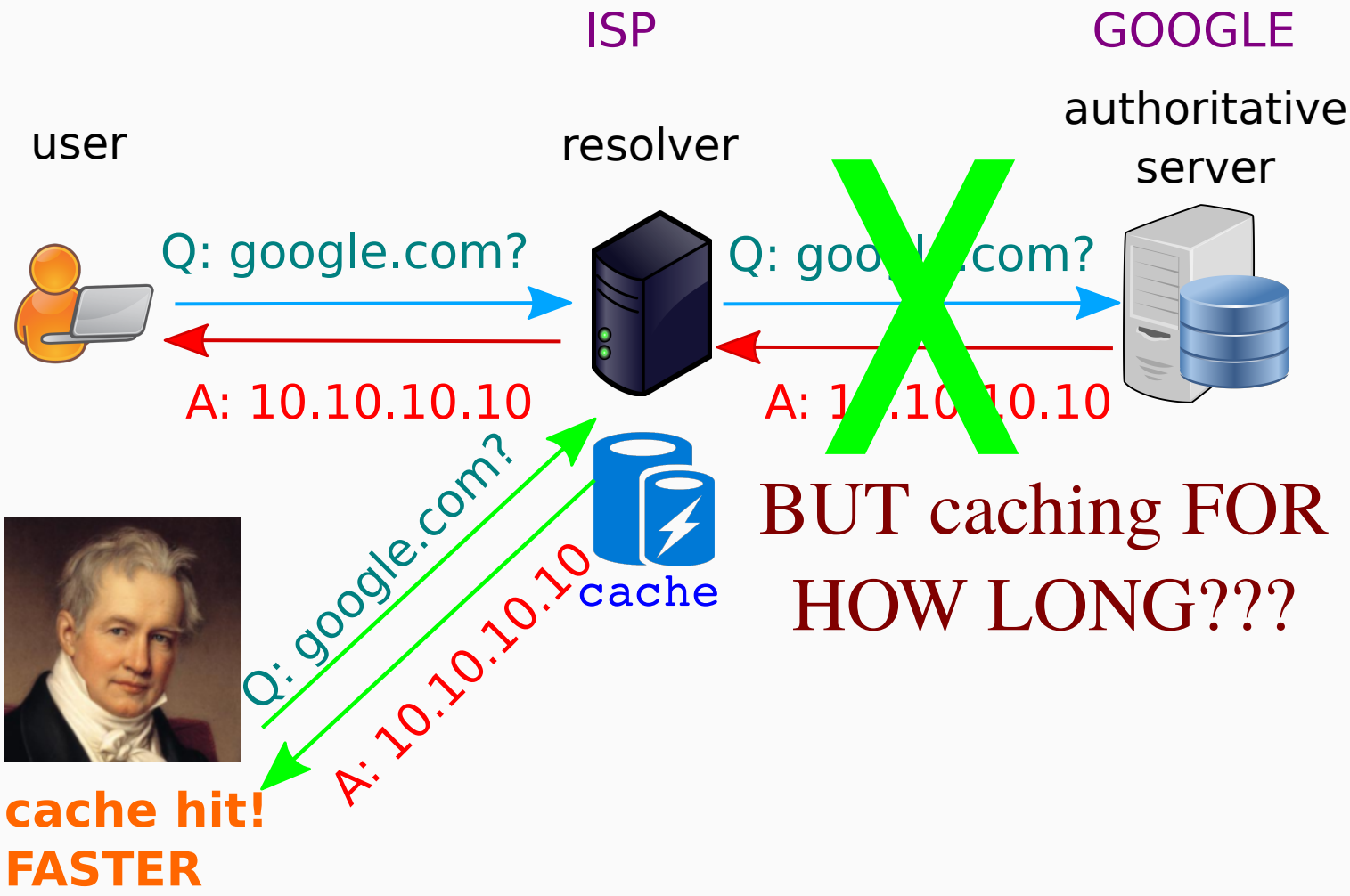

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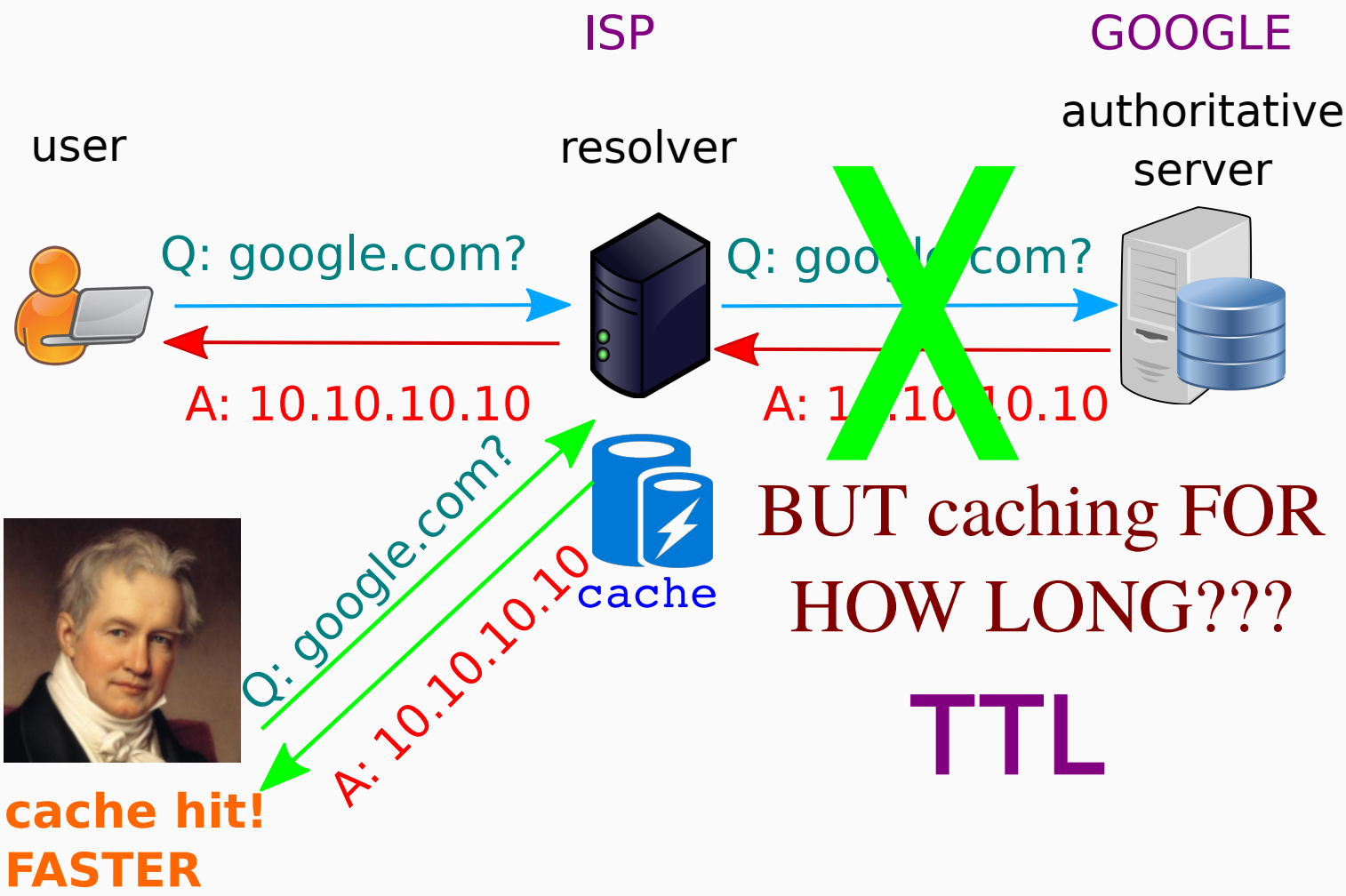

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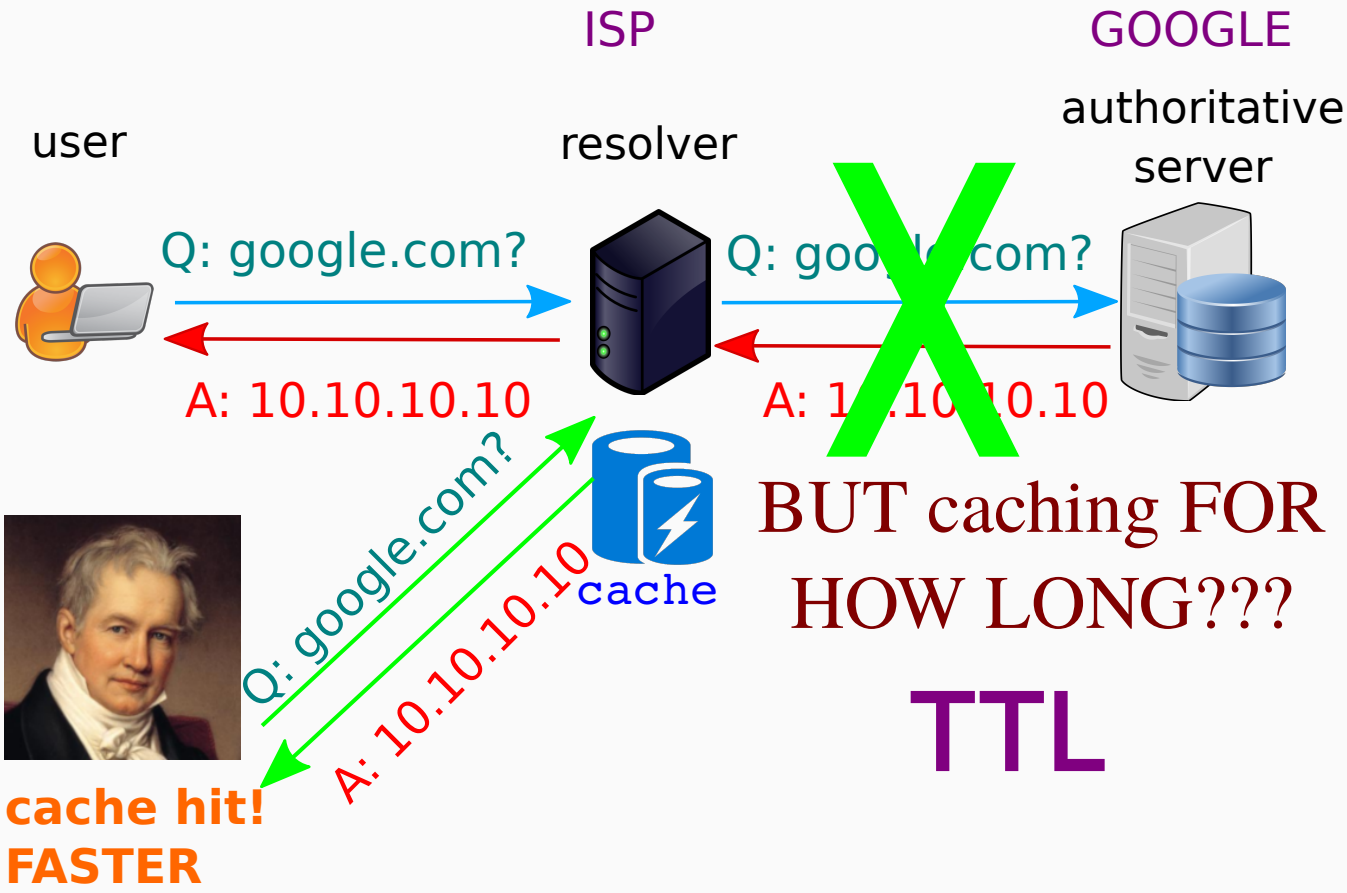
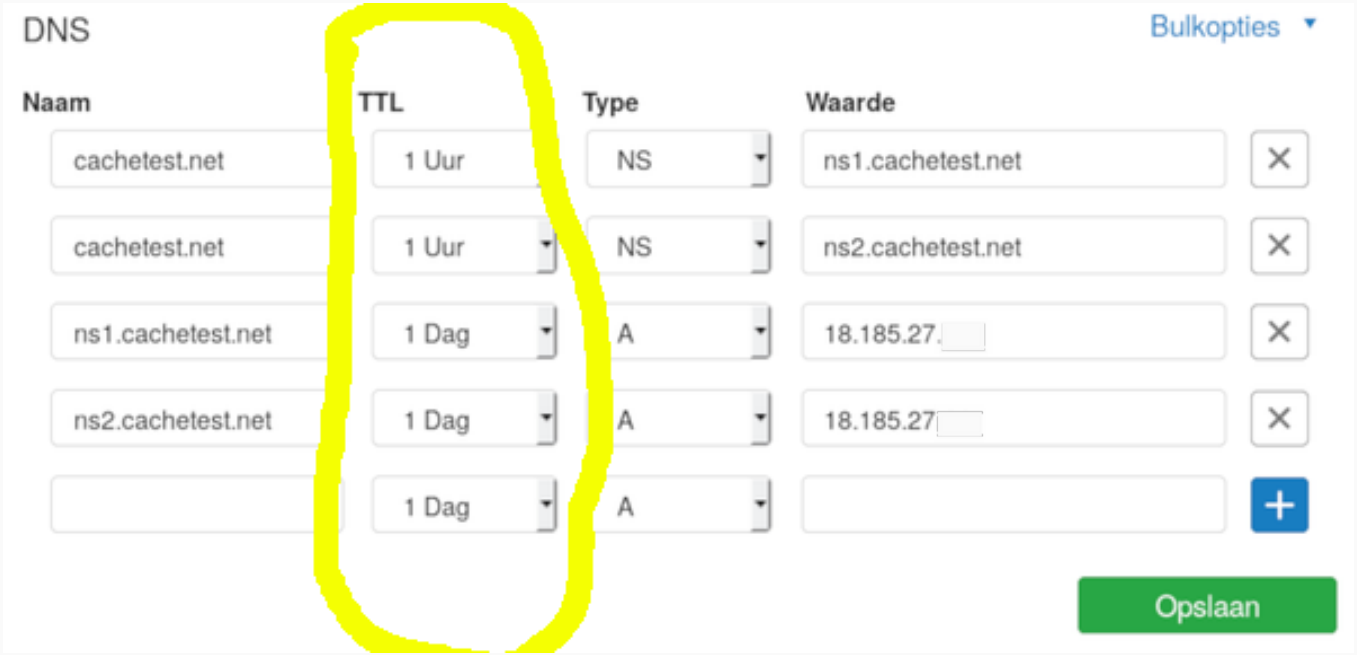


- **TTL controls caching**
  - auth servers SIGNAL to resolvers how long (TTL)
- Caching is VERY important for performance
  - improves user experience

And you must set TTLs

- Say you register `cachetest.net`



What TTL values are good?

Today it is unclear what an operator should do

- DNS OPs folks on TTLs: “**if it ain’t broke don’t fix it**”

We think we can help

Figure 1: DNS ops chaging TTLs. src: `trainworld.be`

Our contribution

Because of conflicting and under-explained TTL advice, we show:

1. the effective TTL comes from **multiple** places
    - Parent and Child authoritative servers
    - NS and A records (sometimes)
2. TTLs are unnecesssarily short
    - a. because sometimes multiple places $\rightarrow$ one is shorter and wins
    - or operators don't realize the cost
3. We show that longer TTLs are **MUCH** faster
4. Our results were adopted by 3 ccTLD for $\sim$**20ms median latency improvement; 171ms 75%ile**

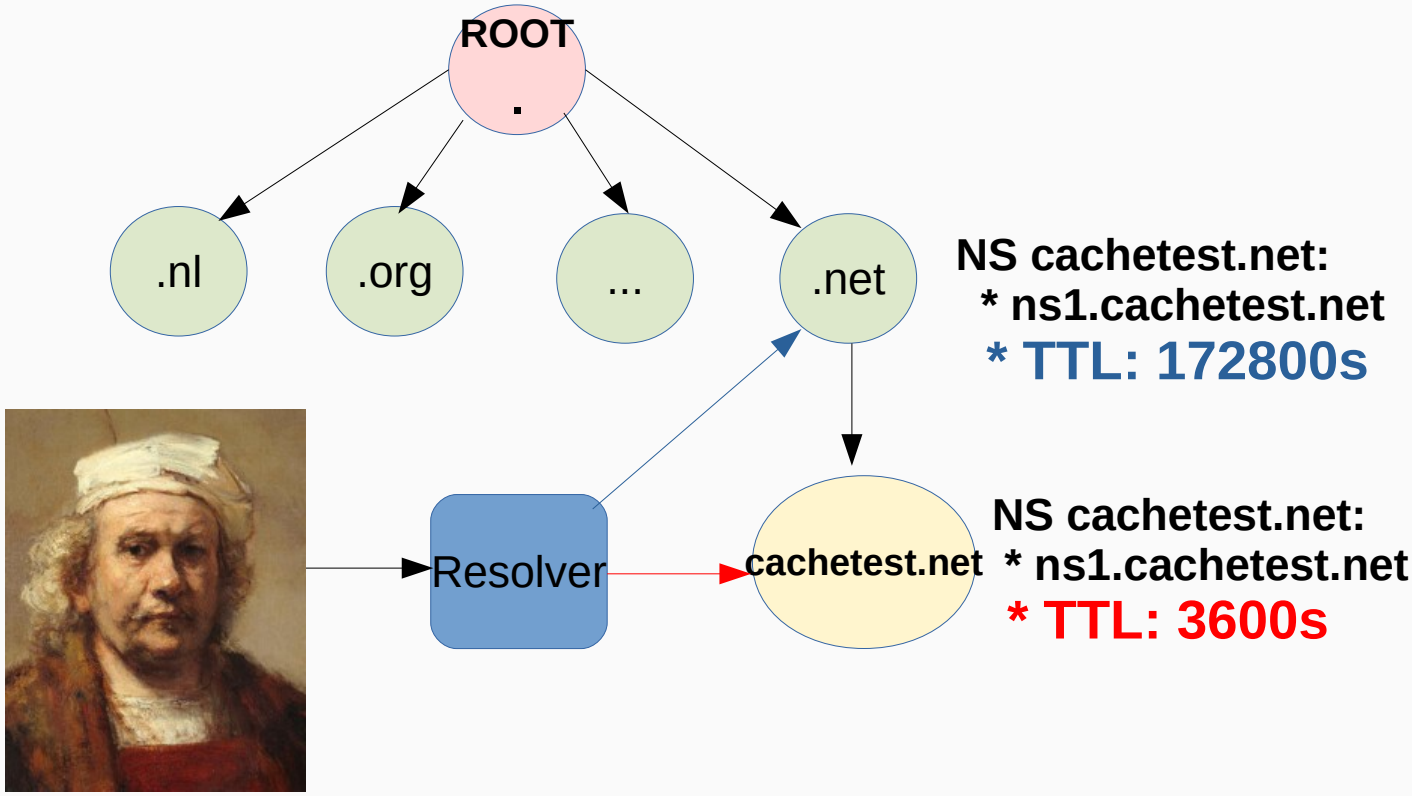
The rest of this talk

1. Parent vs Child: who really sets the TTL?
2. NS and A records: are they limited? And bailiwick?
3. Real-world variation exists
4. Longer TTLs are MUCH better
5. Our recommendations

Parent vs Child

Duplicate info: which one is chosen?

- Parent and child TTLs may vary: `dig NS cachetest.net`



Which TTL will Rembrandt use?
Parent (172800s) or child (TTL: 3600s)

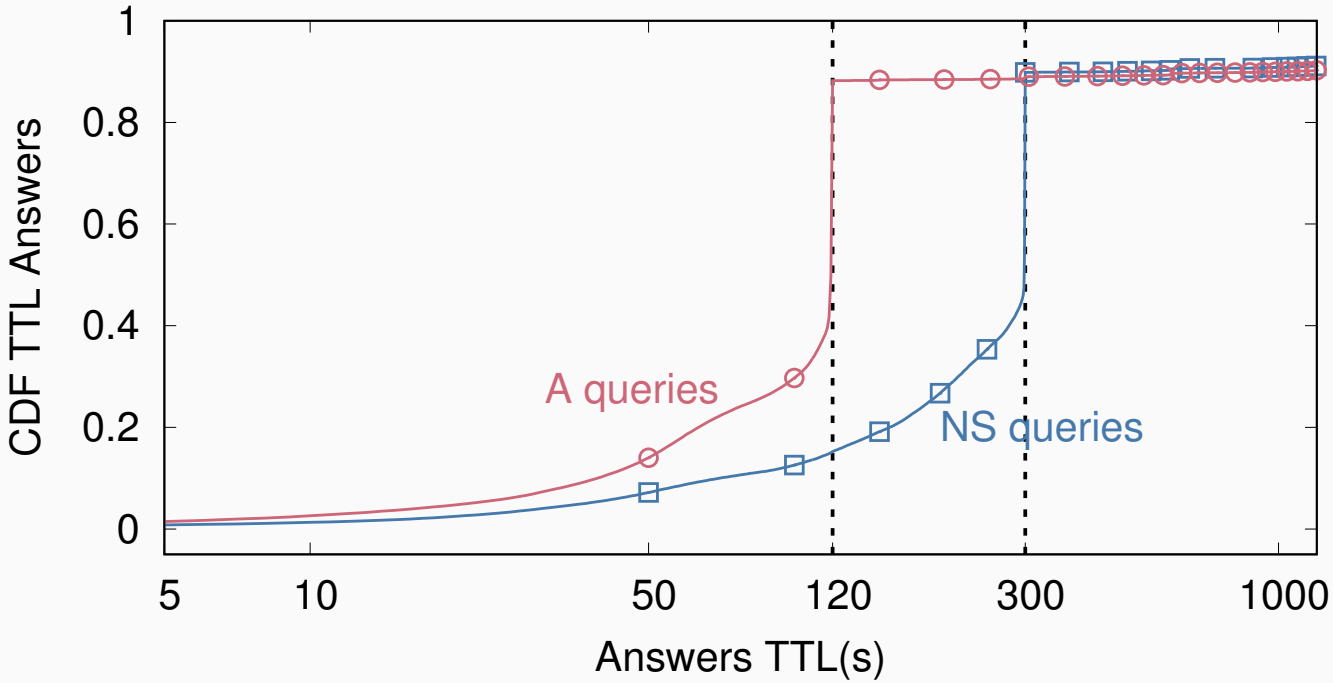
Are resolvers parent- or child-centric?

Parent vs Child experiment

- Test with experiment on `.uy`: (2019-02-14)
  - **Parent** : NS/A TTL: 172800s
  - **Child**: NS TTL: 300s ; A: 120s
- We query with 15k VPs (Ripe Atlas) mutliple times, every 10min
- We analyze TTL values received at VPs

Most Atlas VPs resolvers are child-centric

Figure 2: Observed TTLs from Atlas VPs for .uy-NS and a.nic.uy-A queries.



- Remember: TTL parents: 2 days

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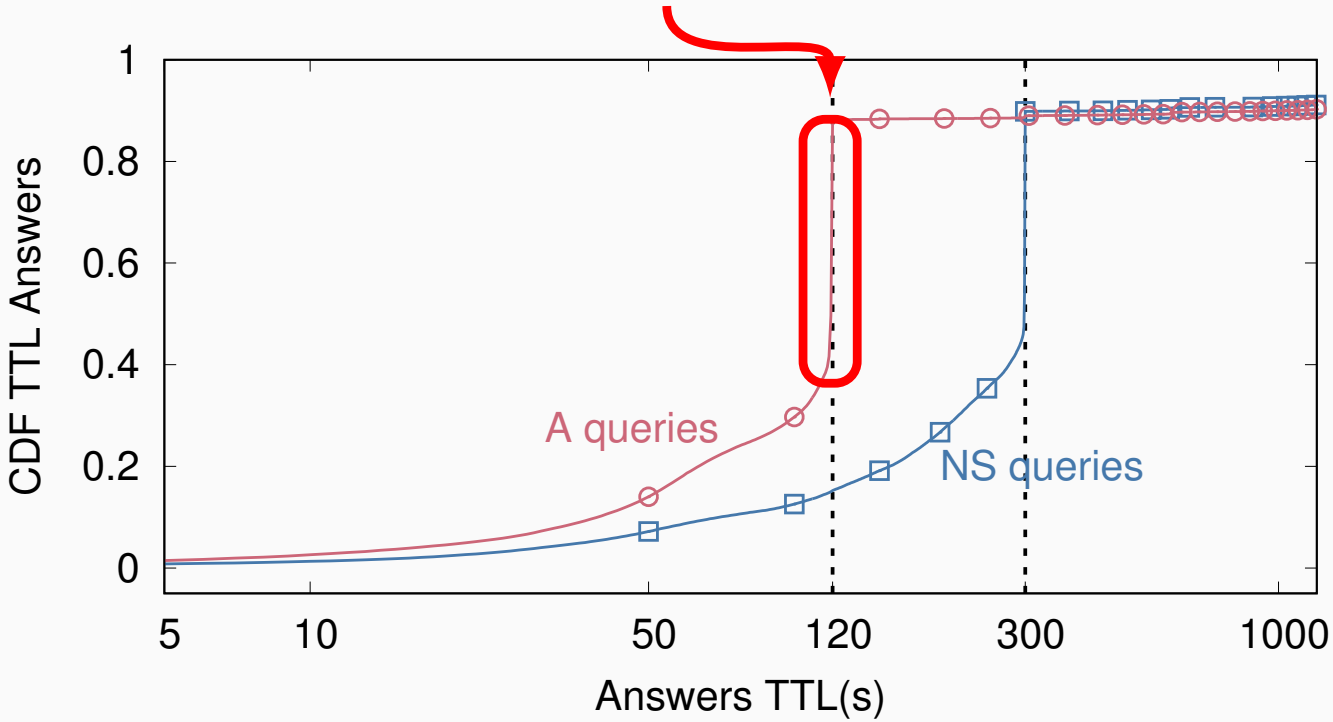
Spike at Child TTL A (120s) : most resolvers are child centric



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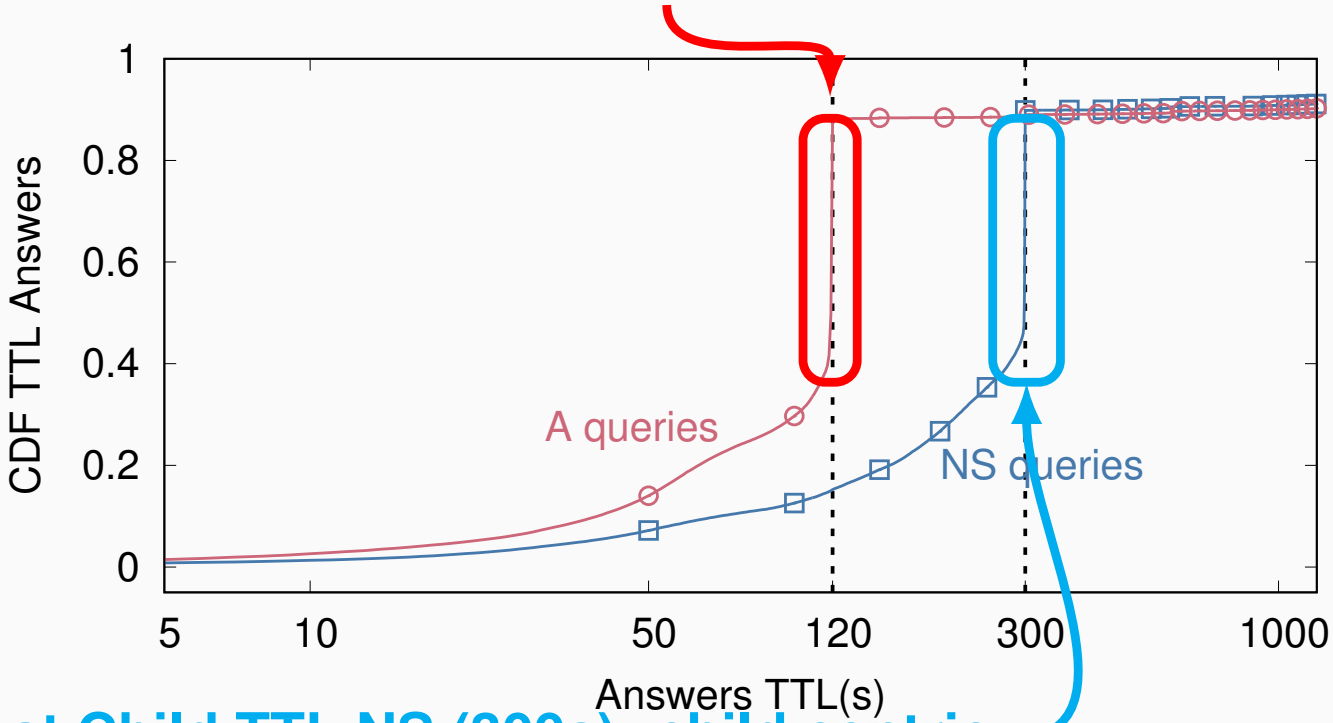


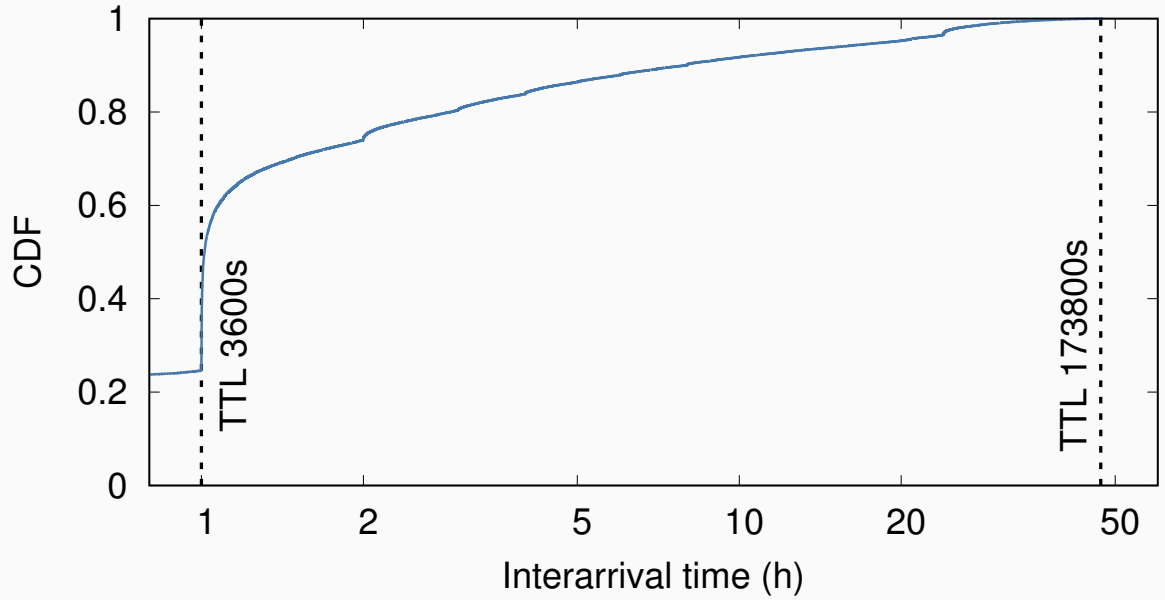
Spike at Child TTL NS (300s): child centric

- Remember: TTL parents: 2 days

Is centricity true for TLDs and SLDs?

- Test with `.nl` TLD A records (ns*.dns.nl)
  - TTLs are 3600s (child) vs. 17800s (parent)

Figure 3: Minimum interarrival time of **A queries for TLD**



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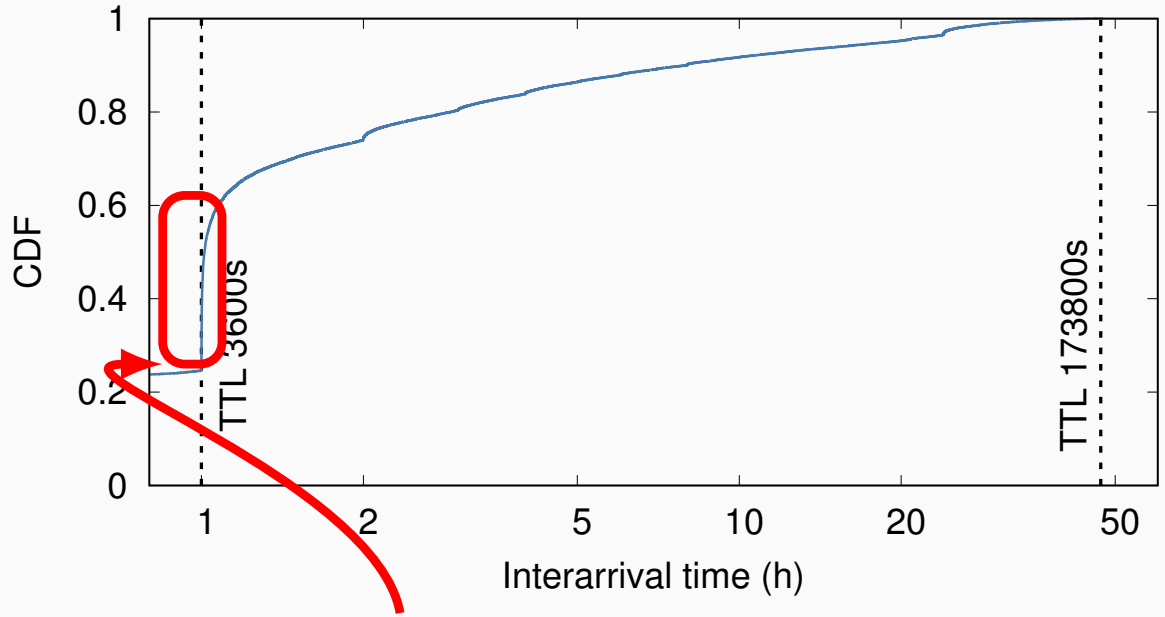

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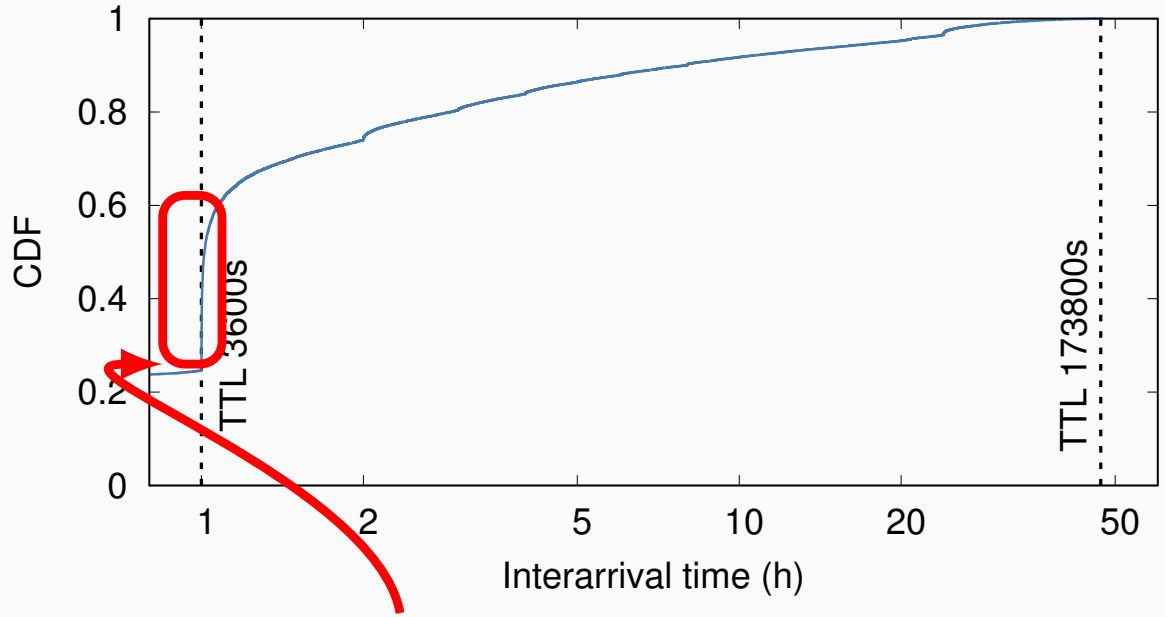

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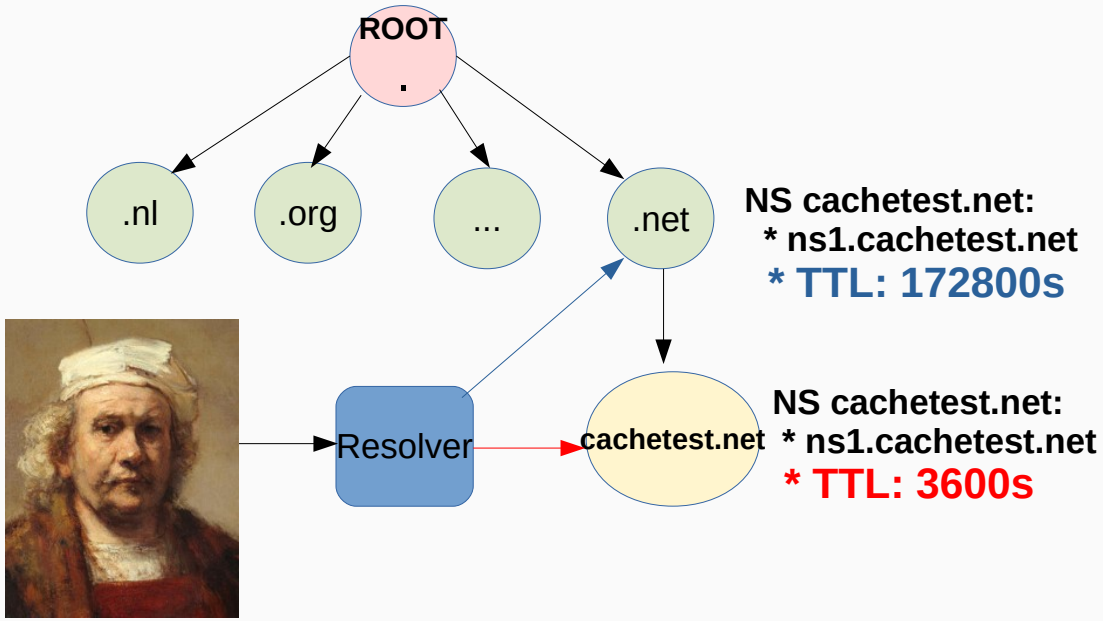
Most resolvers wil use child TTLs

- Rembrant (and users) mostly use child TTLs
- **Child TTL** controls caching (most times)



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Zone configurations and Effective TTL

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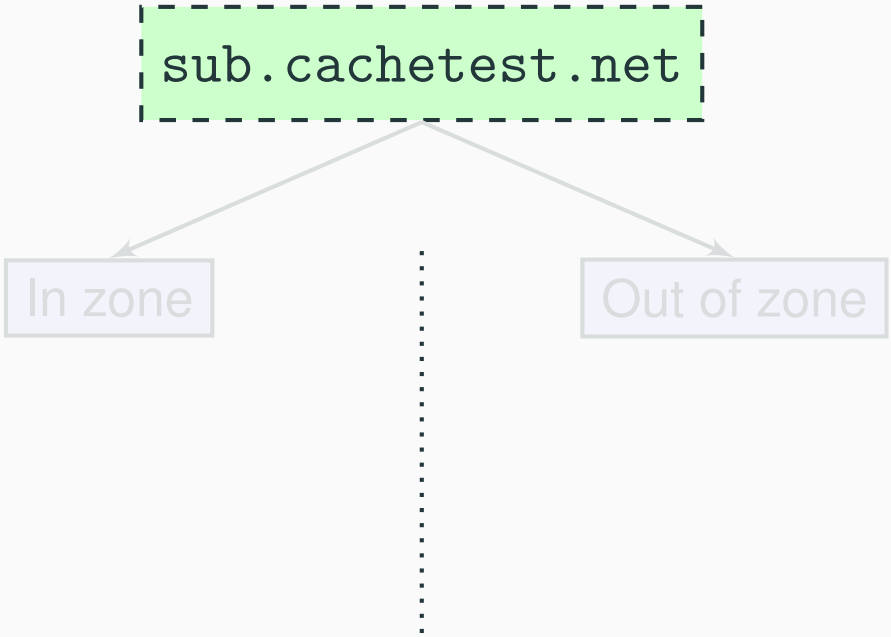

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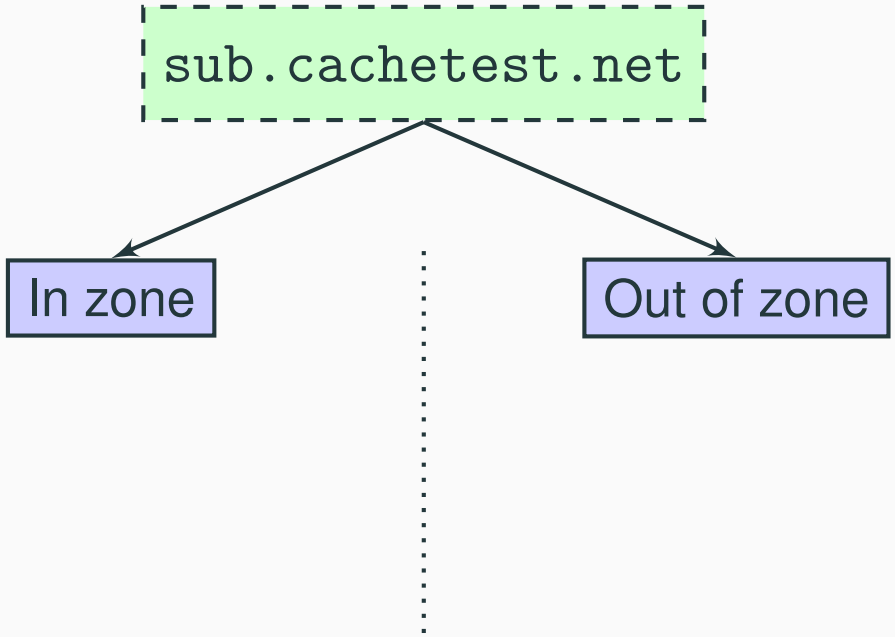

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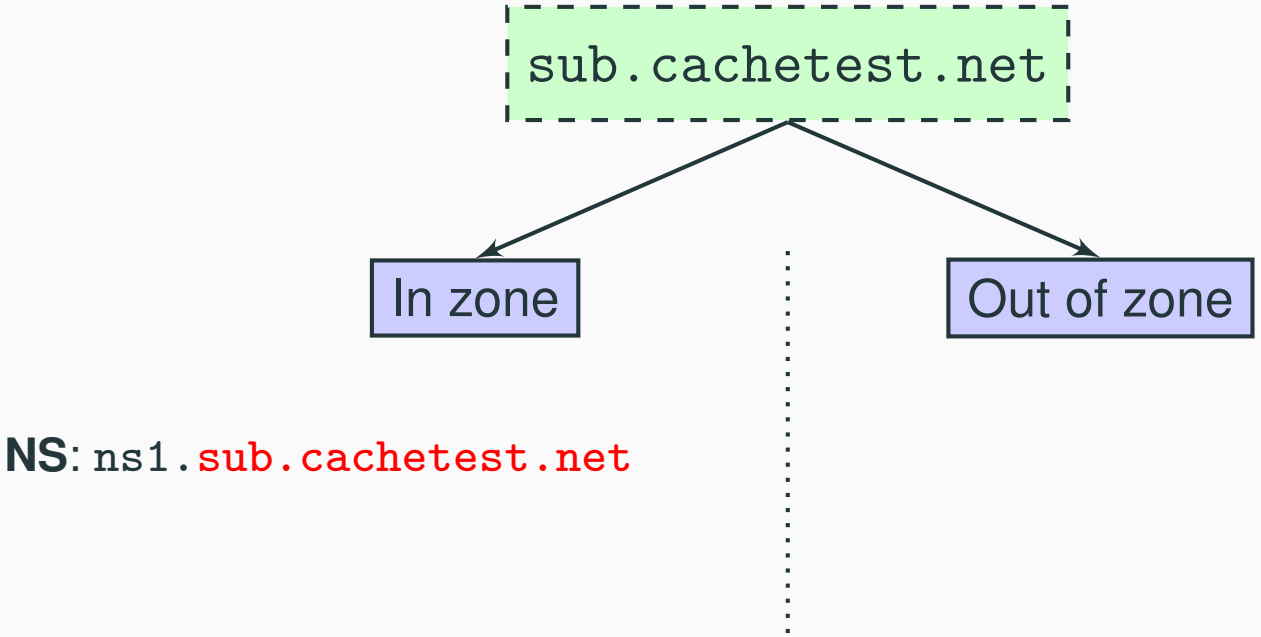

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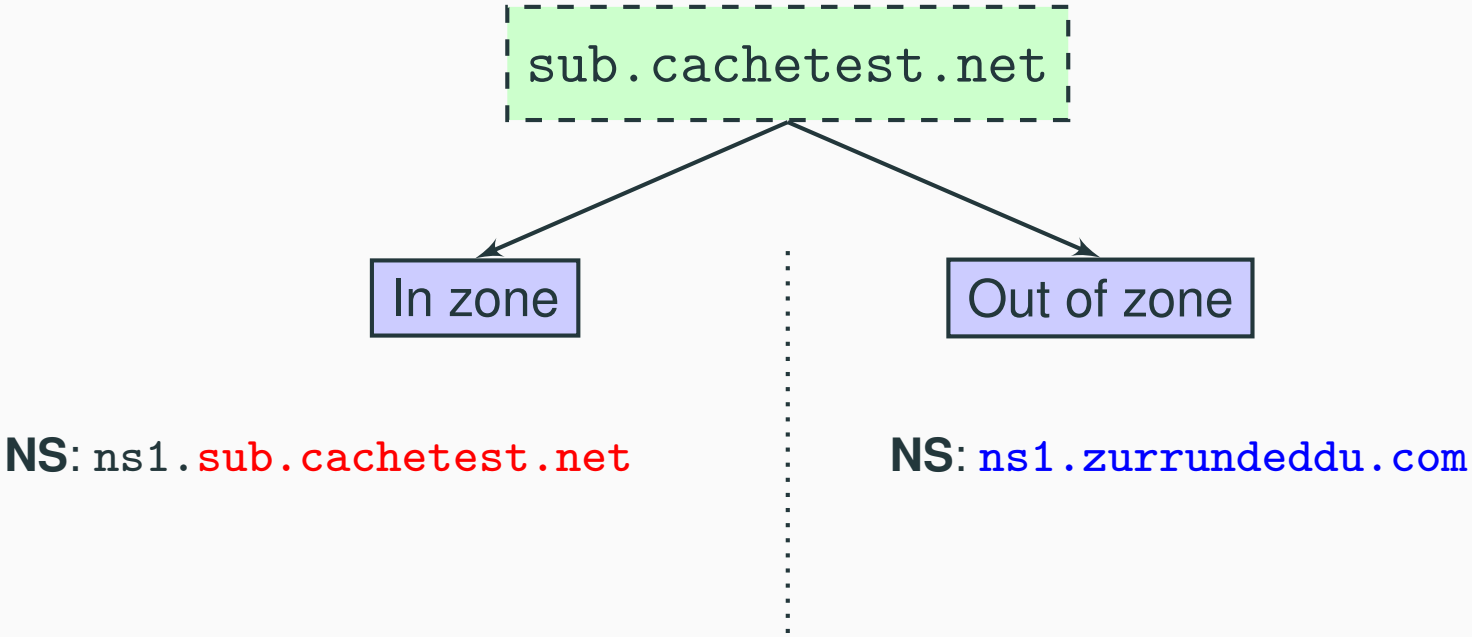

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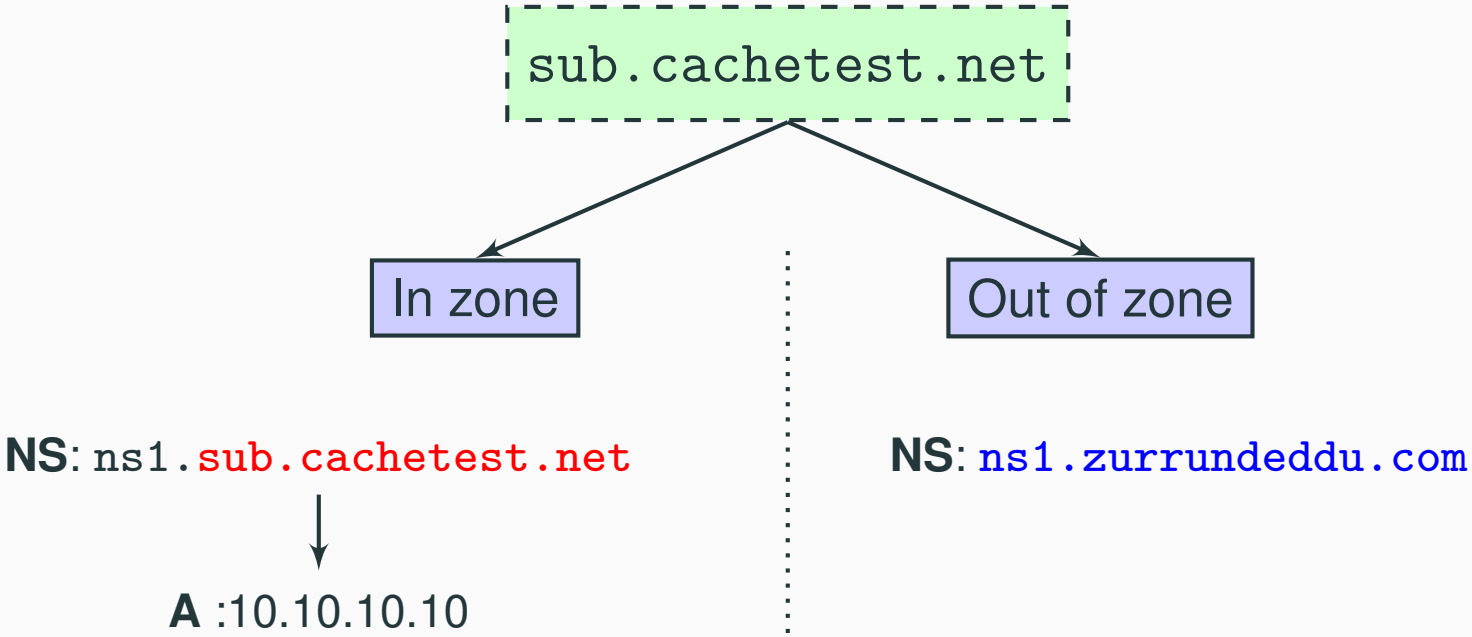

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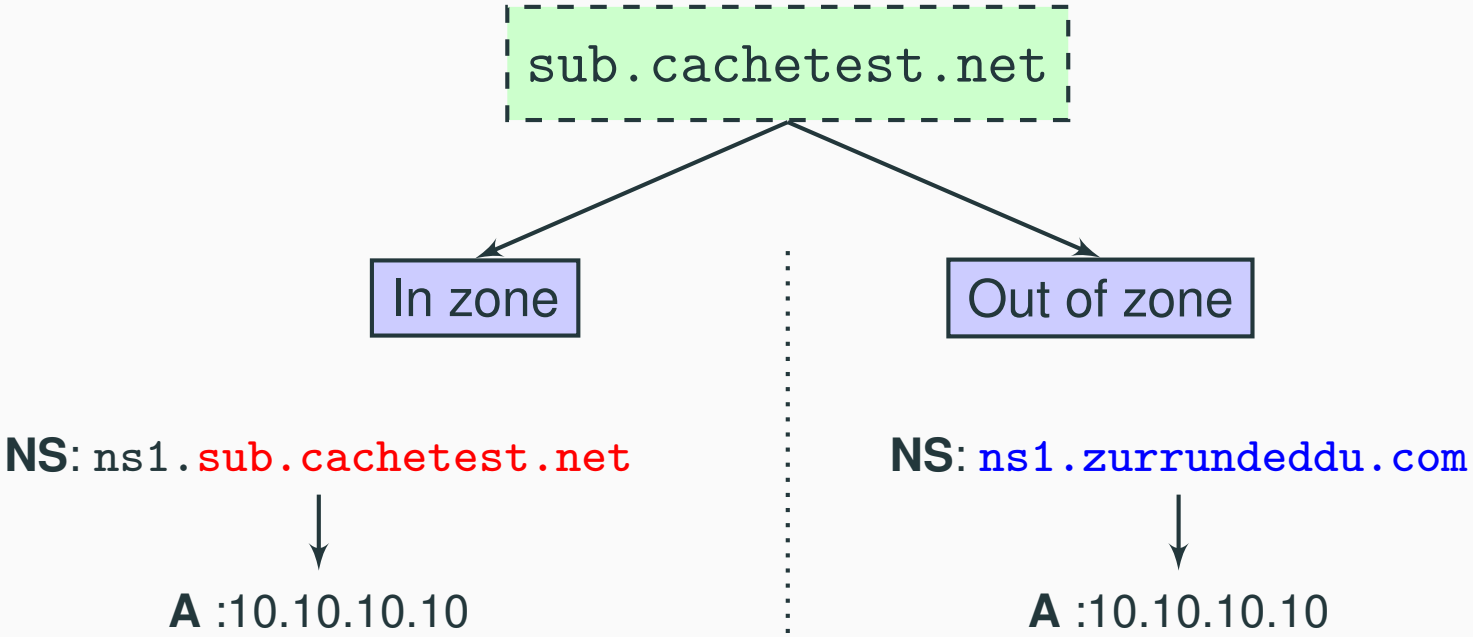

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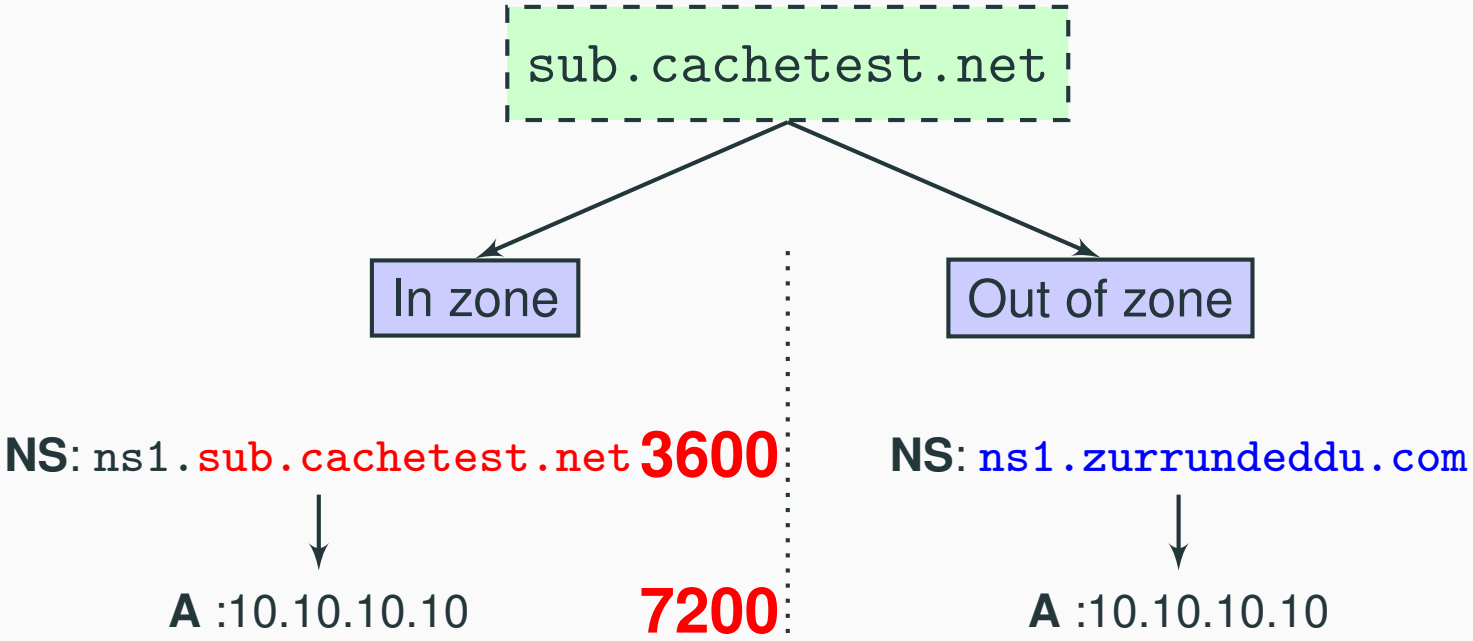

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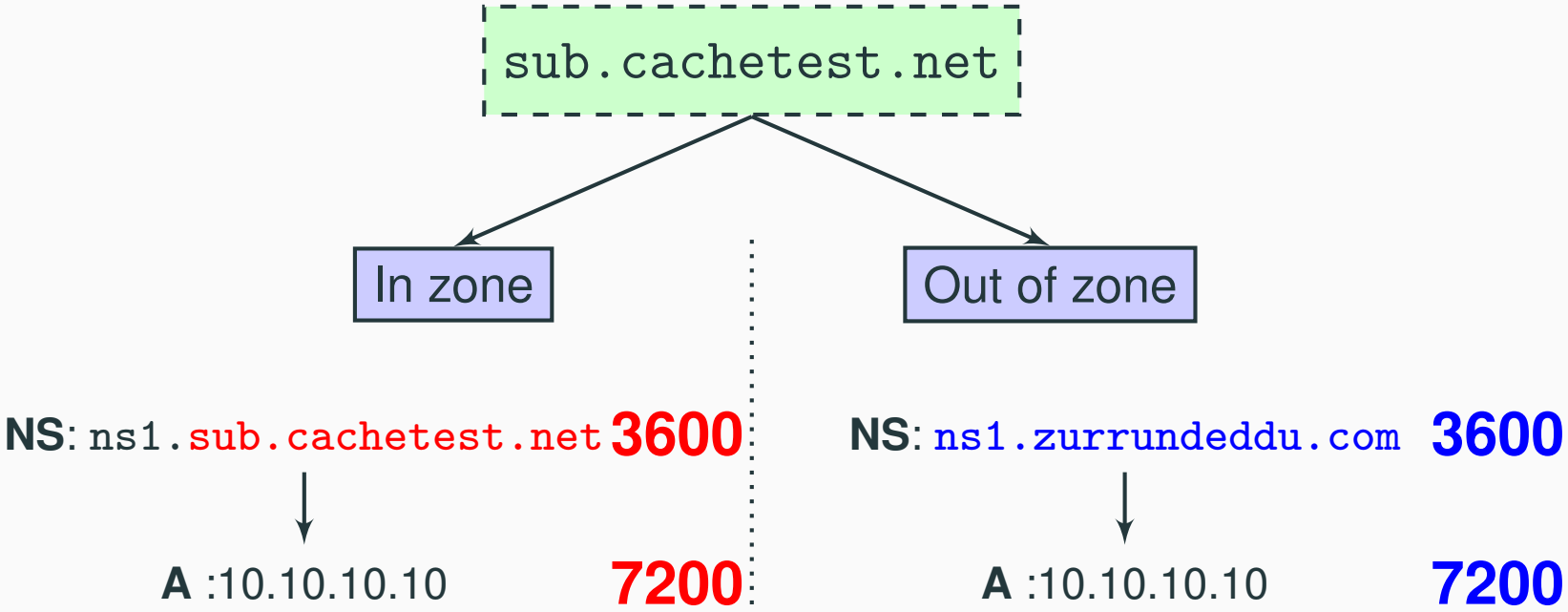

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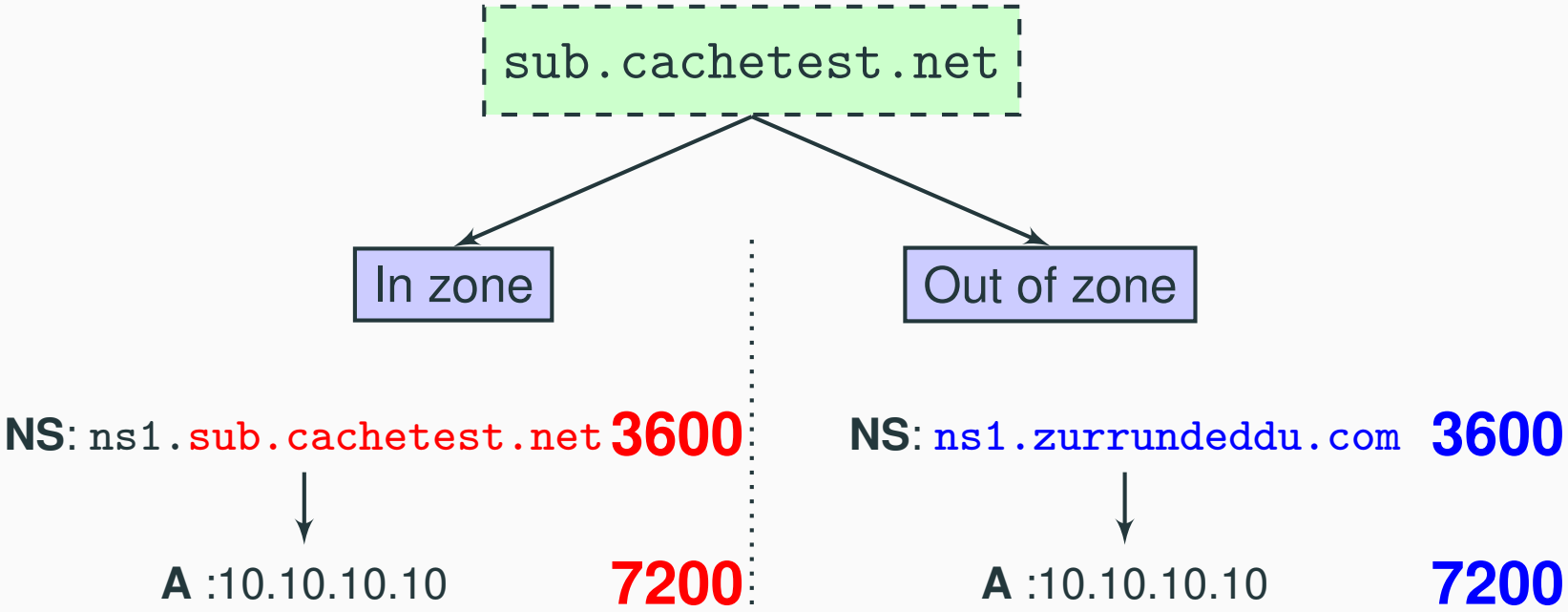

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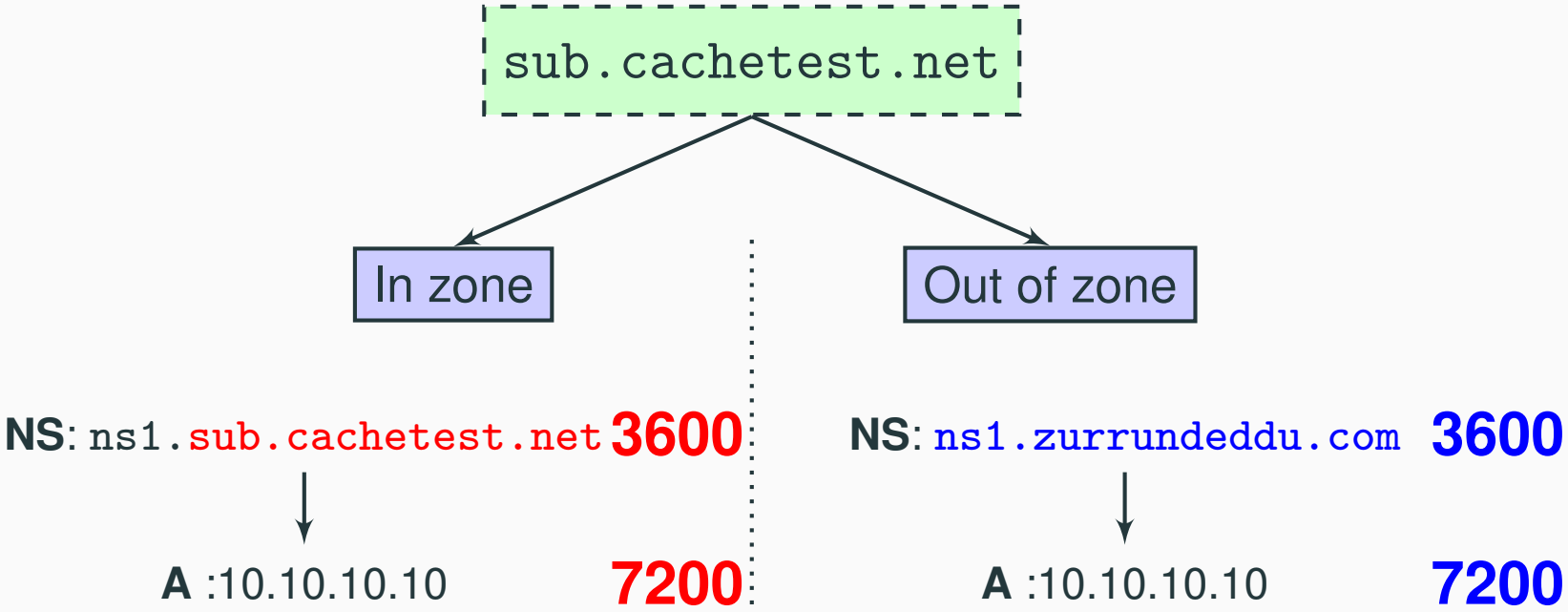

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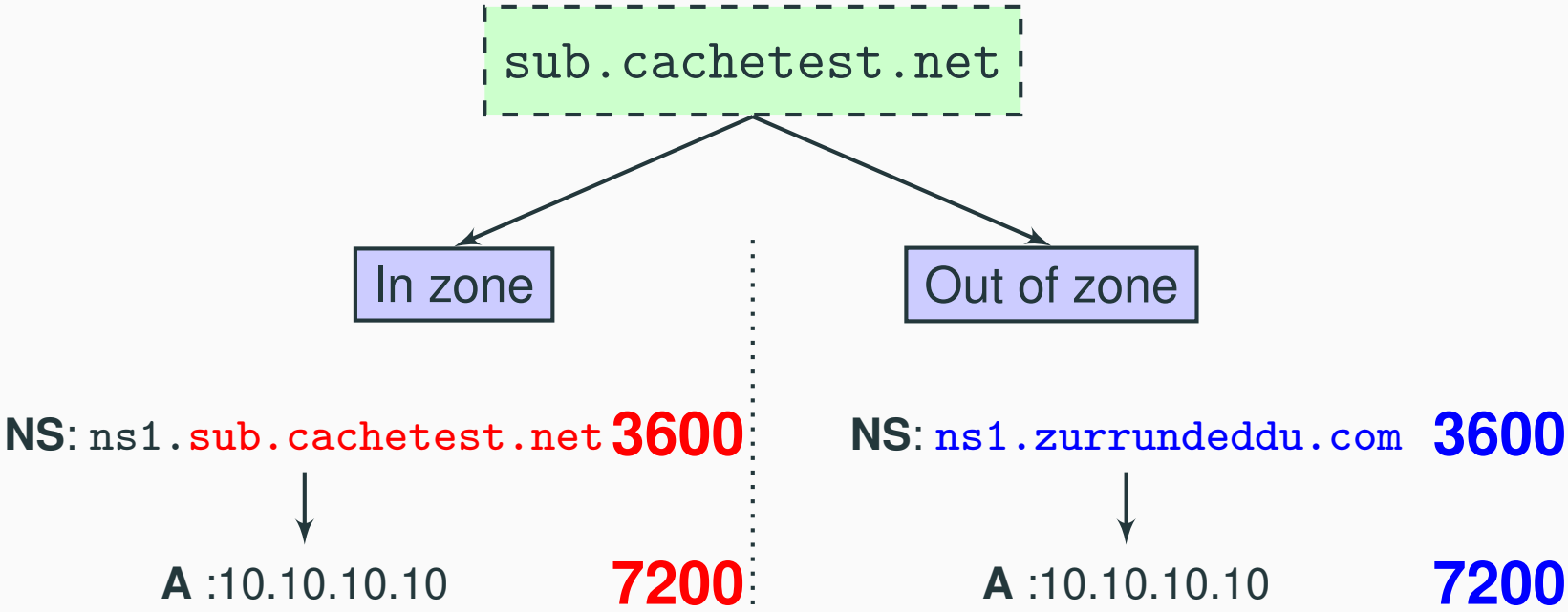

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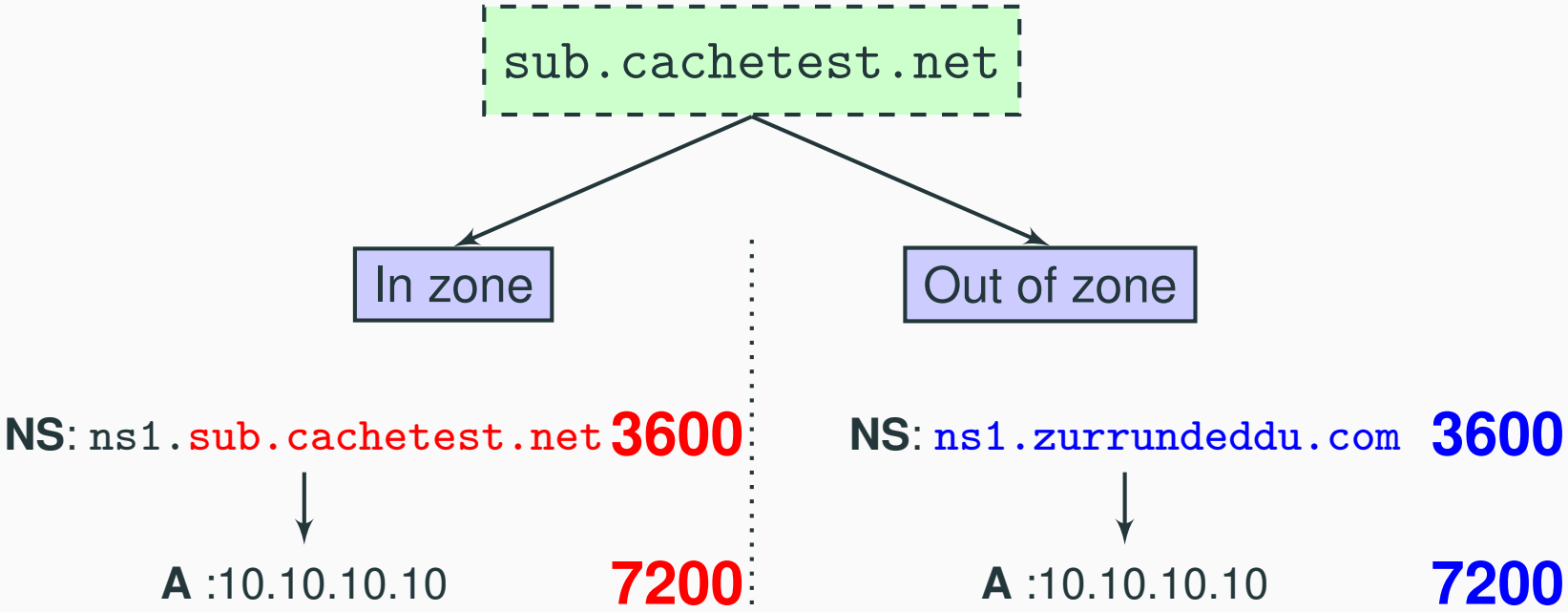

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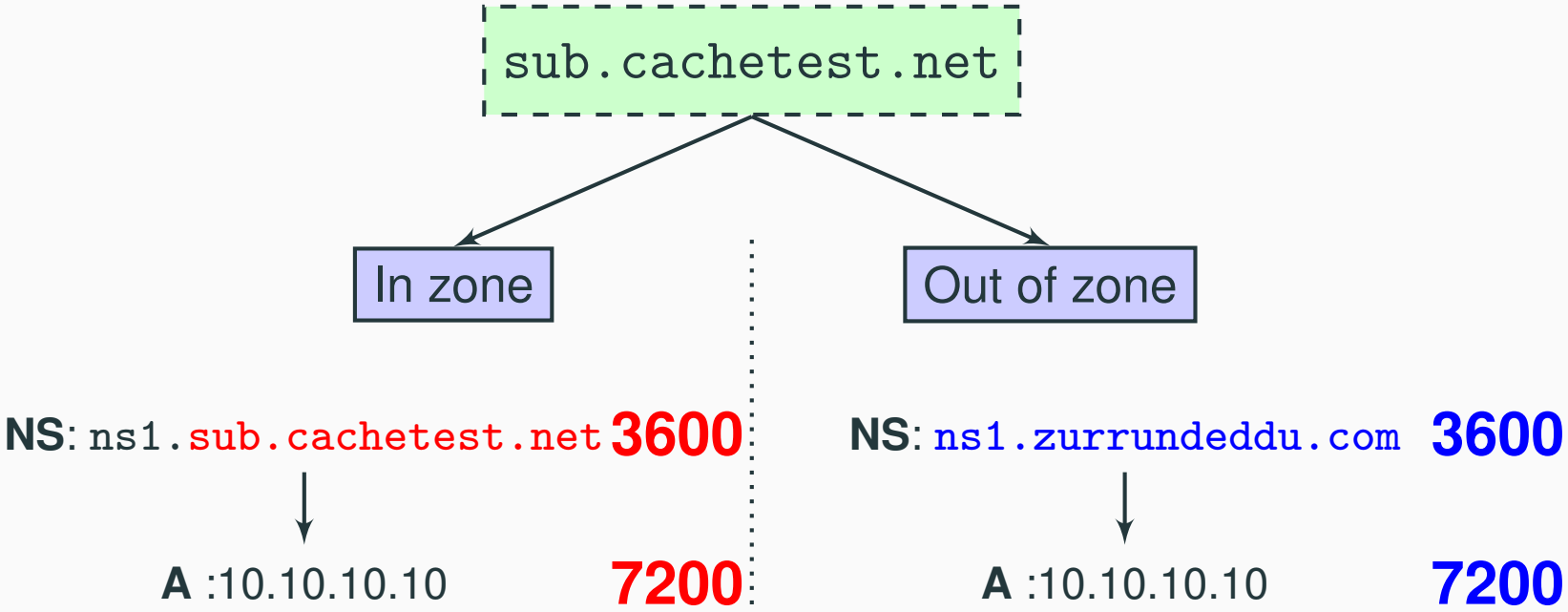

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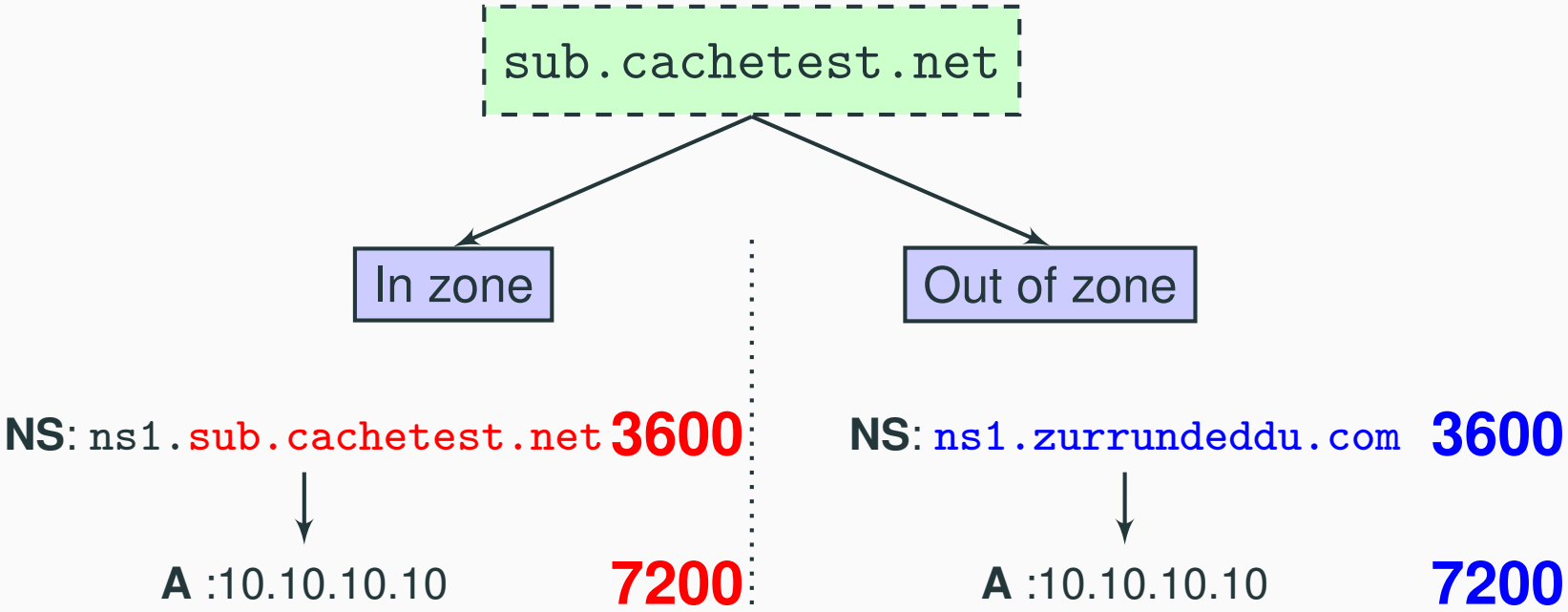

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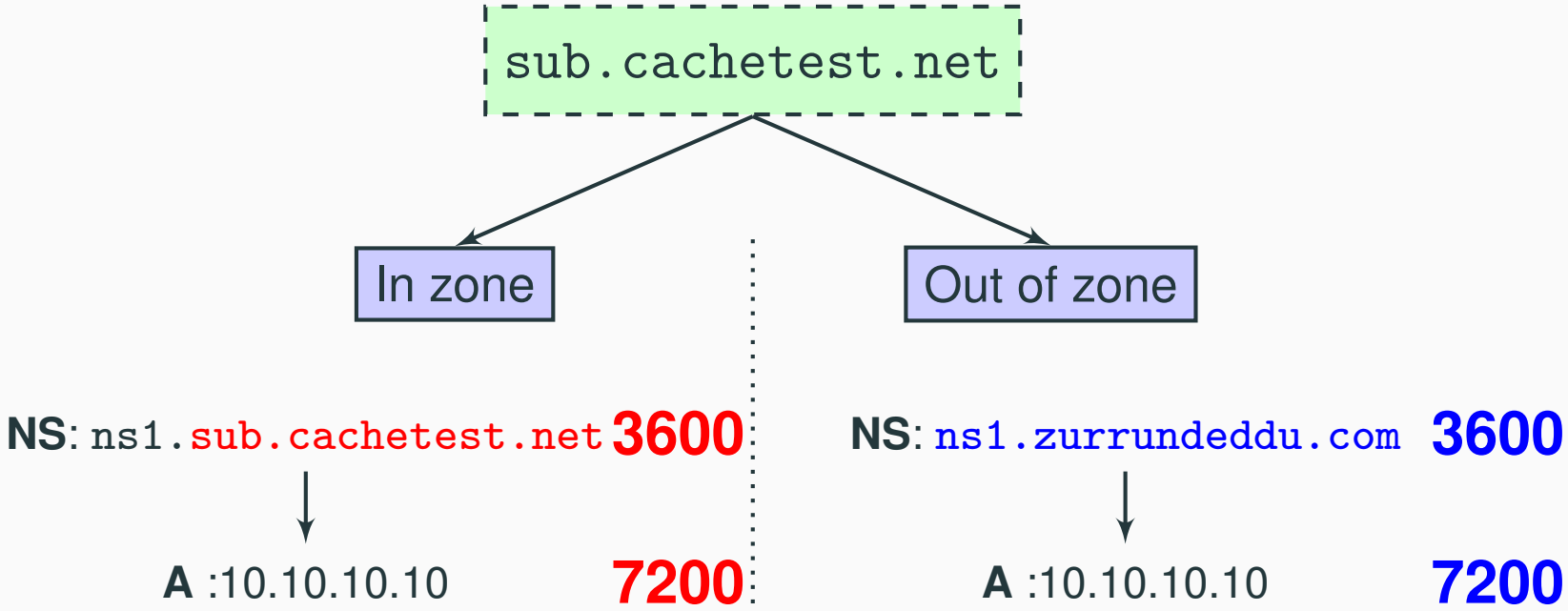

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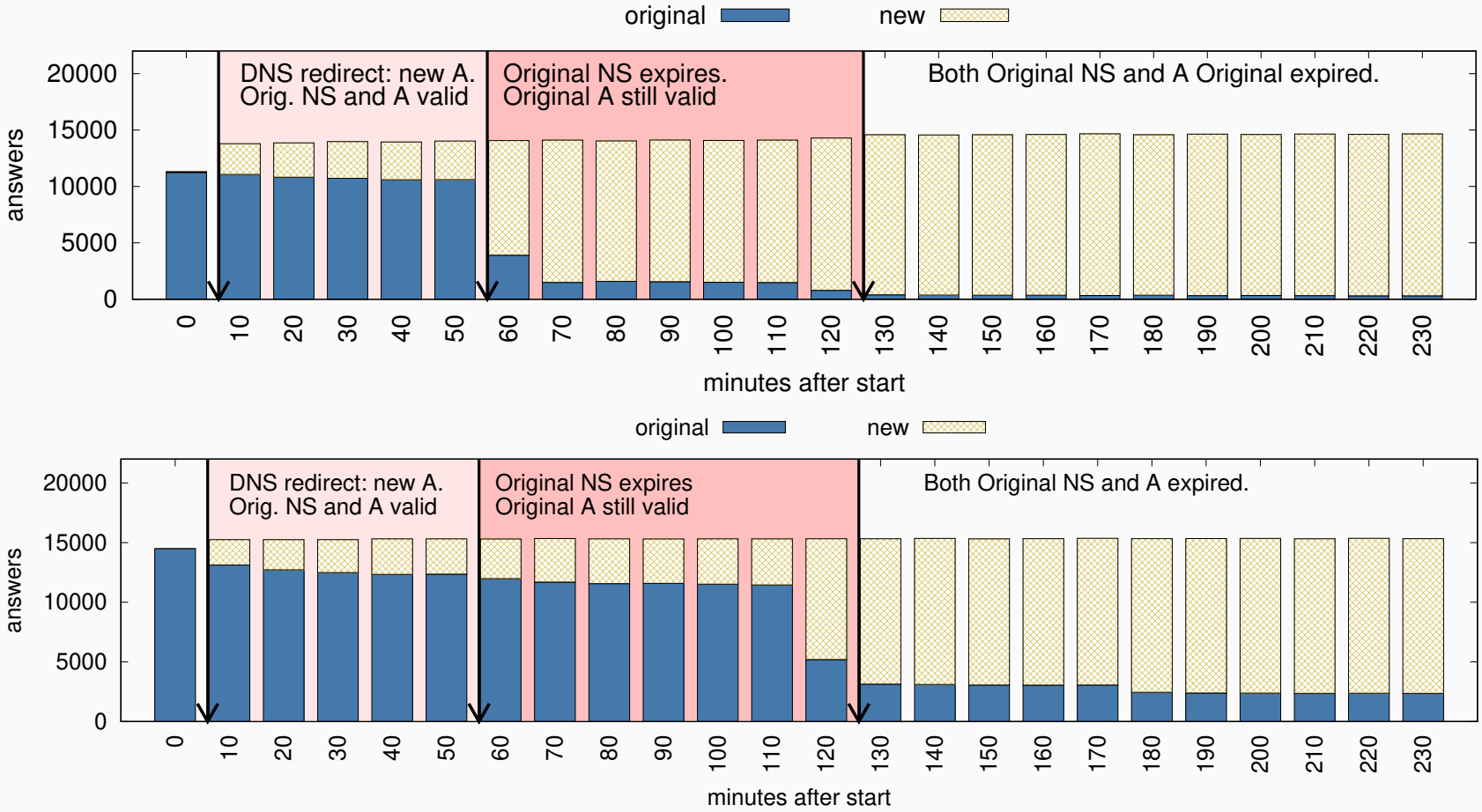
Will Marcus Aurelius receive cached or new answer?

Are they dependent? Yes, for in zone



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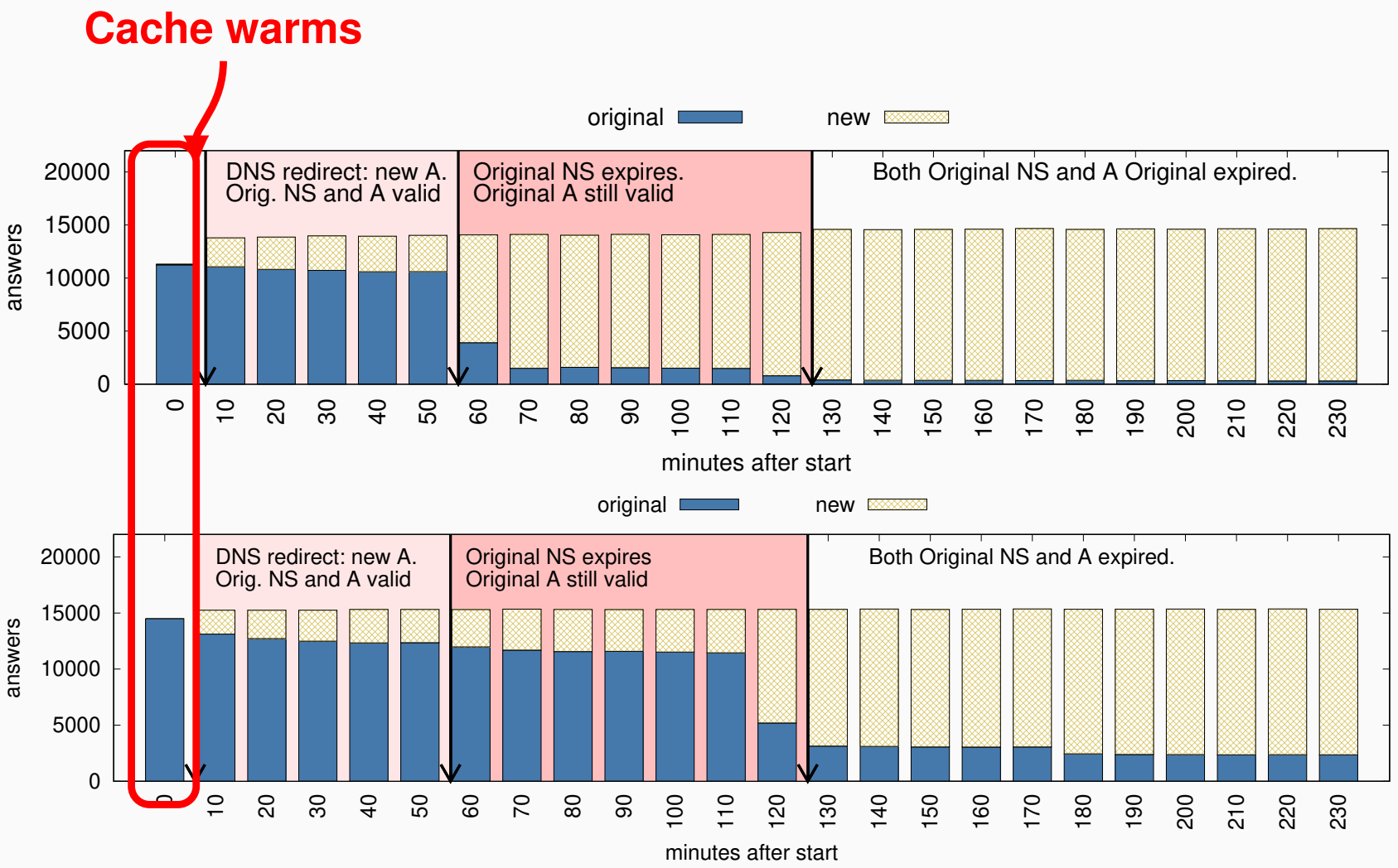

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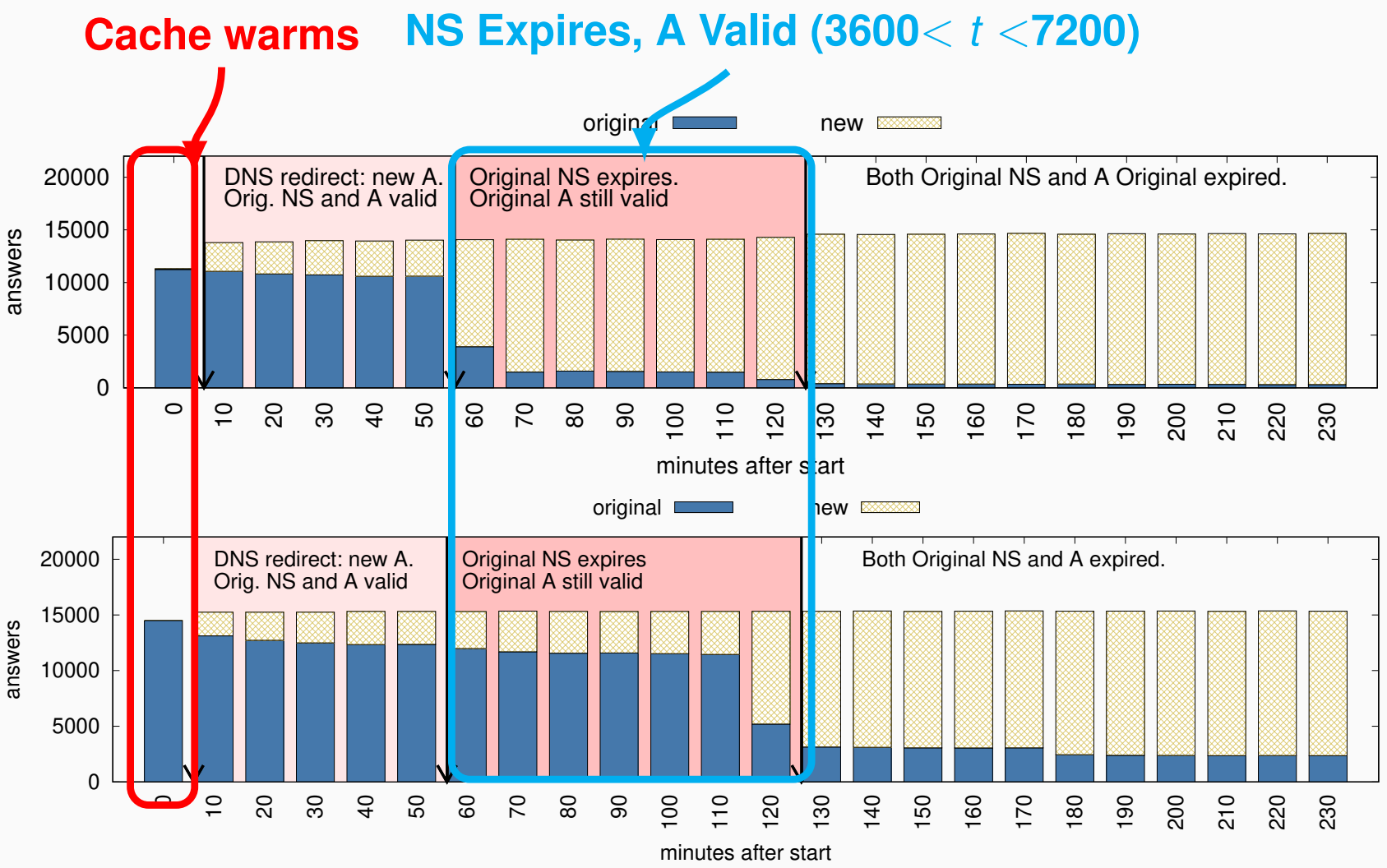

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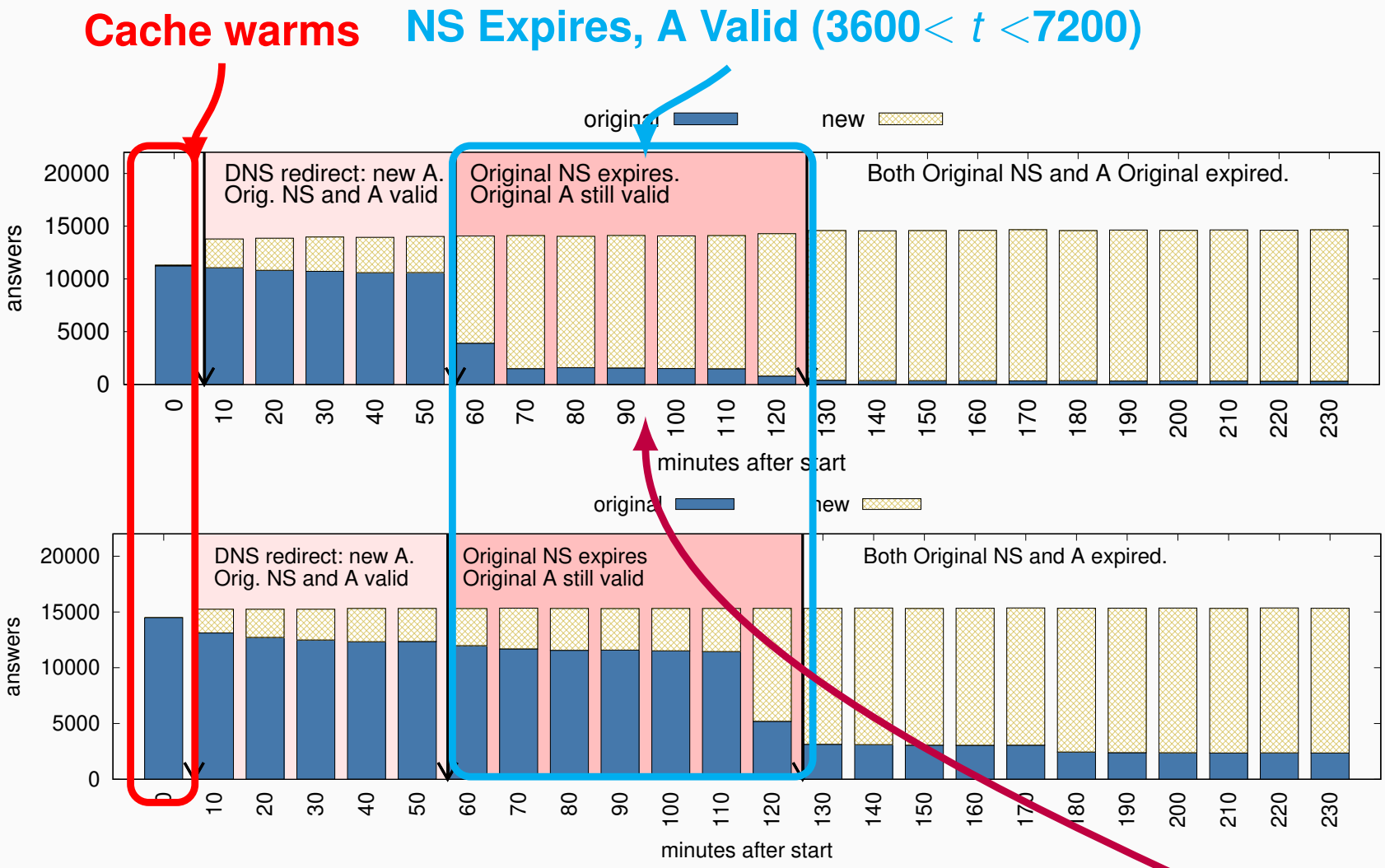
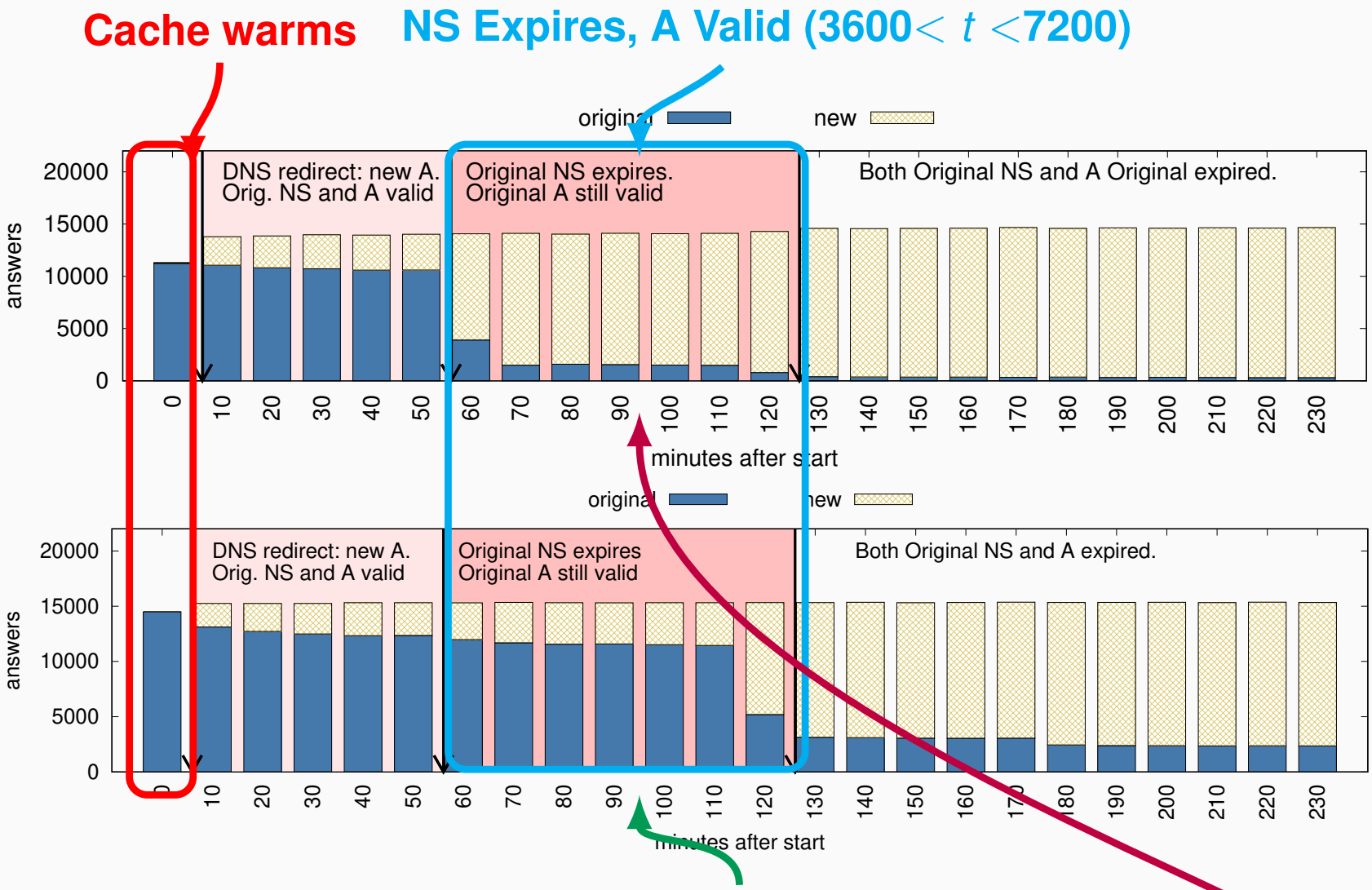


in zone: A refreshed (new server): dependent caching?

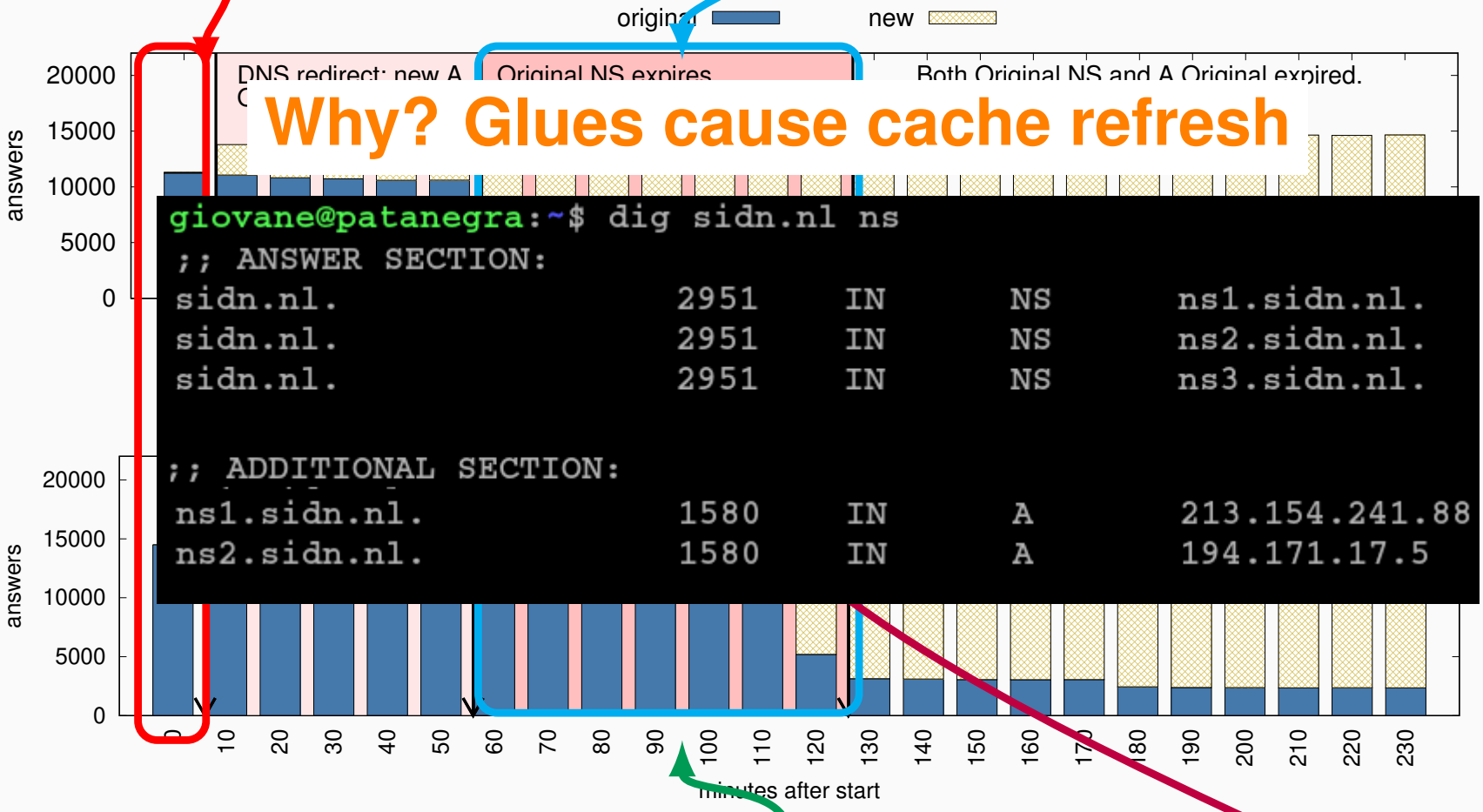
Are they dependent? Yes, for in zone



Are they dependent? Yes, for in zone

Cache warms

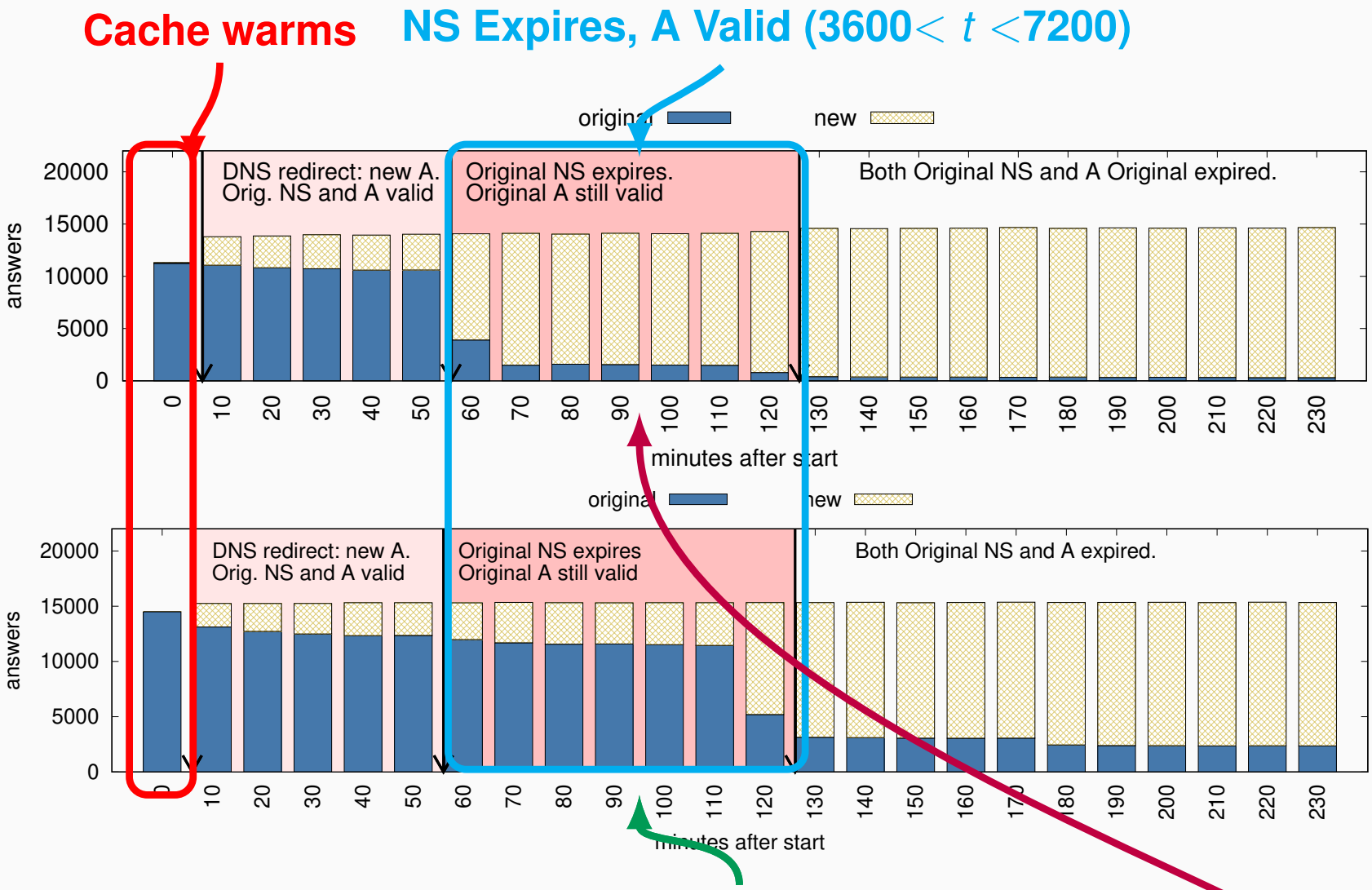
NS Expires, A Valid (3600< t <7200)



out-of- zone: cached A (old server): independent caching?

in zone: A refreshed (new server): dependent caching?

Are they dependent? Yes, for in zone



Are there dependencies between A and NS TTLs?

src:
https://en.wikipedia.org/wiki/Marcus_Aurelius

- Marcus Aurelius will notice“early” refreshed A for in-zone (in bailiwick)
- The way you configure your zone impacts caching , not only TTLs

Outline

TTLs Use in the Wild

How are TTLs used in the wild?

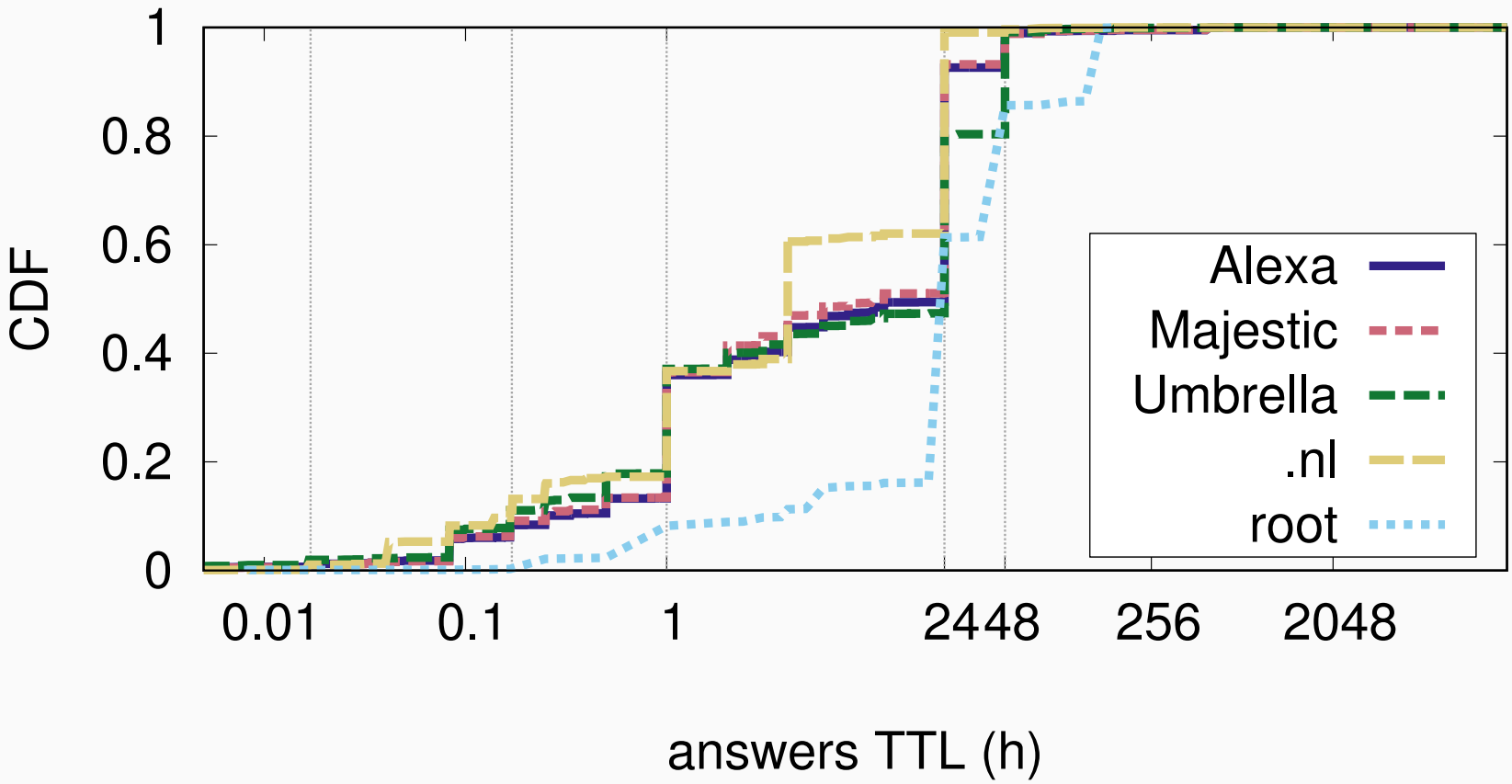
- There is no consensus how to choose TTLs
- But folks have to choose them anyway
- We use 5 lists:
  - Alexa
  - Majestic
  - Umbrella
  - `.nl`
  - Root (TLDs)
- We probe several records types
- We analyze **child TTL** values
- And discuss results with some operators

Most domains are out-of-bailiwick

	Alexa	Majestic	Umbre.	.nl	Root
responsive	988654	928299	783343	5454833	1535
CNAME	50981	7017	452711	9436	0
SOA	12741	8352	59083	12268	0
responsive NS	924932	912930	271549	5433129	1535
Out only	878402	873447	244656	5417599	748
ratio out only	95.0%	95.7%	90.1	99.7%	48.7%
In only	37552	28577	20070	12586	654
Mixed	8978	10906	6823	2941	133

- Out of bailiwick (out-of-zone): **records are cached independently** (no glues)
- Your chosen TTLs values for different records will be respected

NS records have longer TTLs (>24h)



- > 60% NS records are long (**Good** for caching and performance)
- But 40% are one hour or less (not so good)

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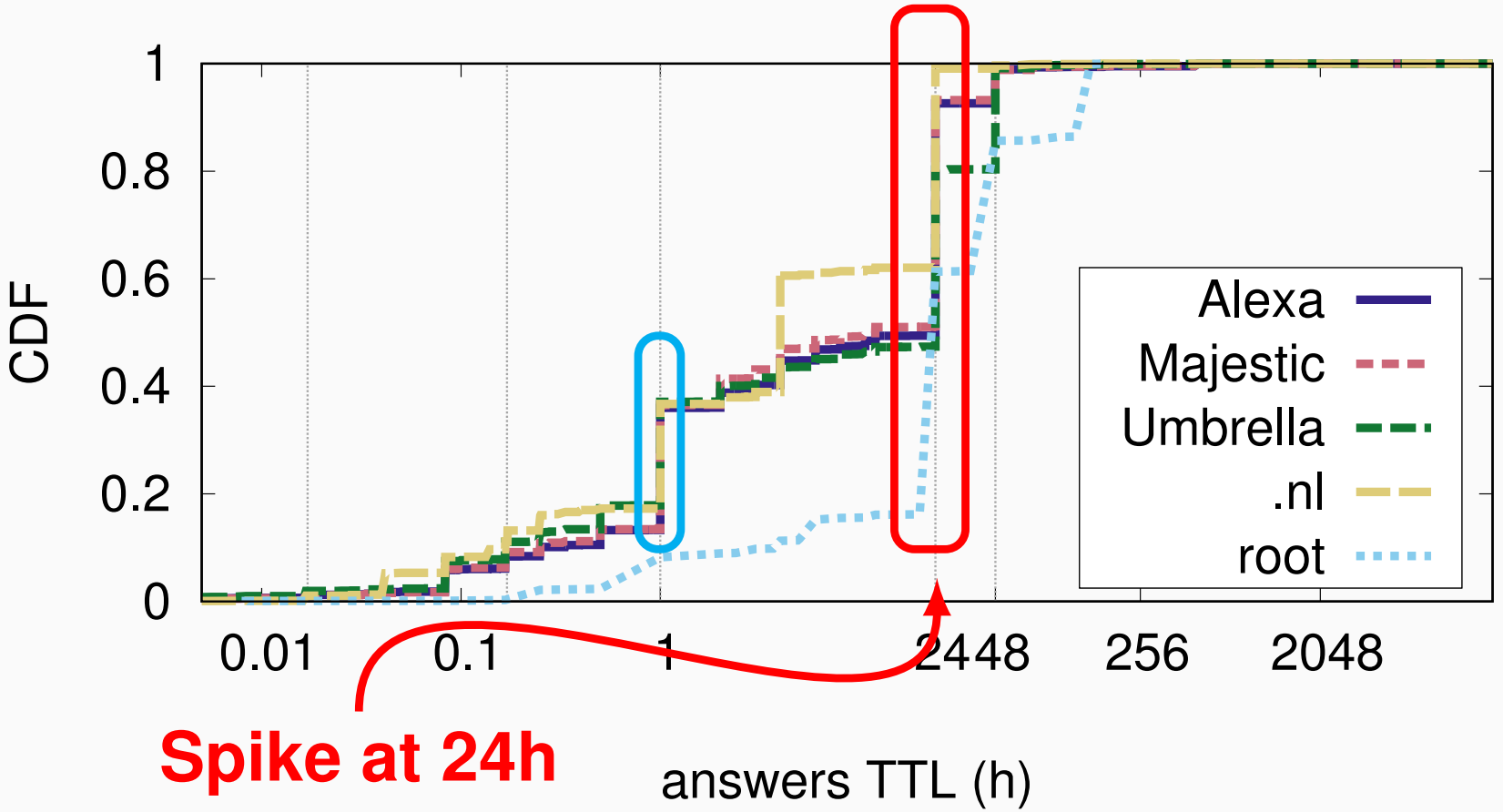

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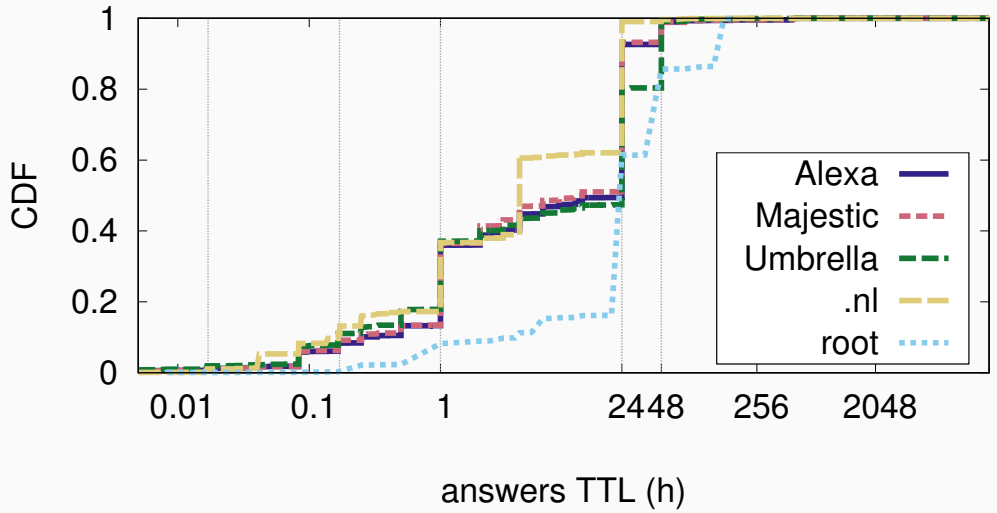
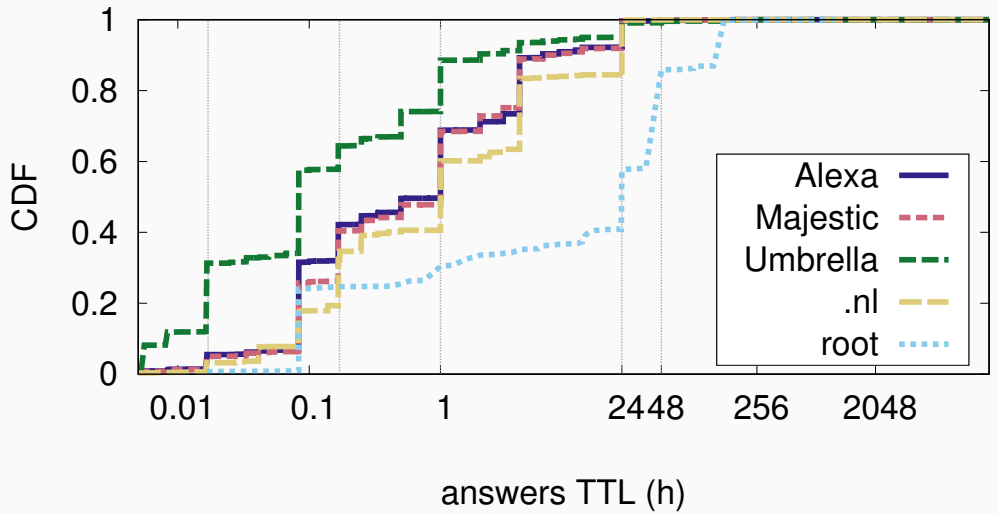
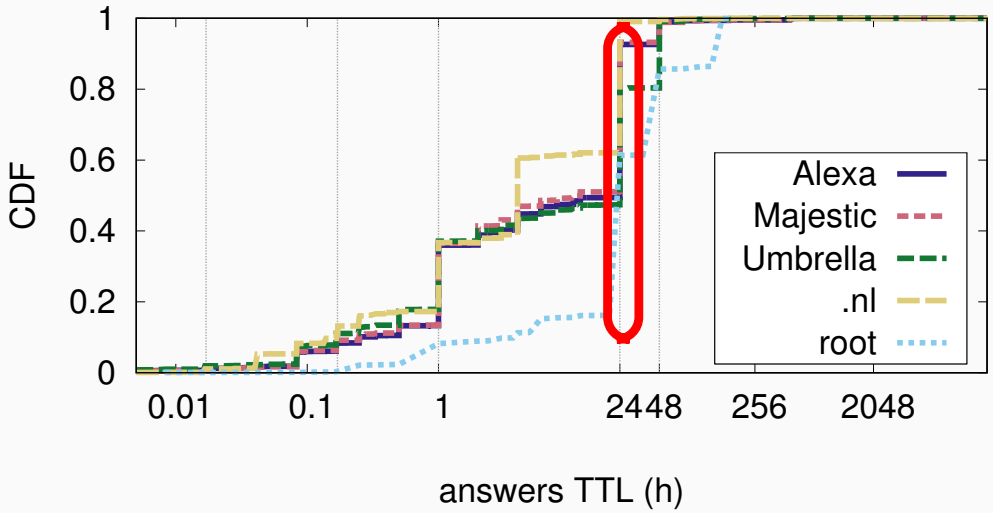
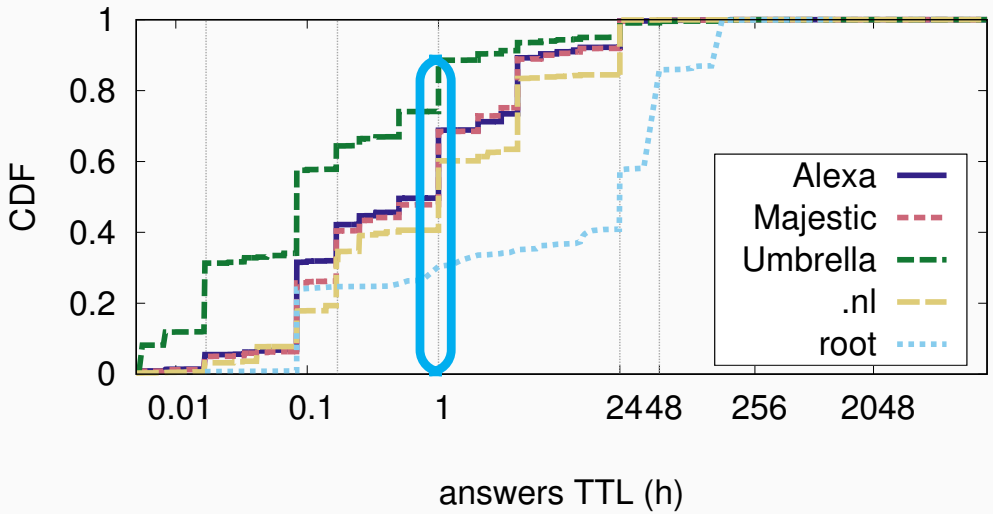
A records TTLs far shorter than NS



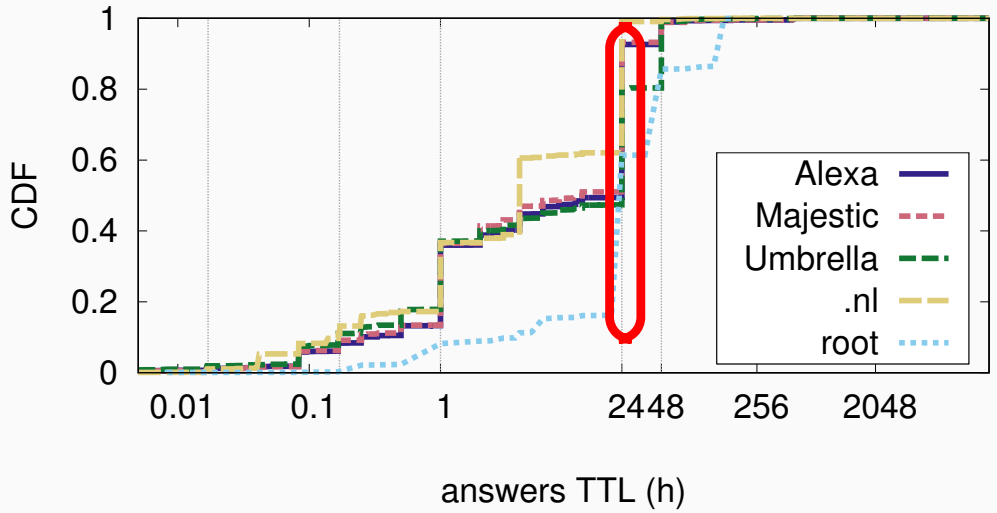


A records TTLs far shorter than NS

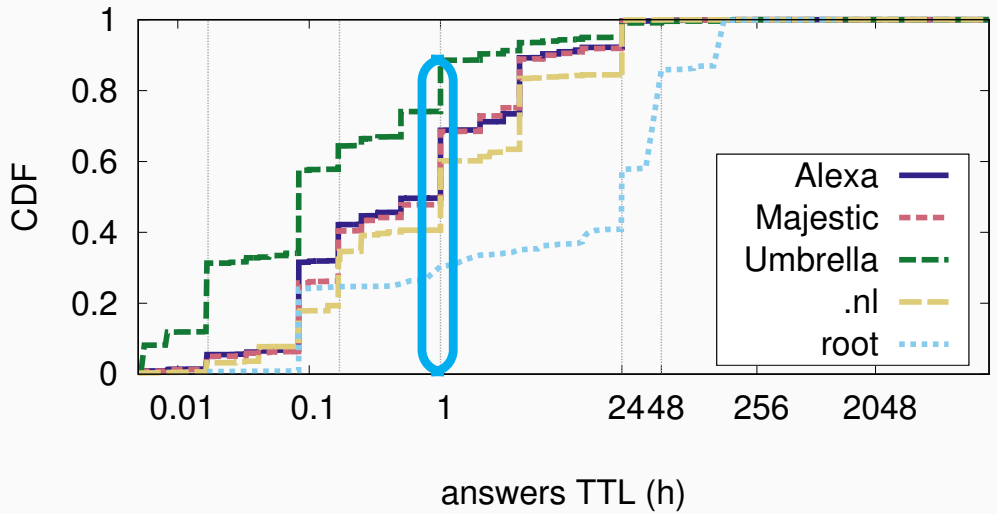




A records TTLs far shorter than NS



Shorter A records TTLs leads to poor caching



Operators Notification: 3 changed their TTLs

- We found **34 TLDs** with short TTL for NSes (<=30min)
- **We notified** 8 ccTLDs
- 3 TLDs *increased their TTL to 1 day* after our notification
  - .uy, and
  - another in Africa
  - and another in the Middle-East

.uy latency reduced a lot!

- .uy NS TTL from 300s to 86400s

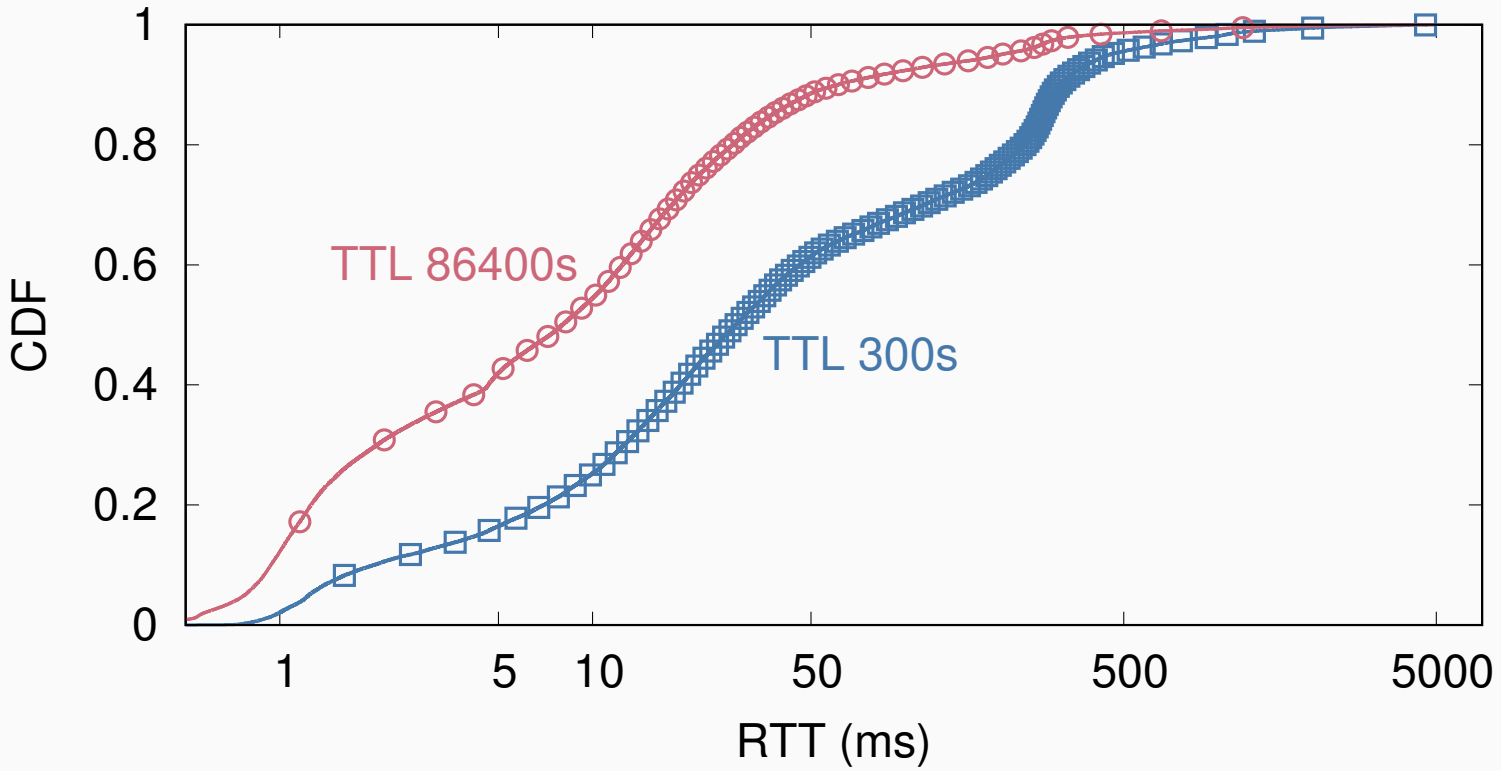


Figure 4: RTT from RIPE Atlas VPs for NS .uy queries (NS)

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- .uy NS TTL from 300s to 86400s

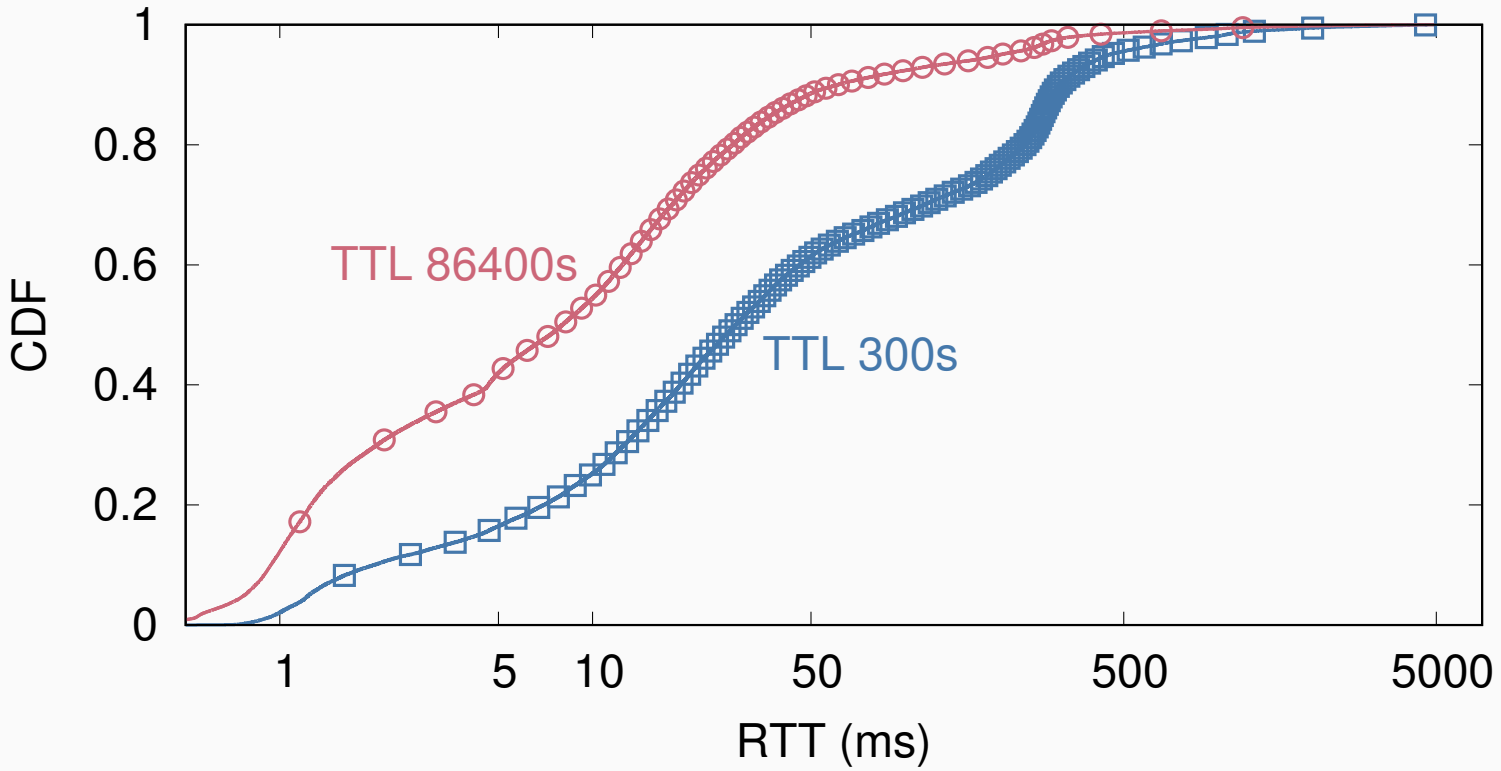


Figure 4: RTT from RIPE Atlas VPs for NS .uy queries (NS)

.uy latency reduced a lot!

- .uy NS TTL from 300s to 86400s: lower latency for clients

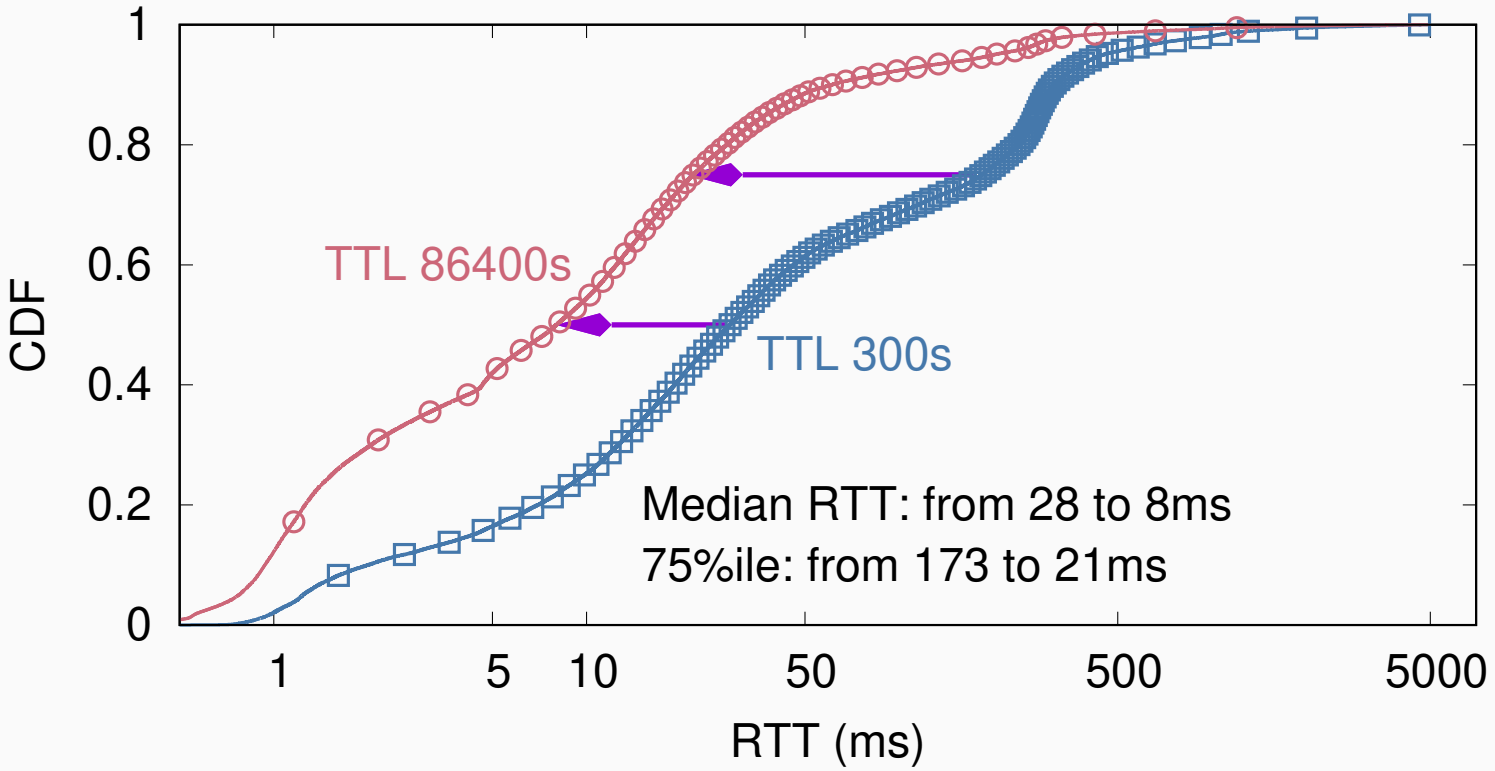


Figure 5: RTT from RIPE Atlas VPs for NS .uy queries (NS)

Median RTT improves by 20ms; 75%ile by 152ms

.uy latency reduced for all regions

Check for Atlas location bias

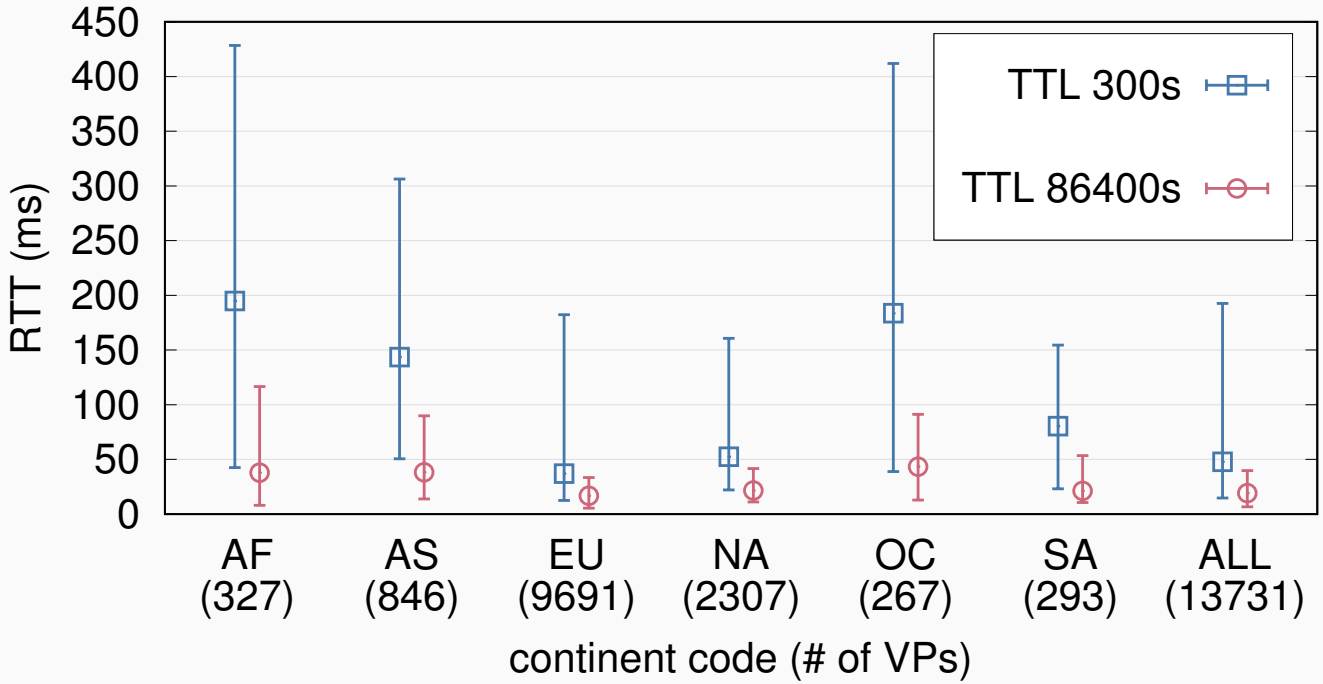


Figure 6: Median RTT as seen by RIPE Atlas VPs per region

Longer TTL → longer caching → faster answers

.uy latency reduced for all regions

Check for Atlas location bias

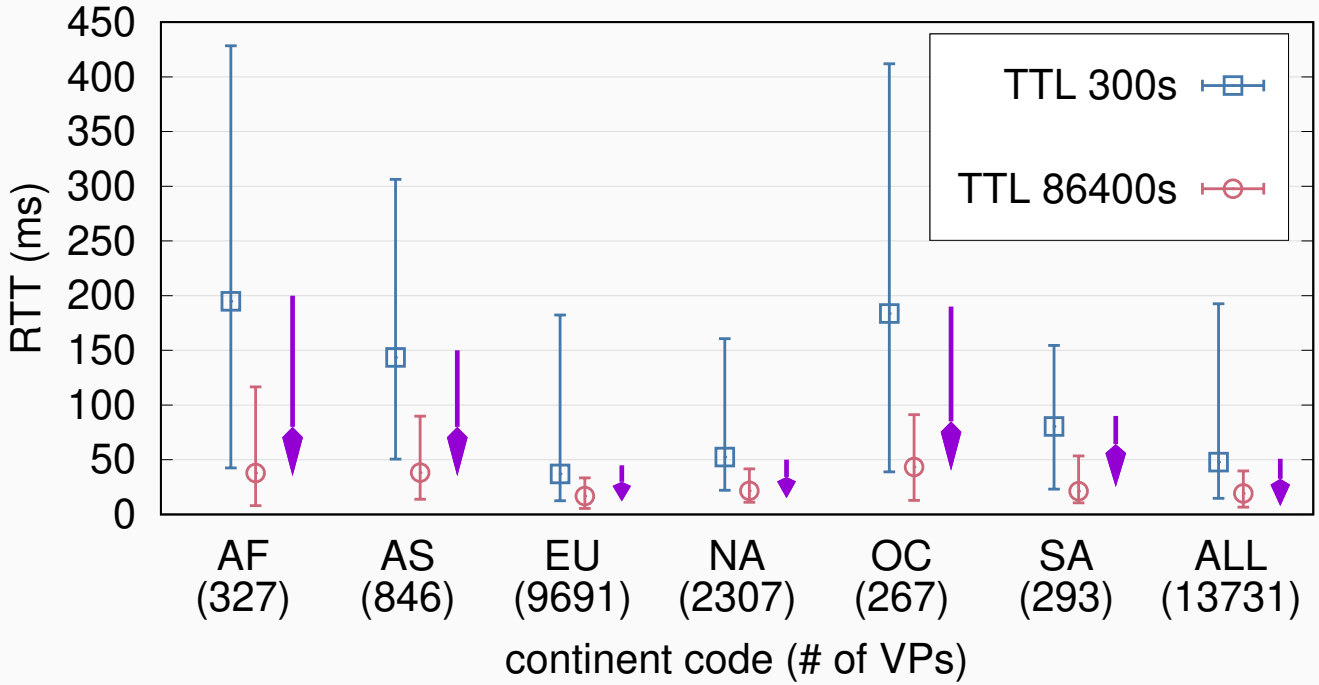


Figure 7: Median RTT as seen by RIPE Atlas VPs per region

Longer TTL → longer caching → faster answers

Up to 150ms median latency reduction (AF)

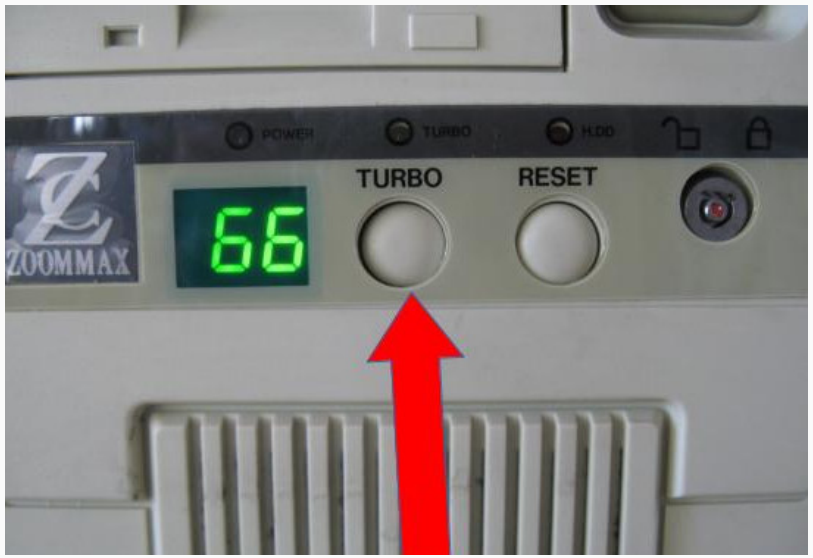
We are no Luiz Suárez... but

- We still helped Uruguayan `.uy` users
- And two other countries:
  - One in East Africa
  - Another one in the Middle East
- Experiment proving how TTLs are important for performance

src: https://commons.wikimedia.org/wiki/File:Luis_Su%C3%A1rez_2018.jpg CC BY-SA 3.0

Longer TTLs are like the old Turbo button

- Some DNS OPs spend 1000s too reduce latency
- Longer TTLs improve latency at **zero cost**



src: wikipedia.org

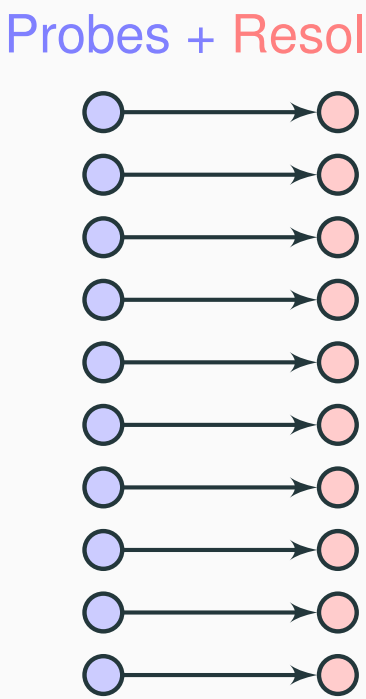
Outline

Caching (Longer TTL) vs Anycast

Caching vs Anycast

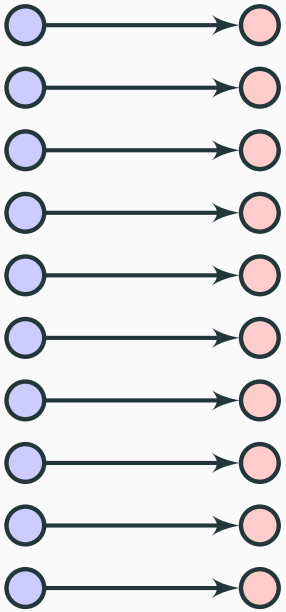
- People and CDNs spend lots on huge anycast deployments
- OPs could say: "*I'll have short TTL since I use anycast*", because anycast can make it up for it.
- **Does anycast really beats caching?**

Caching vs Anycast: experiment

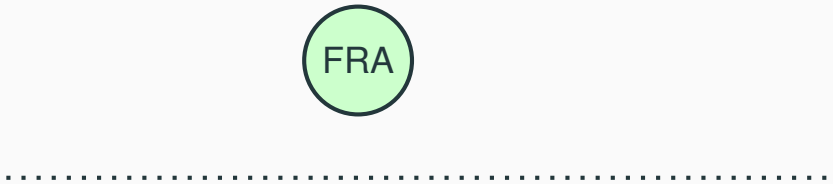


Caching vs Anycast: experiment

Probes + Resolver



Unicast (EC2)



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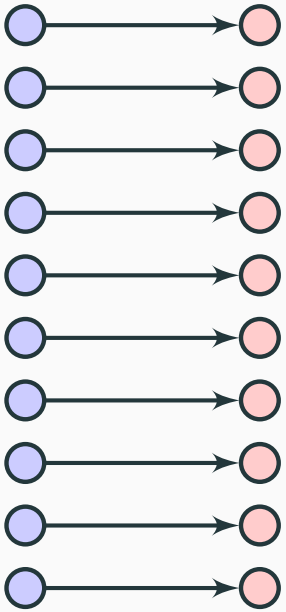

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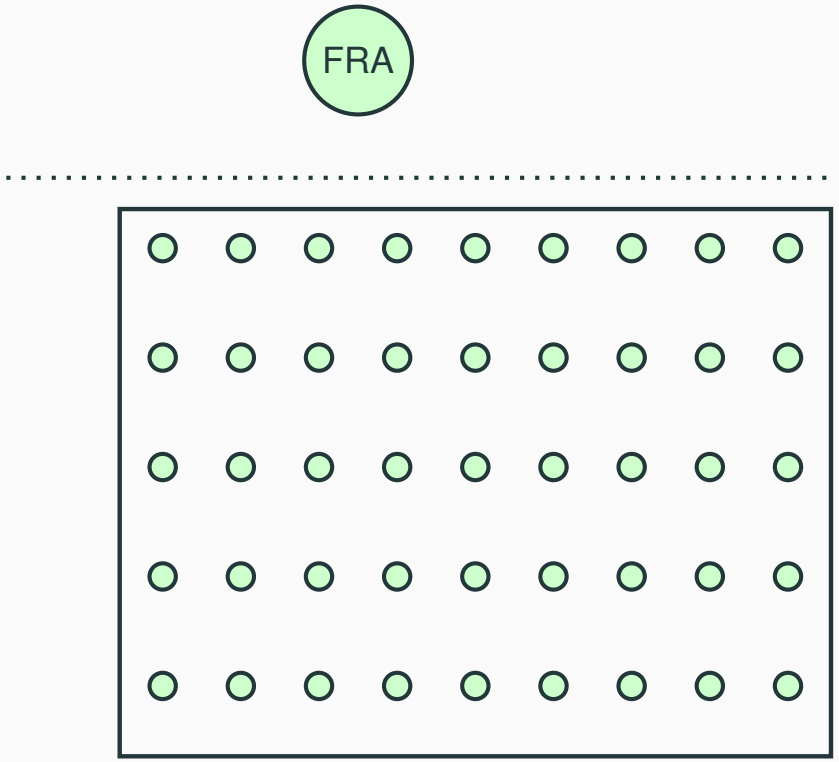
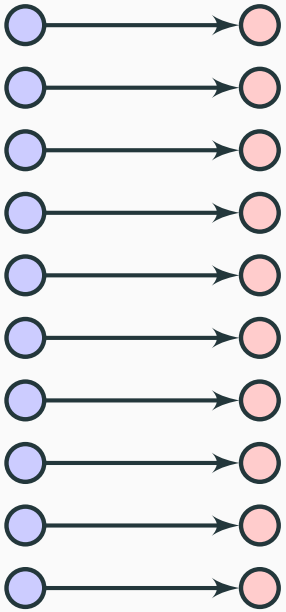


Anycast (Route53)

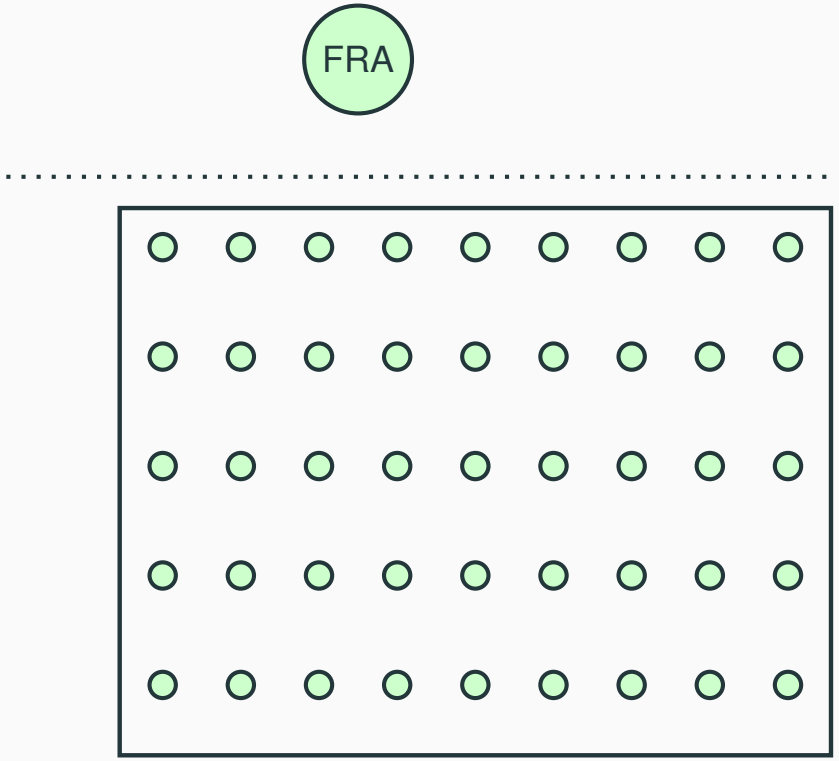
Caching vs Anycast: experiment

Probes + Resolver



Unicast (EC2)

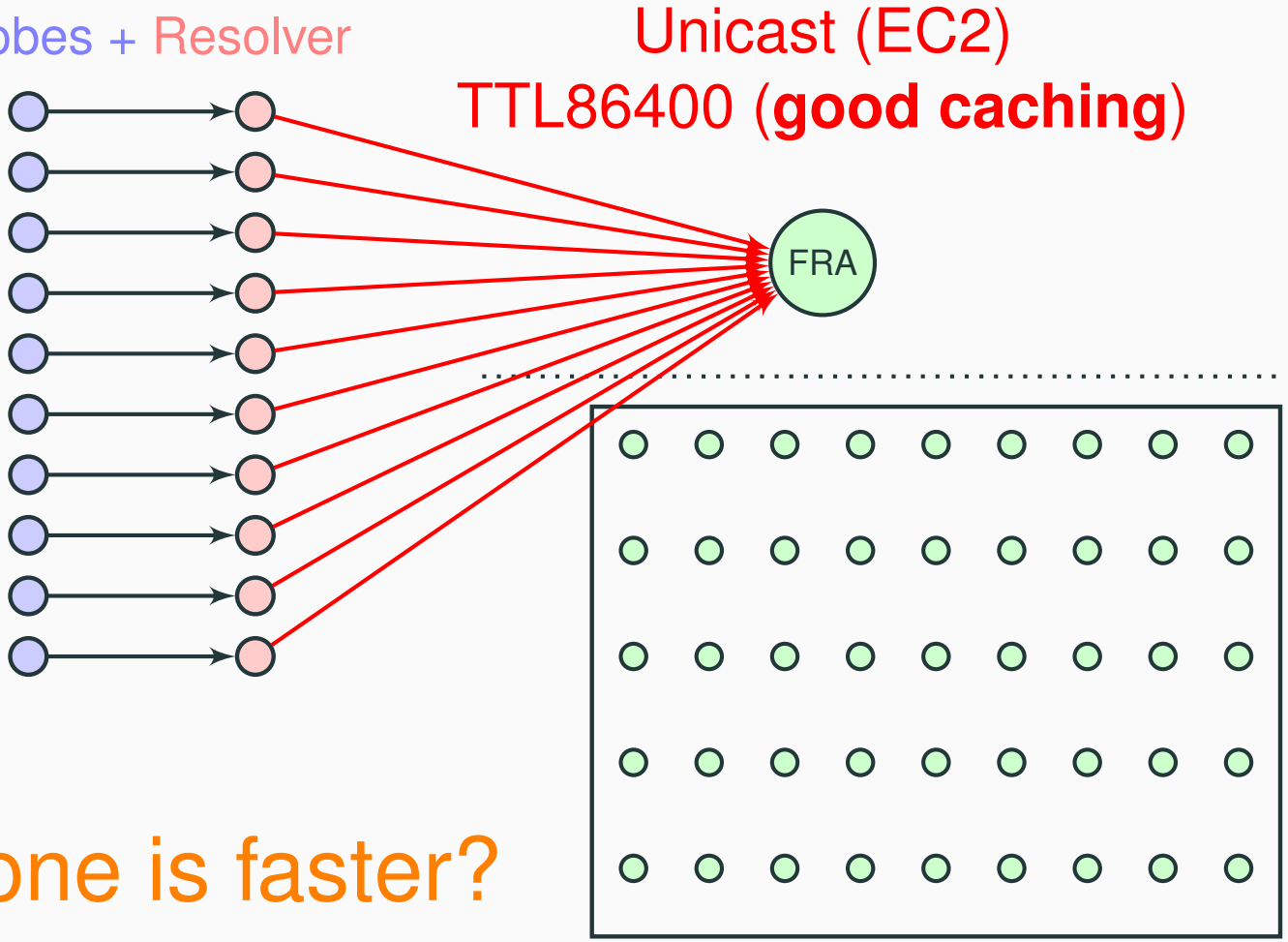
TTL86400 (**good caching**)



TTL60s (**no caching**)

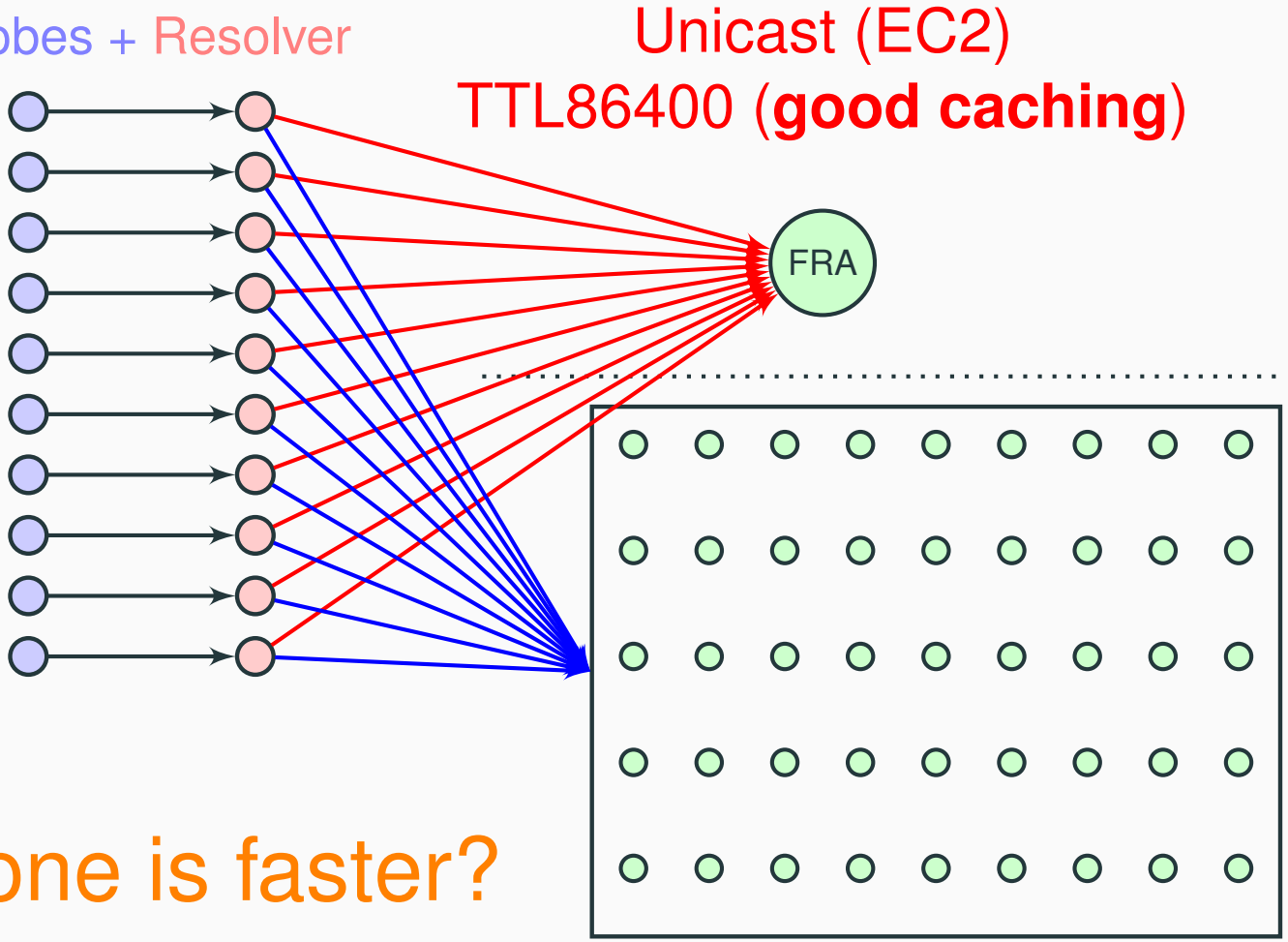
Anycast (Route53)

Caching vs Anycast: experiment



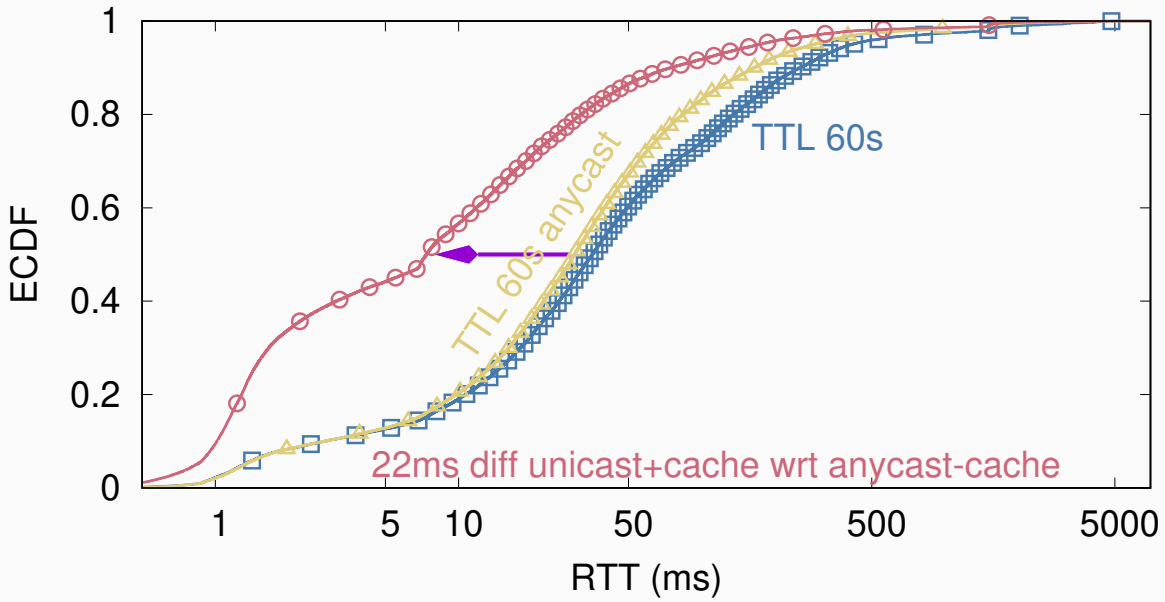
Which one is faster?

Caching vs Anycast: experiment



Which one is faster?

TTLs (caching) matter more than anycast



- Caching near client beats even great server infrastructure!
  - Anycast TTL60 (no cache): **29.96ms** (median)
  - Unicast TTL86400 (cache): **7.38ms** (median):
  - **22ms median latency reduction**
- Query load: **77% down** with caching
- so TTLs matter more for performance
  - (anycast is great to many things too, DDoS for example [2])
  - **We strongly recommend anycast** [5]

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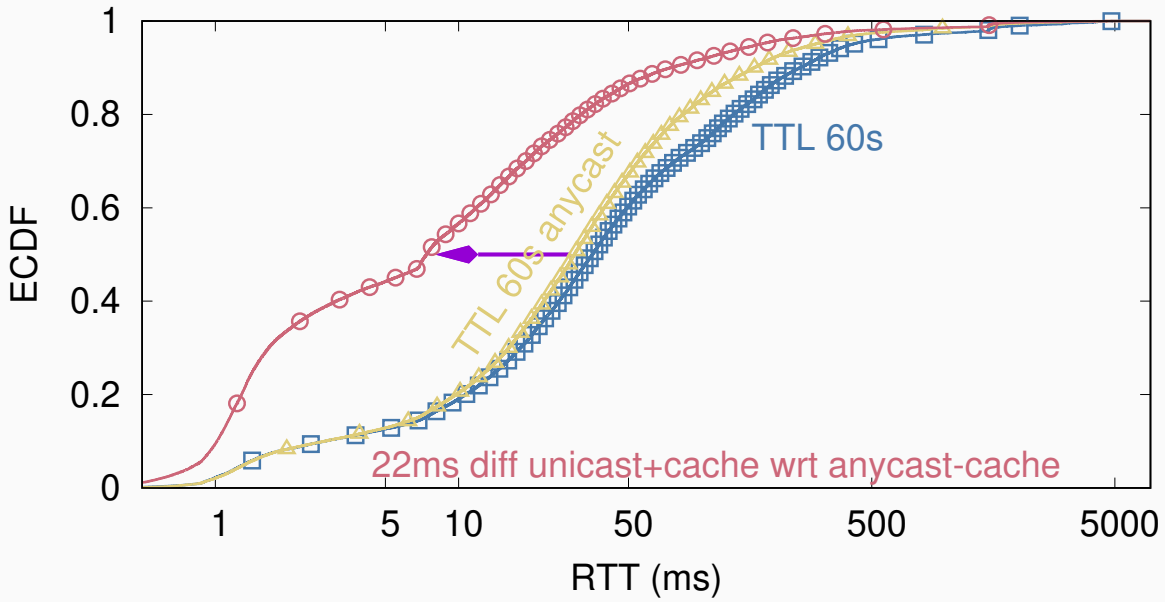

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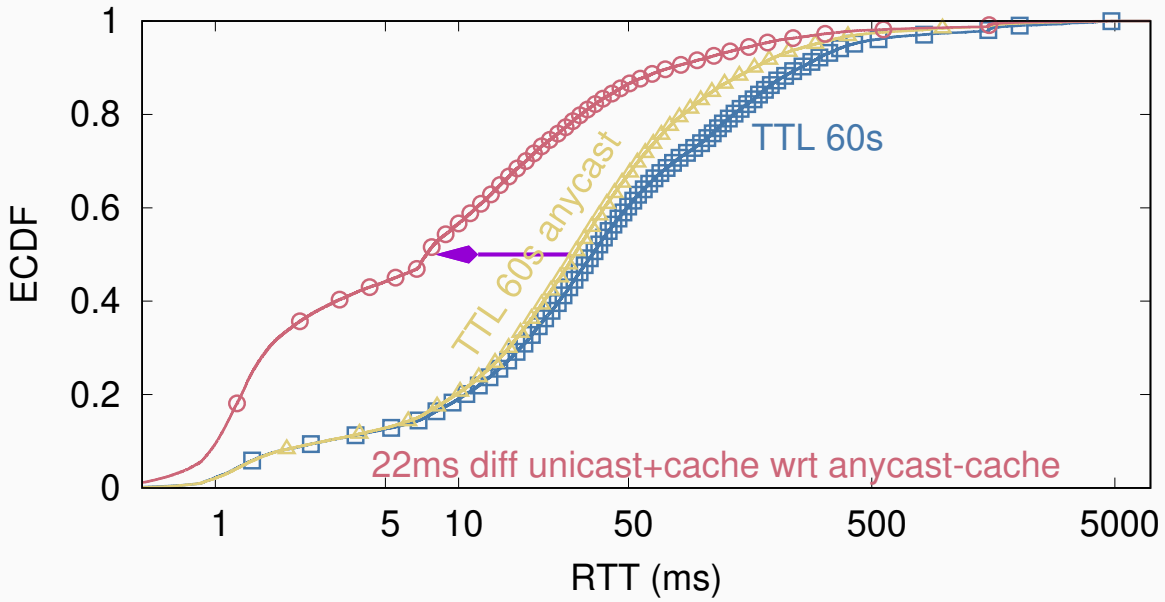

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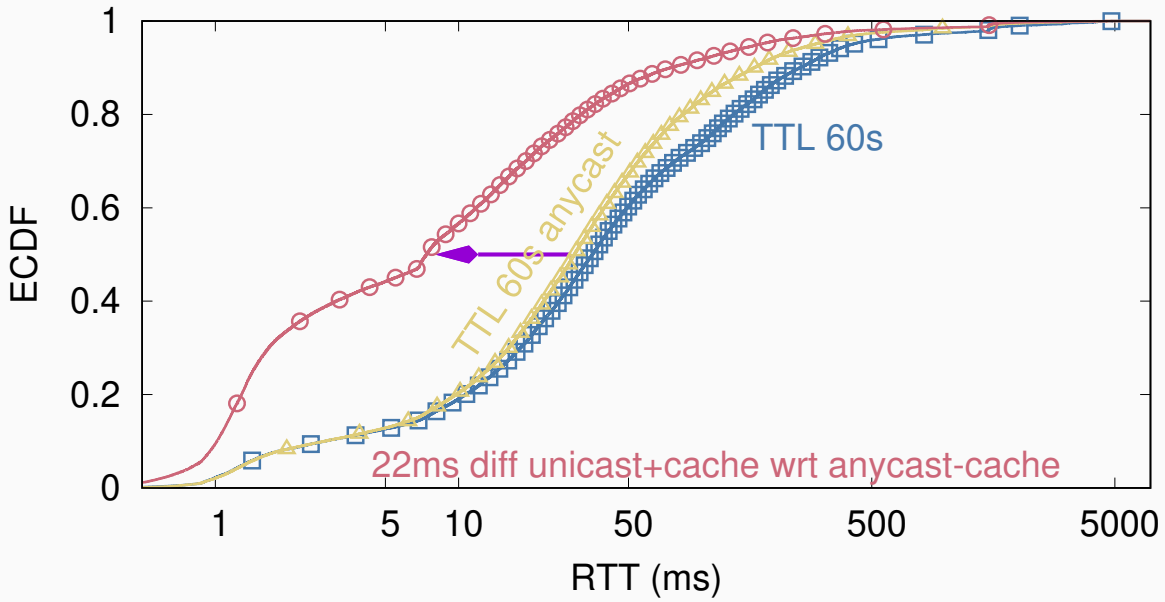

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Outline

Reasons for Longer or shorter TTLs

- **Longer caching**:
  - faster responses
  - lower DNS traffic
  - more robust to DDoS attack [4]
- **Shorter caching**:
  - faster operational changes
  - useful for DNS redirect based DDoS
  - DNS-load balance

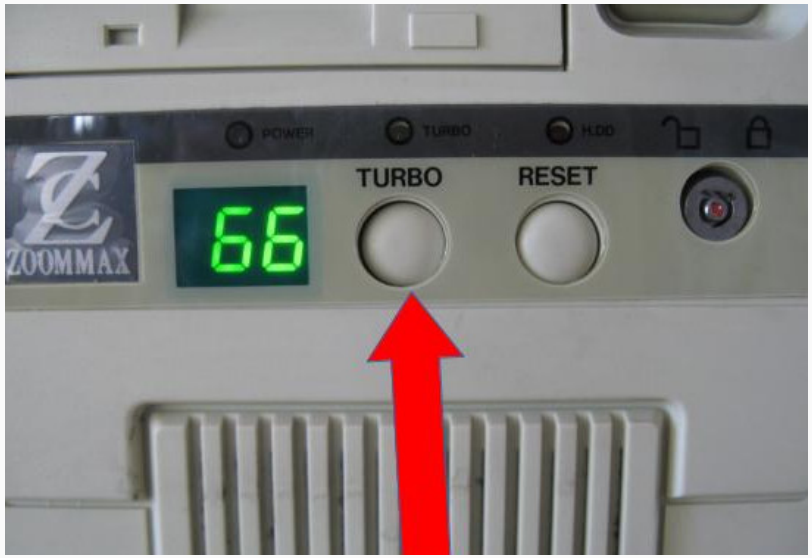
Organizations must weight these trade-offs to find a good balance

Recommendation and Conclusions

Conclusions

- **Recommendation**: **longer TTLs (1 day)** if you can
  - unless using CDN load-balancing or DNS-redir DDoS
- Why? Because it can save you more than 50ms or more
  - But **keep on using anycast** too [2, 5]
- People have designed caches; use them wisely
- **Should you reconsider your TTLs as well?**

- Paper: https://www.isi.edu/~johnh/PAPERS/Moura19b.html
- IETF draft: draft-moura-dnsop-authoritative-recommendations



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[1] de Vries, W. B., de O. Schmidt, R., Haraker, W., Heidemann, J., de Boer, P.-T., and Pras, A.

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In *Proceedings of the ACM Internet Measurement Conference* (London, UK, 2017).

[2] Moura, G. C. M., de O. Schmidt, R., Heidemann, J., de Vries, W. B., Müller, M., Wei, L., and Hesselman, C.

Anycast vs. DDoS: Evaluating the November 2015 root DNS event.

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[3] Moura, G. C. M., Heidemann, J., de O. Schmidt, R., and Hardaker, W.

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[5] Müller, M., Moura, G. C. M., de O. Schmidt, R., and Heidemann, J.

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