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

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Outline

Introduction

Parent vs Child

Zone configurations and Effective TTL

TTLs Use in the Wild

- Operators Notification

Caching (Longer TTL) vs Anycast

- Shorter vs Longer TTLs

Recommendation and Conclusions

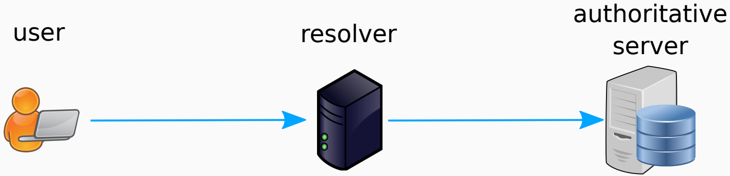
Our research on DNS over the last years

Our research 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)

Introduction

The role of TTL



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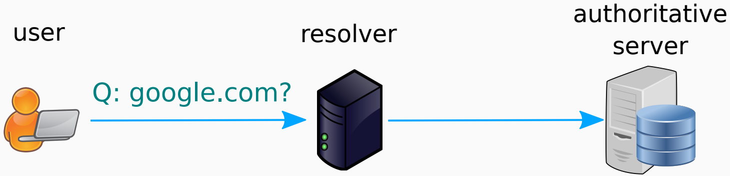

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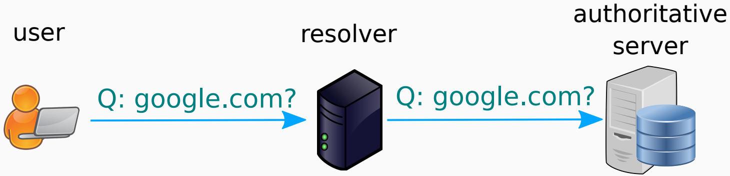

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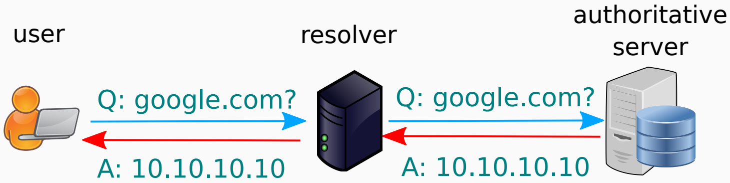

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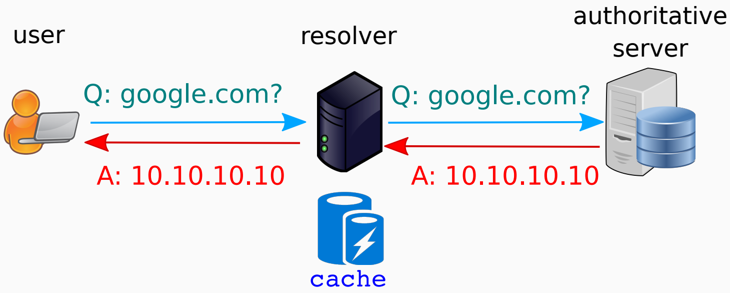

user

resolver

authoritative server

Q: google.com?

Q: google.com?

A: 10.10.10.10

A: 10.10.10.10

cache

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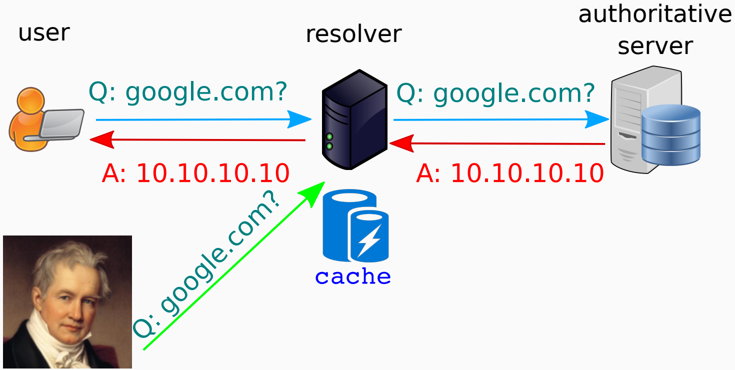

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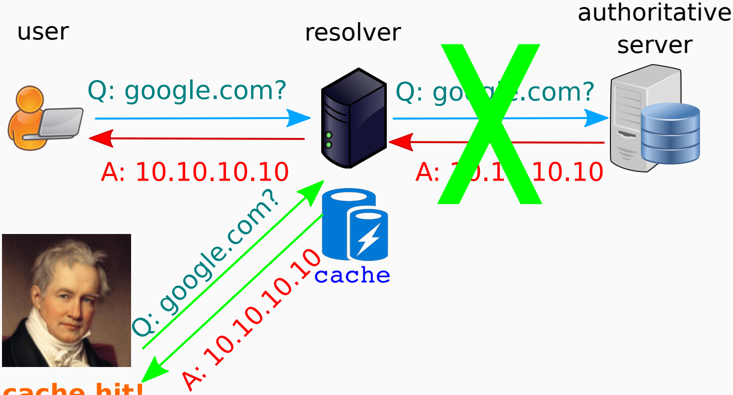

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Q: google.com?

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X

cache

Q: google.com?

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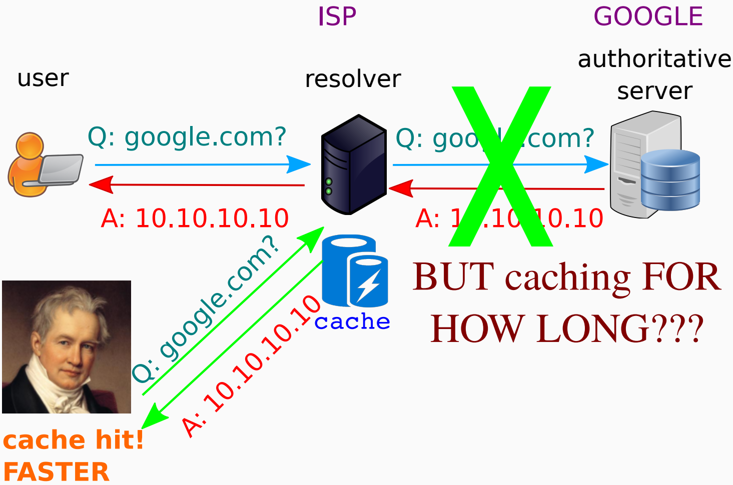
cache hit!
FASTER

The role of TTL



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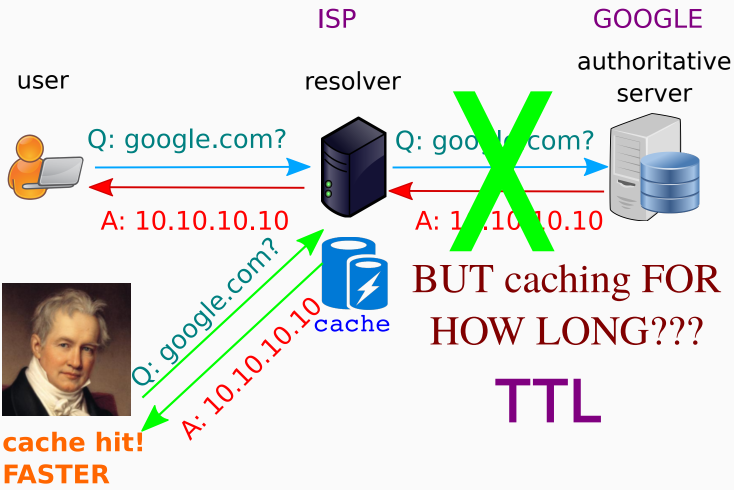
BUT caching FOR HOW LONG???

The role of TTL



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FASTER

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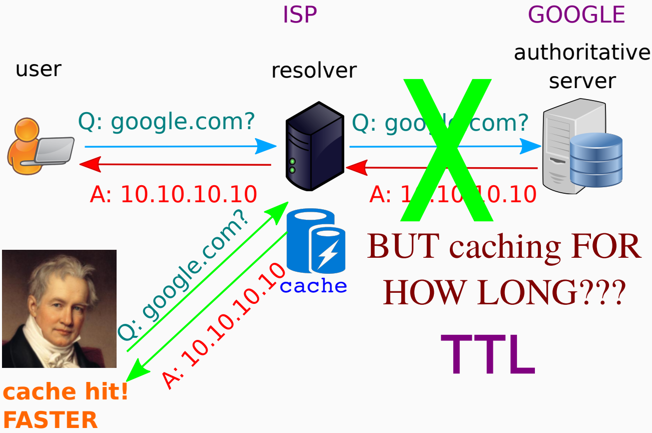
TTL

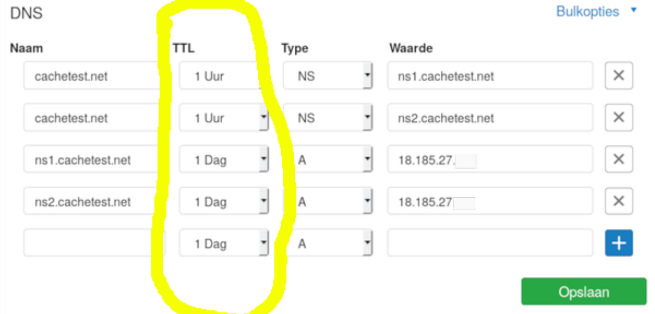
The role of TTL



- **TTL controls caching**
  - SIGNAL from auth servers to resolvers: **maximum** time length
- Caching is VERY important for performance
  - improves user experience *(aka happy eyeballs)*

And you must set TTLs

- Say you register `cachetest.net`



DNS

Naam	TTL	Type	Waarde
cachetest.net	1 Uur	NS	ns1.cachetest.net
cachetest.net	1 Uur	NS	ns2.cachetest.net
ns1.cachetest.net	1 Dag	A	18.185.27.[redacted]
ns2.cachetest.net	1 Dag	A	18.185.27[redacted]
	1 Dag	A	

What TTL values are good?

Operators:

- are given little guidance today about correct values
- and are resistant to (scared to!) make changes
  - **“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

Our research contributions:

1. The *effective* TTL comes from **multiple** places
   - Parent authoritative servers
   - Child authoritative servers
   - Both NS and A records (sometimes)
2. Currently popular TTLs are unnecesssarily short
   - a. because sometimes multiple places → 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 ∼**20ms median latency improvement; 171ms 75%ile**

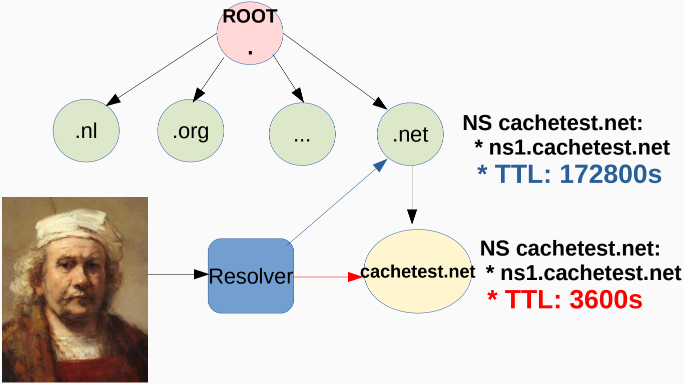
The rest of this talk

1. Parent vs Child: which TTLs to resolvers believe?
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`



NS cachetest.net:
* ns1.cachetest.net
* TTL: 172800s

NS cachetest.net:
* ns1.cachetest.net
* TTL: 3600s

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

Are resolvers parent- or child-centric?

Parent vs Child experiment

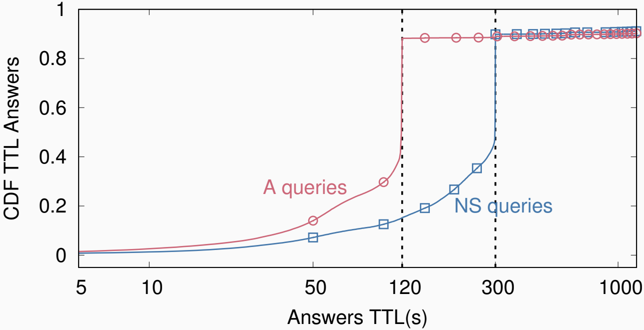
- Test with experiment on `.uy`: (2019-02-14)

Parent	NS TTL	172800s
	A TTL	172800s
Child	NS TTL	300s
	A TTL	120s

- We query with 15k Atlas VPs multiple 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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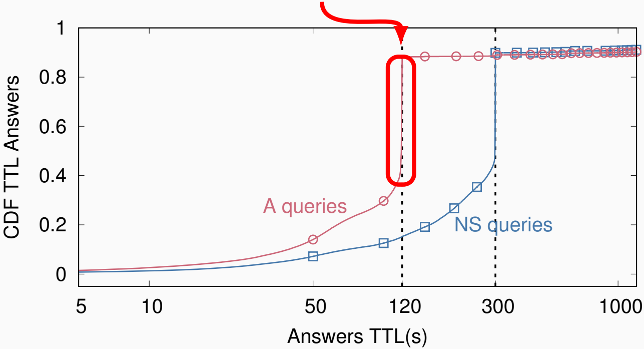

Spike at Child TTL A (120s) : most resolvers are child centric

- Remember: TTL parents: 2 days

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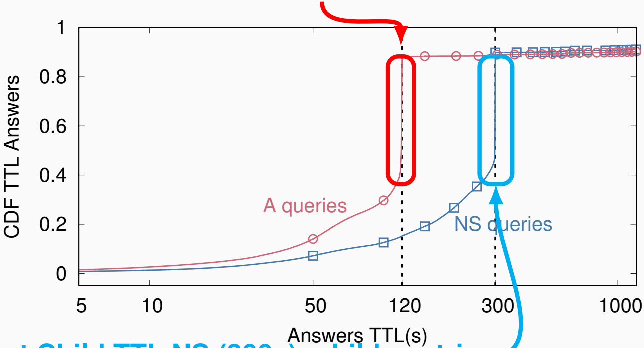


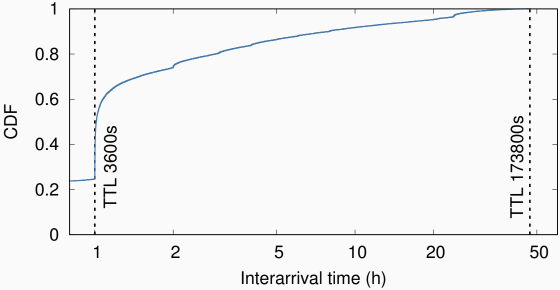
Spike at Child TTL NS (300s): child centric

- 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**



We confirmed this with a second-level domain (paper)

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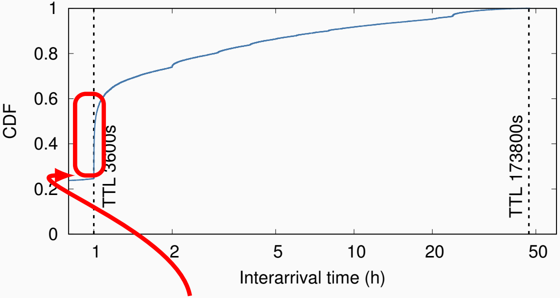

Spike at Child TTL A (3600s): confirm child centric for TLD

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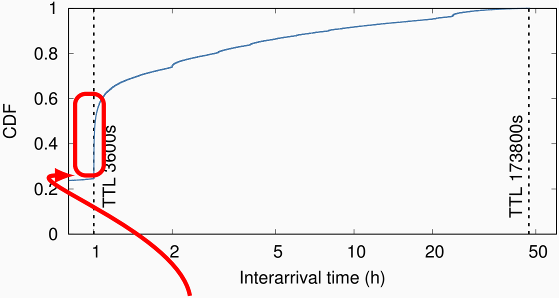
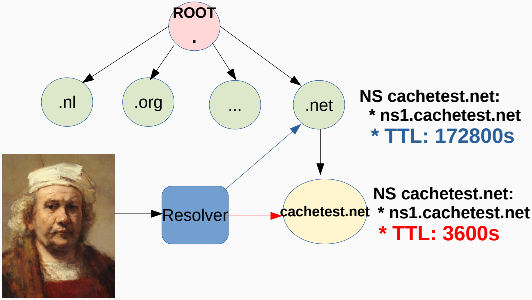


Spike at Child TTL A (3600s): confirm child centric for TLD

We confirmed this with a second-level domain (paper)

Most resolvers will use child TTLs

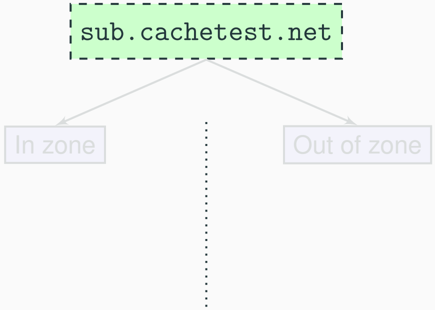
- Rembrant (and users) mostly use child TTLs
- The **Child TTL** controls caching (most times)



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

Zone configurations and Effective TTL

Are there dependencies between A and NS TTLs?



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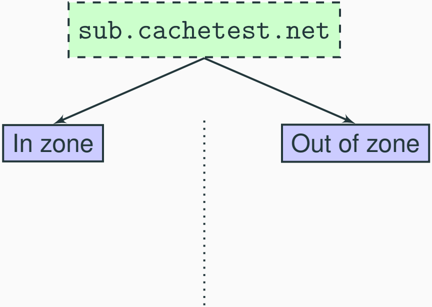

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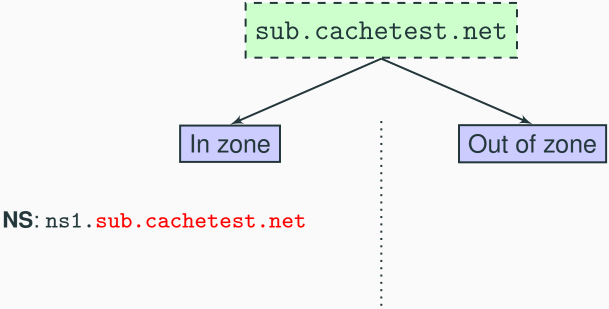

sub.cachetest.net

In zone

Out of zone

NS: ns1.sub.cachetest.net

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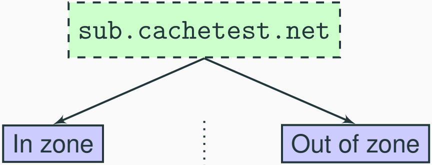

NS: ns1.sub.cachetest.net

NS: ns1.zurrundeddu.com

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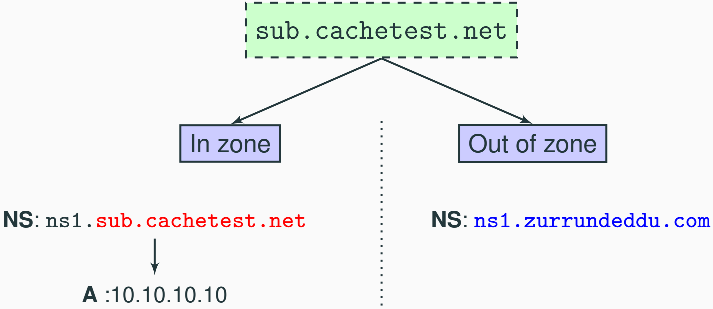

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In zone

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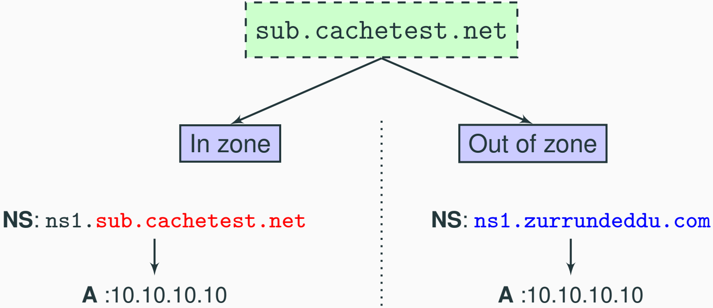

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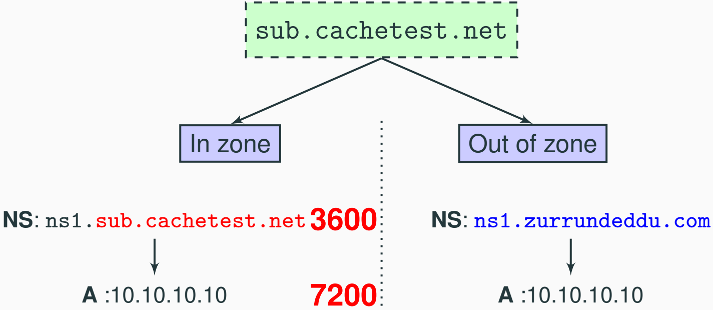

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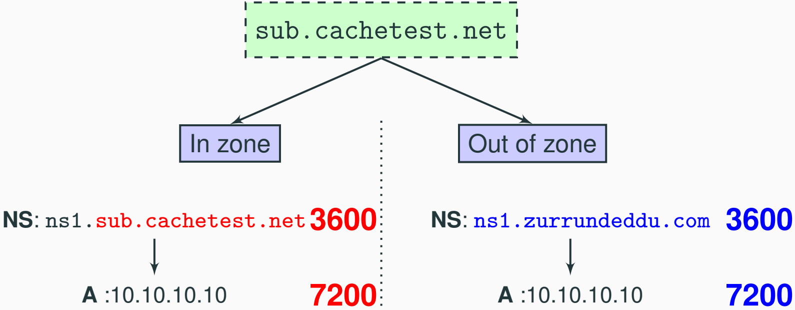

`sub.cachetest.net`

In zone

NS: `ns1.sub.cachetest.net` **3600**

A :10.10.10.10 **7200**

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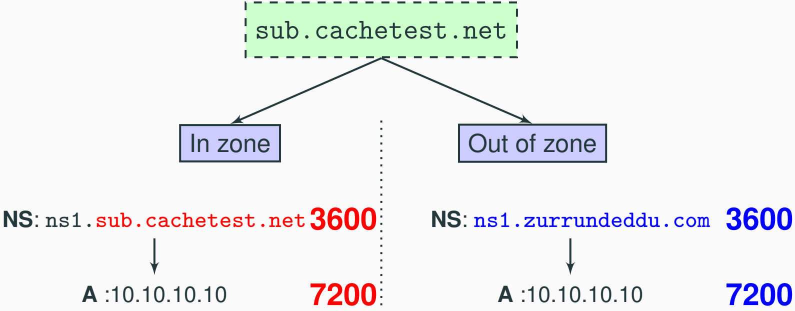

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To resolve *.sub.cachetest.net, you need both **NS** and **A**

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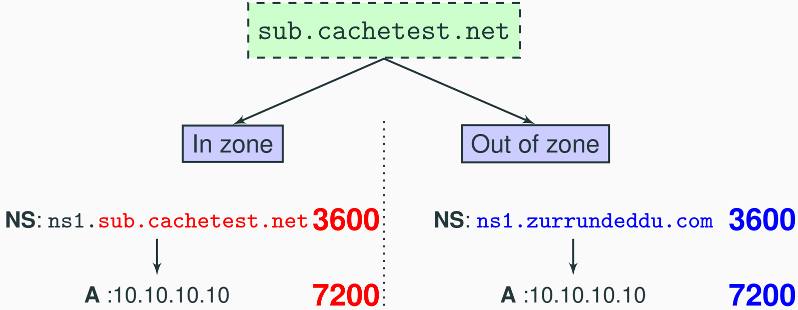

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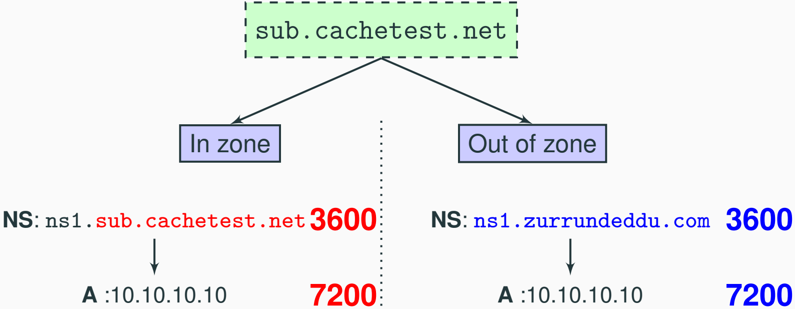

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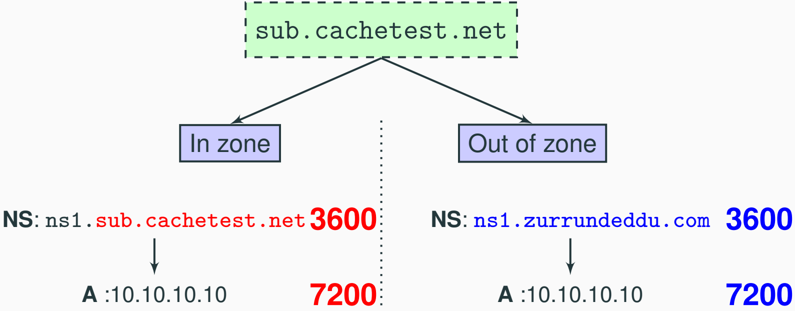

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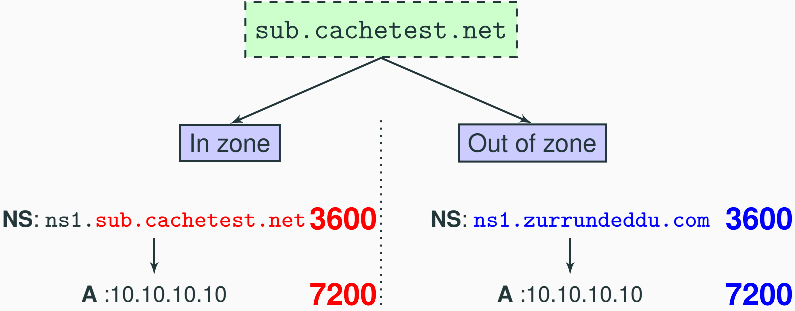

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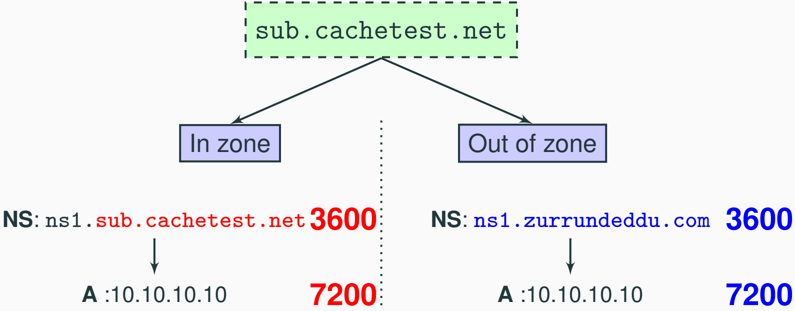

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trick: at `t=540`, *we renumber A to 10.10.10.2* (diff answer)

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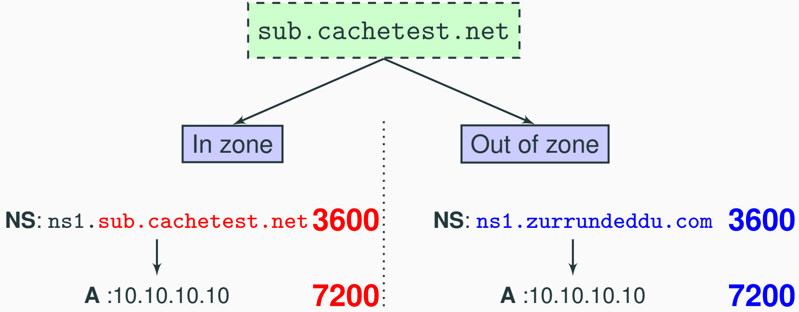

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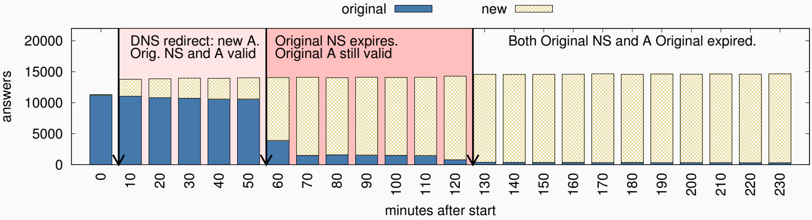
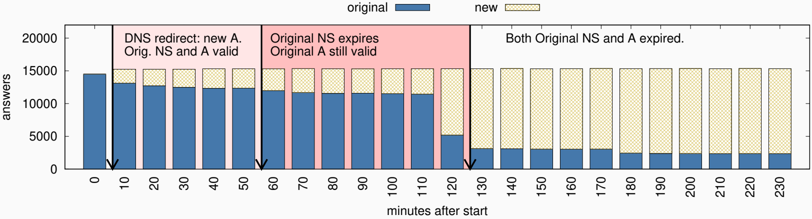
Will Marcus Aurelius receive cached or new answer?

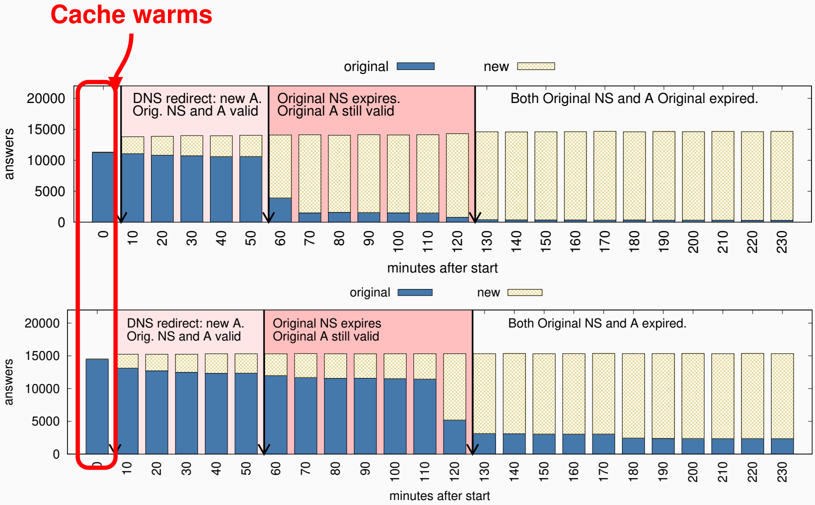
Are they dependent? Yes, for in zone





Are they dependent? Yes, for in zone

Cache warms



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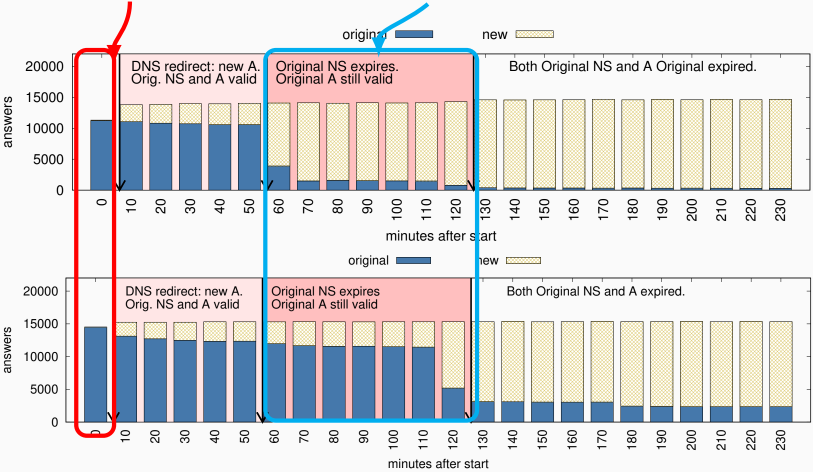
Cache warms

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



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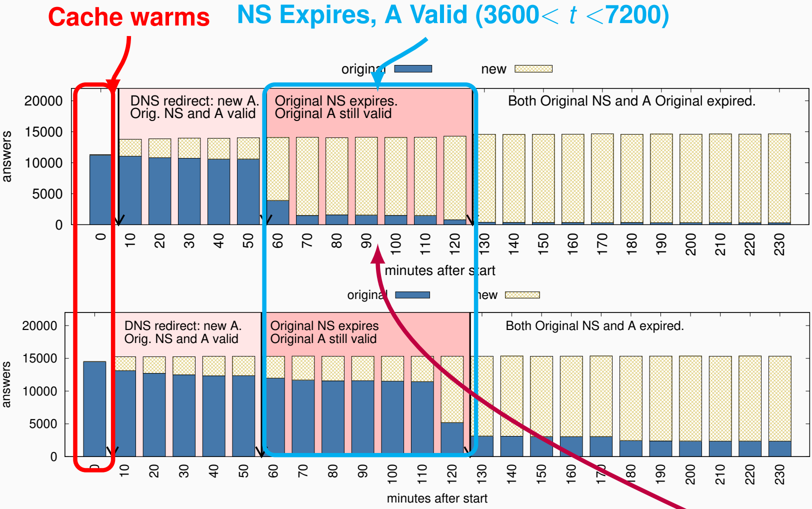

Cache warms

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

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

Are they dependent? Yes, for in zone

Cache warms

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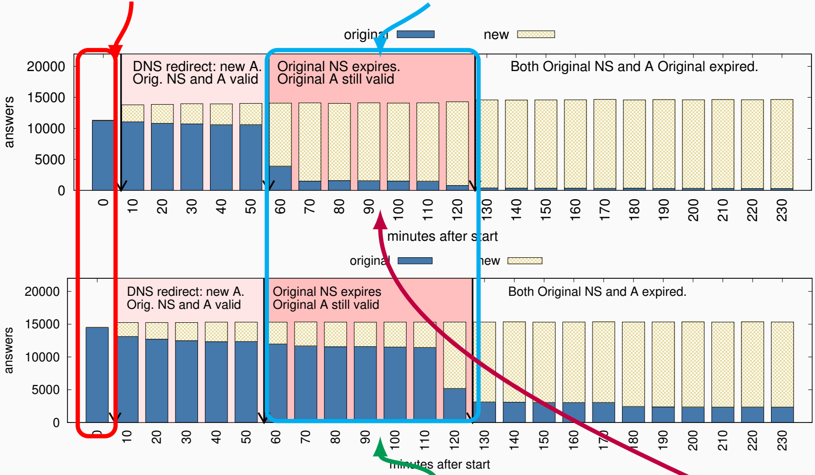

out-of- zone: cached A (old server): independent caching?

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

Are they dependent? Yes, for in zone

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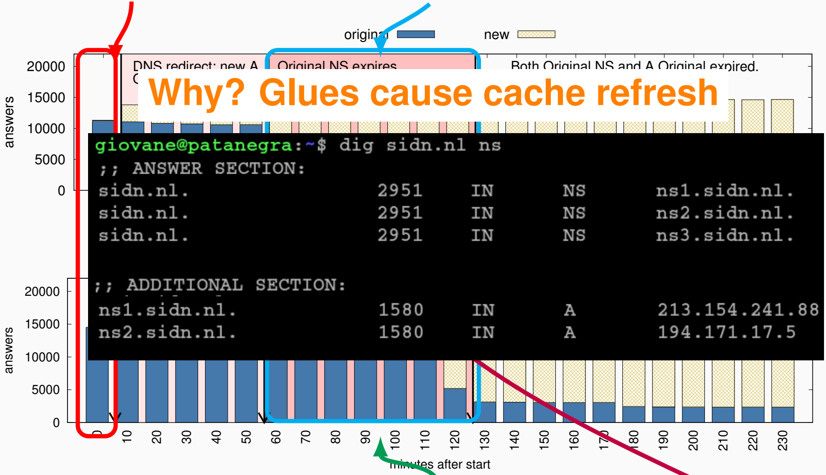

Why? Glues cause cache refresh

```
giovane@patanegra:~$ dig sidn.nl ns
;; ANSWER SECTION:
sidn.nl.                2951    IN      NS      ns1.sidn.nl.
sidn.nl.                2951    IN      NS      ns2.sidn.nl.
sidn.nl.                2951    IN      NS      ns3.sidn.nl.

;; ADDITIONAL SECTION:
ns1.sidn.nl.            1580    IN      A       213.154.241.88
ns2.sidn.nl.            1580    IN      A       194.171.17.5
```

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

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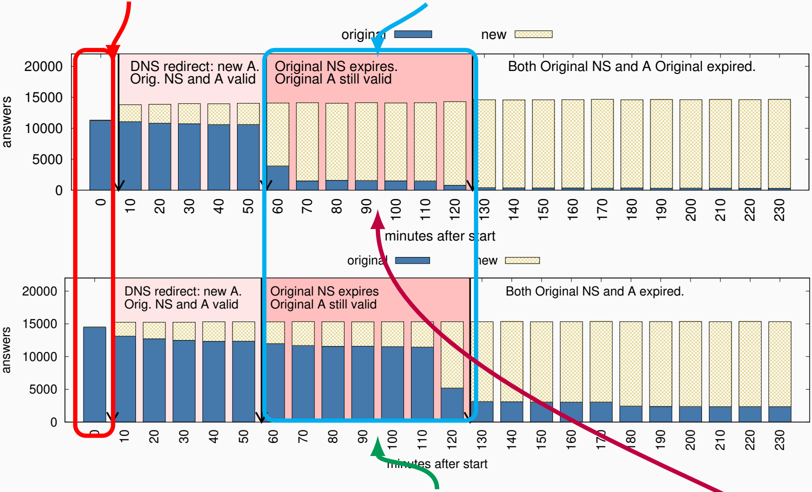
Cache warms

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



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

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

Are there dependencies between A and NS TTLs?

src:
https://en.wikipedia.org/wiki/Marcus_Aurelius
CC BY-SA 3.0

- Marcus Aurelius will notice“early” refreshed A for in-zone (in bailiwick)
- Zone configuration impacts caching too, not just TTLs

Outline

- Introduction
- Parent vs Child
- Zone configurations and Effective TTL
- TTLs Use in the Wild
    - Operators Notification
- Caching (Longer TTL) vs Anycast
    - Shorter vs Longer TTLs
- Recommendation and Conclusions

TTLs Use in the Wild

How are TTLs used in the wild?

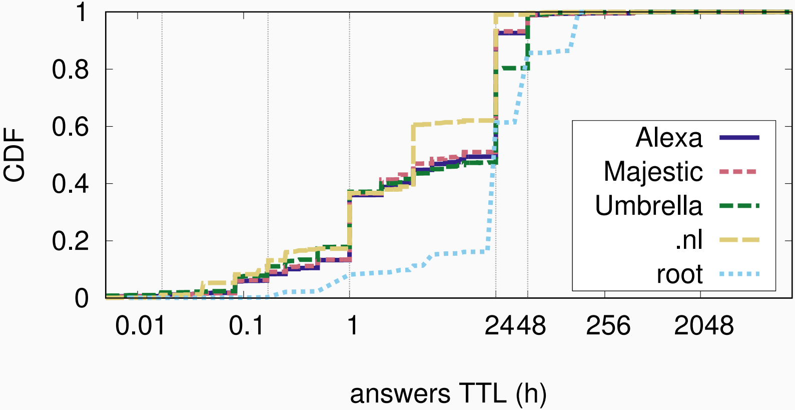
- There is no consensus how to choose TTLs
- But folks have to choose them anyway
- We use 5 lists:
  - Alexa
  - Majestic
  - Umbrella
  - `.nl` Zone
  - Root Zone (TLDs)
- We probe several records types
- We analyze **child TTL** values
- We discussed results with some operators

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

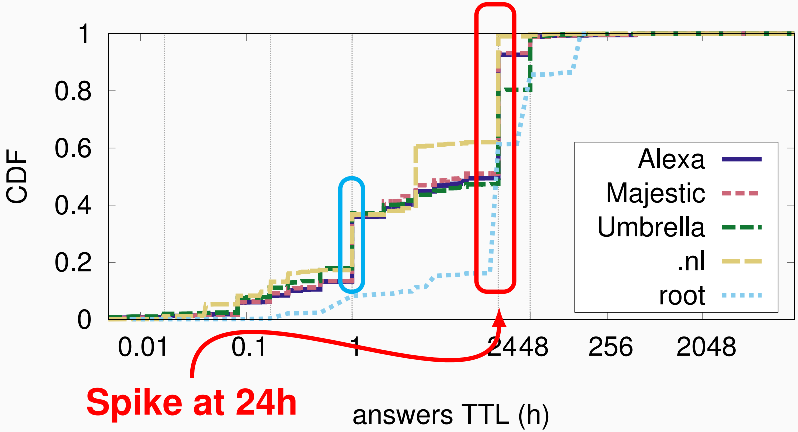
- Out of bailiwick (out-of-zone):
    - **records are cached independently** (no glues)
- Chosen TTLs values for different records will be respected

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)

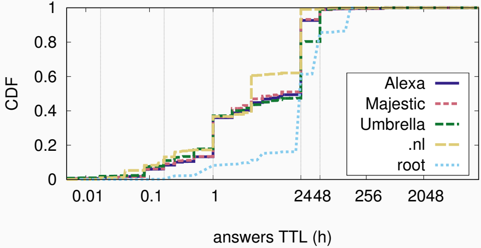
NS records have longer TTLs (>24h)

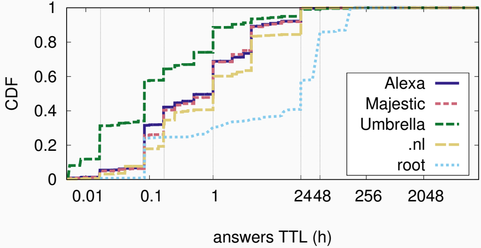


Spike at 24h

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

A records have far shorter TTLs than NS





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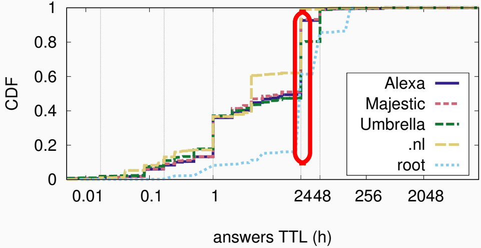
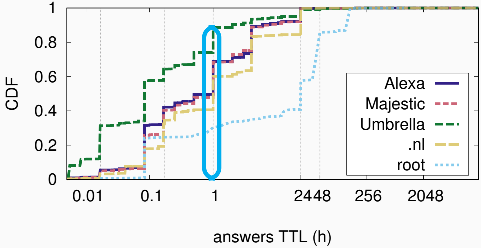
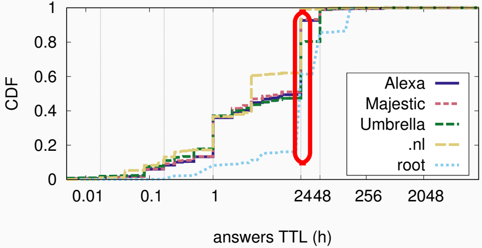
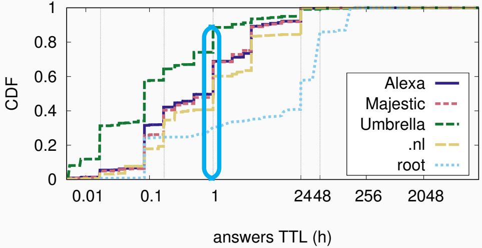




A records have far shorter TTLs than NS



Shorter A records TTLs leads to poor caching



Operators Notification: 3 changed their TTLs

- We found **34 TLDs** with short NS TTL ($<=$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 changed: 300s to 86400s

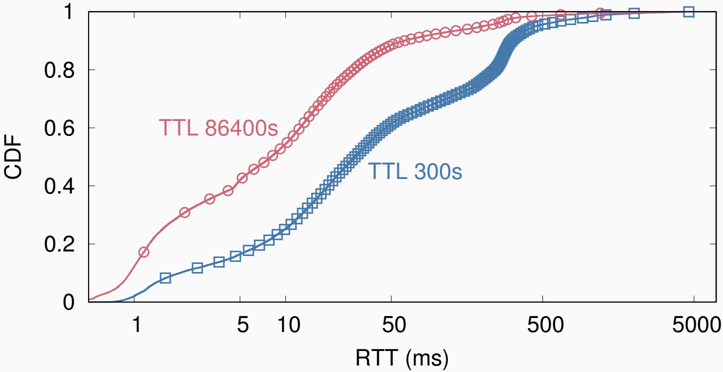


Figure 4: RTT from RIPE Atlas VPs for NS .uy queries (NS)

.uy latency reduced a lot!

- .uy NS TTL changed: 300s to 86400s

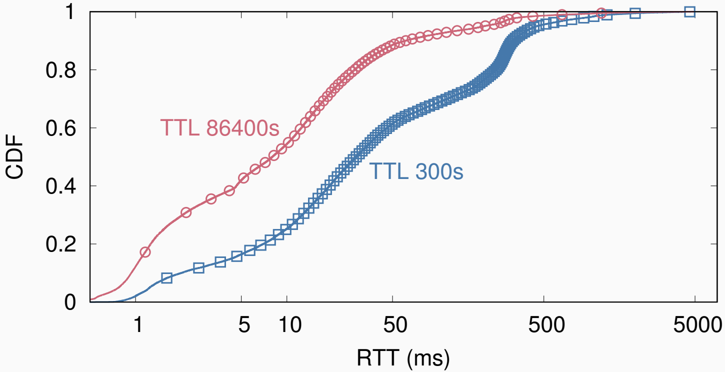


Figure 4: RTT from RIPE Atlas VPs for NS .uy queries (NS)

.uy latency reduced a lot!

- .uy NS TTL changed: 300s to 86400s: lowered client latency

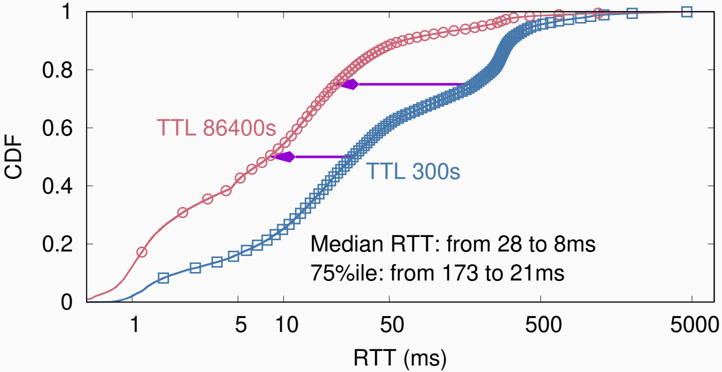


Figure 5: RTT from RIPE Atlas VPs for NS .uy queries (NS)

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

.uy latency reduced for all regions

Check for Atlas location bias

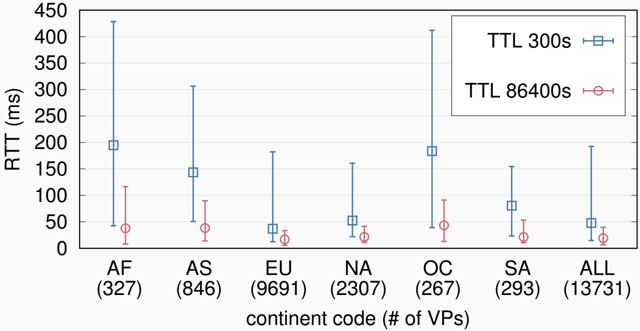


Figure 6: Median RTT as seen by RIPE Atlas VPs per region

Longer TTL → longer caching → faster answers

.uy latency reduced for all regions

Check for Atlas location bias

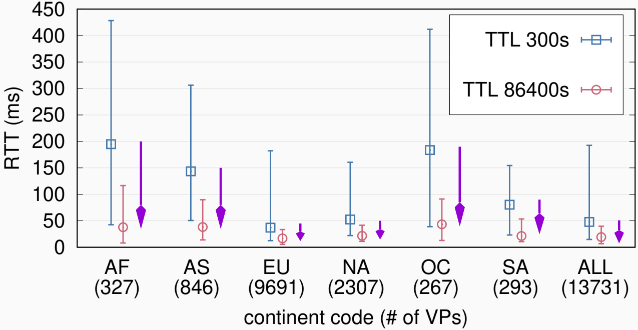


Figure 7: Median RTT as seen by RIPE Atlas VPs per region

Longer TTL → longer caching → faster answers

Up to 150ms median latency reduction (AF)

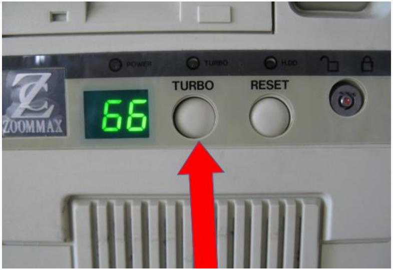
We are no Luiz Suárez... but

- We still helped Uruguayan `.uy` users
- And two other countries:
  - One in East Africa
  - Another one in the Middle East
- Experiment proved 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 of *(your currency here)* too reduce latency
- Longer TTLs improve latency at **zero cost**



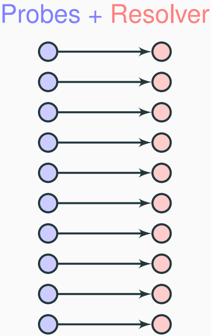
src: wikipedia.org

Caching (Longer TTL) vs Anycast

Caching vs Anycast

- There are many large, expensive anycast deployments
- OPs could say:
  - “*I’ll have short TTL since I use anycast*”,
  - because anycast can make it up for it.
- **Does anycast actually beat caching?**

Caching vs Anycast: experiment



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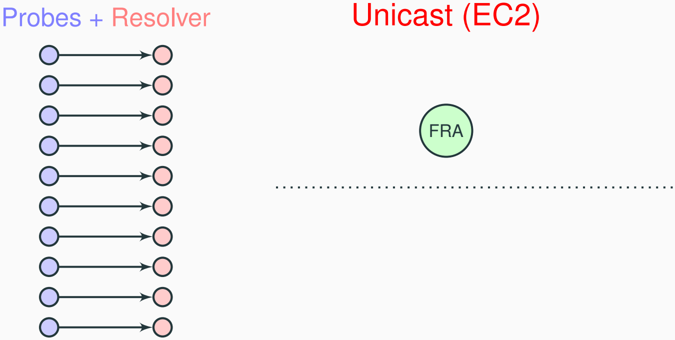

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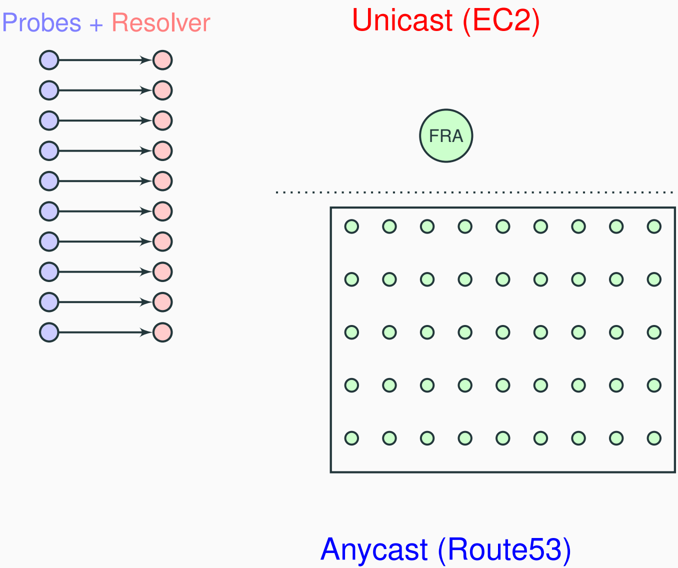

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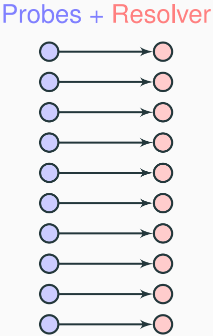
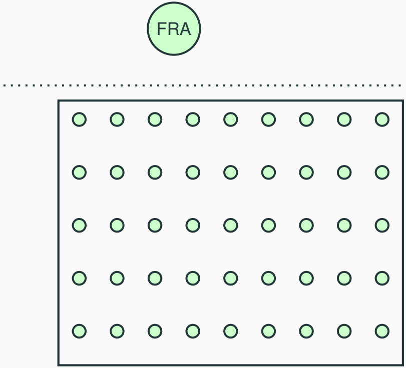
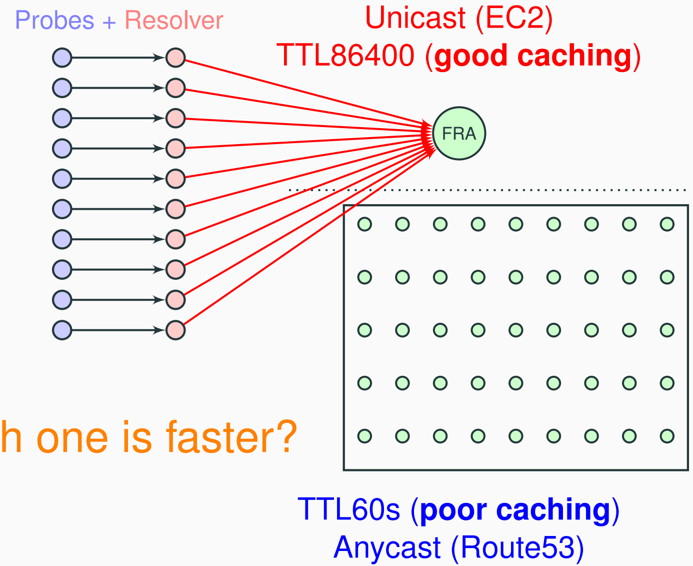


Unicast (EC2)
TTL86400 (**good caching**)



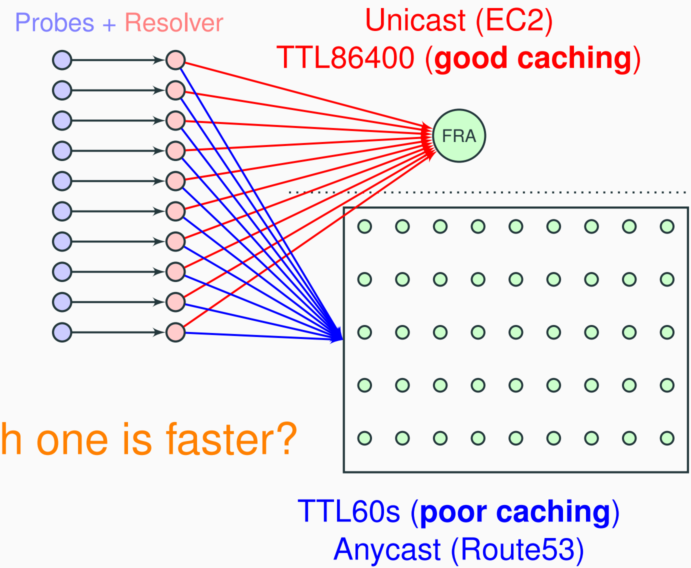
TTL60s (**poor caching**)
Anycast (Route53)

Caching vs Anycast: experiment



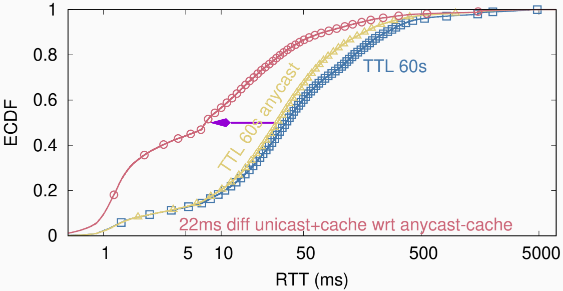
Which one is faster?

Caching vs Anycast: experiment



Which one is faster?

TTLs (caching) matter more than anycast



- Near-client caching beats great infrastructure!
  - Anycast TTL60 (no cache): **29.96ms** (median)
  - Unicast TTL86400 (cache): **7.38ms** (median):
  - **22ms median latency reduction**
- Query load: **77% down** with caching
- Conclusion: TTLs matter more for performance
  - (anycast is needed for other things too, e.g. DDoS [2])
  - **We still strongly recommend using anycast** [5]

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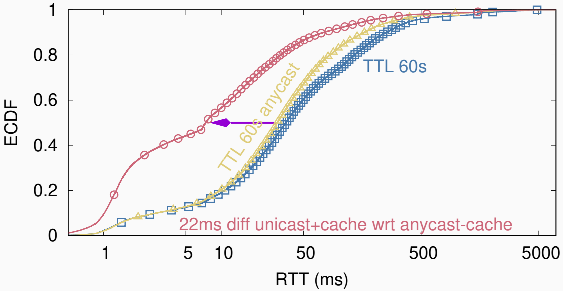

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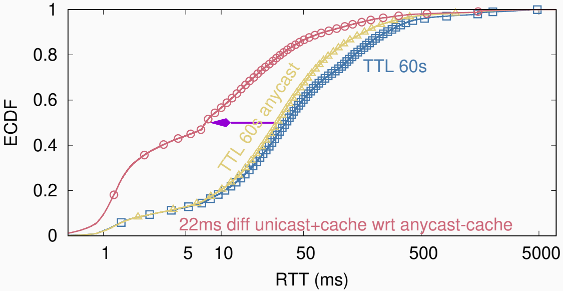

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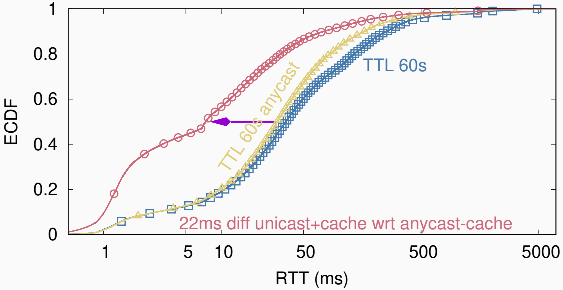

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Reasons for Longer or shorter TTLs

- **Longer caching**:
  - faster responses to clients
  - lowers DNS traffic levels
  - more robust to DDoS attacks [4]
- **Shorter caching**:
  - faster operational value changes
  - useful for DNS redirect based DDoS scrubbing services
  - DNS-load balancing

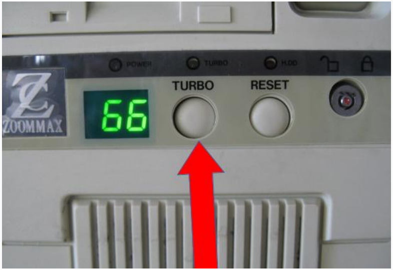
Organizations must weight these trade-offs to find a good balance

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 50ms or more
  - But **keep on using anycast** too [2, 5]
- **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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[2] Moura, G. C. M., de O. Schmidt, R., Heidemann, J., de Vries, W. B., Müller, M., Wei, L., and Hesselman, C.

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[3] MOURA, G. C. M., HEIDEMANN, J., DE O. SCHMIDT, R., AND HARDAKER, W.

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