

# DNS: Unveiling the Critical Link in Internet Security and Exploring Diverse Use Cases

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**Giovane C. M.Moura**

SIDN Labs and TU Delft

**WTMC'23 – Opening Keynote**

Delft, The Netherlands

2023-07-07



# Today's Goals



No

img src: [Unsplash](#)



Yes

img src: [wallpaperflare](#)

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1. Show how can you use DNS in your research on:
  - Internet Security
  - Networking
2. Provide references and pointers
  - papers
  - datasets
  - (text in red is clickable)



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\$whoami

- Data Scientist at **SIDN Labs**
  - research team of SIDN, .nl registry
- Assistant Professor at **TU Delft**
  - my office at TU Delft is in this building :)
- Research focus on **operations**:
  - Internet Security
  - Networking
  - Systems
- PhD (2013, **UTwente**, NL)
- MSc (2008, **UFRGS**, BR)



*Presentation @ RIPE86, Rotterdam, May 2023*

# Today's presentation

Counterfeit webshops

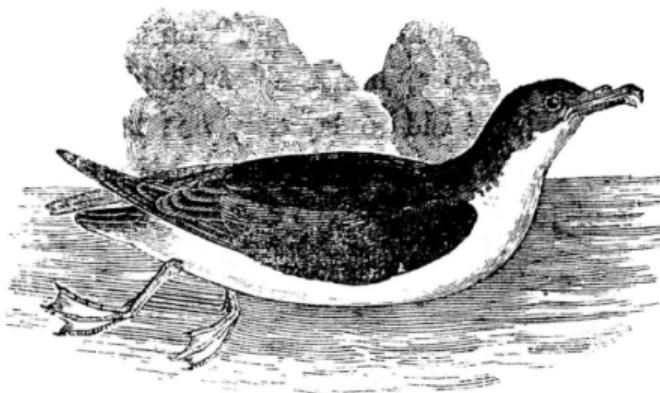
Logo Misuse

E-gov DNS

Wrap-up

# Common reactions when people here “DNS”

Reaction #1



DO NOT CARE, GOODBYE

@EFFINBIRDS

Reaction #2



# My hope for the day



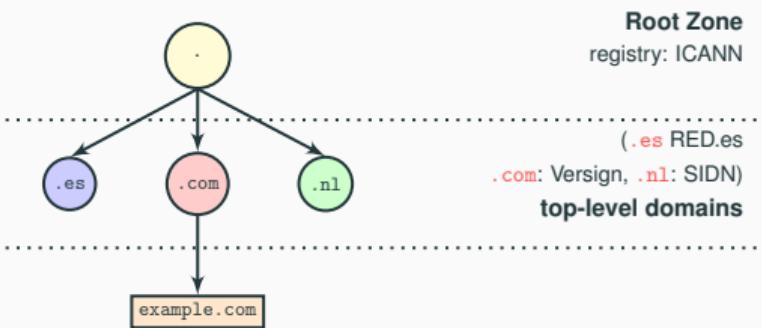
img src: [Unsplash](#)

(Slides will be online, content in red is clicklable link)

# What is DNS?

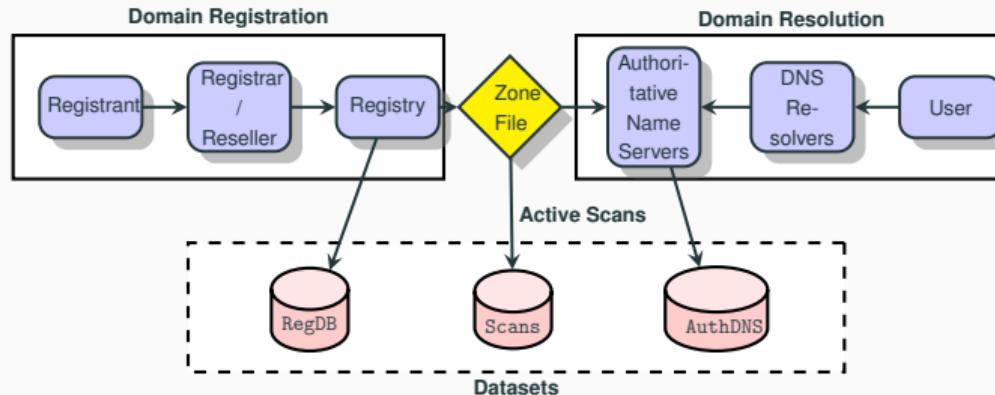
- several protocols
- distributed database
- client-server-server architecture
- routing
- governance
- security
- performance
- 2000+ pages of documentation ([DNS Camel](#))

# DNS as a distributed database



- Each node in the tree is managed by a different organization
- Why?

# A DNS registry and .nl



**Figure 1:** TLD operations: registration (left), domain resolution (right), and datasets.

# Outline

Counterfeit webshops

Logo Misuse

E-gov DNS

Wrap-up

# Back in 2016 ... strange websites

- We stumbled on these websites while looking for phishing
- They were rather *odd*
- We had many questions:
  1. does anyone even *buy* from them?
  2. what is their *business model*?
  3. how many they were (on .nl)?
  4. what can we do about it?

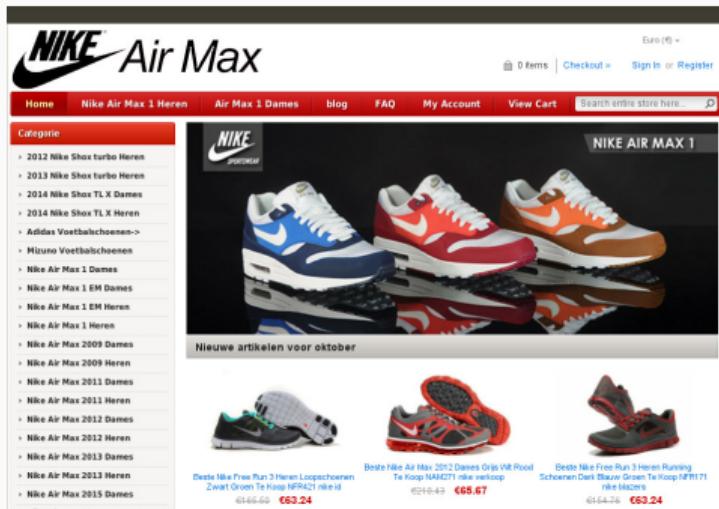


Figure 2: Screenshot of 2016 .nl website

# Does anyone even buy from them?

- Yes, they were
- Scam: getting fake or no product
- Dealing with financial losses



Figure 3: NOS news (2018)

# OK, so what to do about it

- SIDN is a Internet registry, not police
  - But we have a mission to make the .nl zone safer for users
  - And we were sitting on the data
- Ethical dilemma:
    - Turn the blind eye OR
    - Do something about it
  - We talked to our lawyers
  - We need to conform to our mandate and EU and NL laws

*We decided to go ahead and measure it*

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# What is their *business model*?

- Counterfeit (fake) industry is **huge**: books, computers, shoes, bags
  - EU borders seizures 2016: 670 million EUR
  - US 2017: US\$ 1.2 Billion
- Luxury goods have a massive demand



If you buy a fake from the street, you know it

- but not online
- so we got involved

# What is their *business model*?

- The business model goes like this:
  1. Consumer demand [4]
  2. Manufacturing in China [1]
  3. These webshops connect both of them
- It's not only a .nl problem:
  - .de, .be, .com, and many others have the same issue
- We are dealing with *pros* here

# How many were on the .nl zone?

- Back to 2016: we stumbled on them
- We realized they all share a similar pattern:
  1. long `html <title>` tags

```
1 <title>Vans Schoenen On Sale 70% OFF | Geen  
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- 2. tags listing many brands (Nike, Reebok, Gucci, you name it..)
- **Question: Why this tactic?**
  - Search Engine optimization → more clicks, more money [5]

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# Our measurements

1. Get all .nl domain names (5.8M)
  - private data
2. Scrape their websites (if they have)
  - We used DMap [6], we are trying to open it
3. We deployed “state-of-the art” ML to detect
  - simply count the number of brands on <title>

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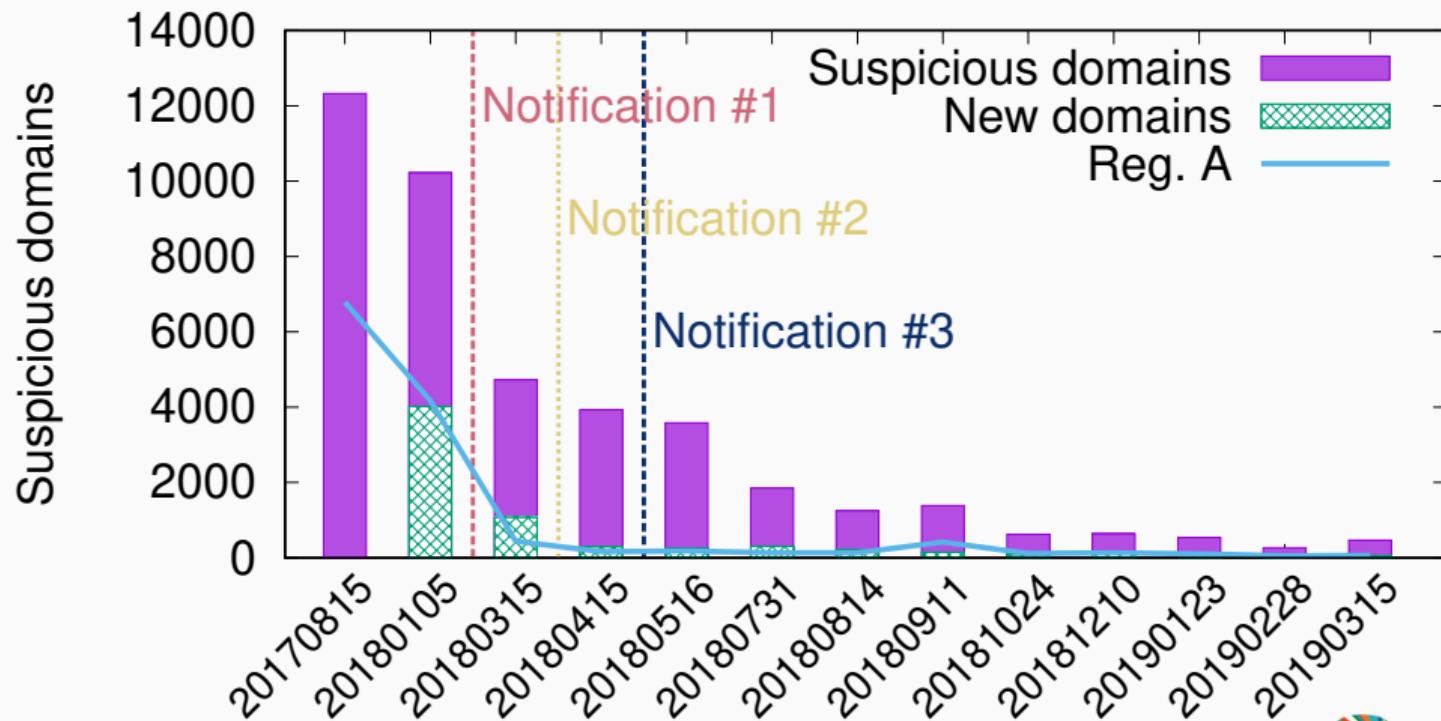
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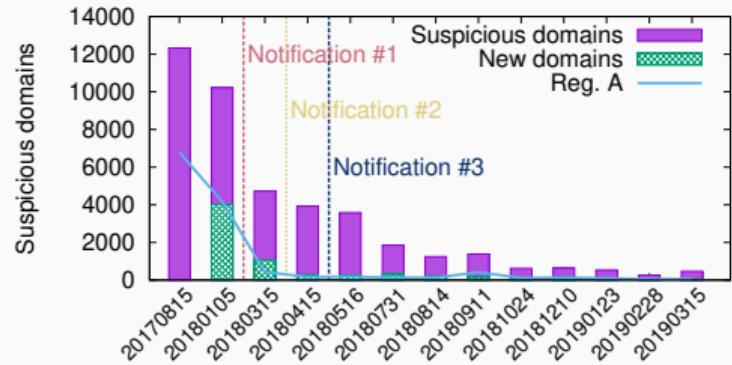
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# What did we find?



# How to take them down it?

- We could not take them down
- But there was a way to validate them:
  1. Notify a registrar that registered the domain
  2. Ask them to verify the ID of the registrant
  3. If it fails, then they can suspend the domain



# Lessons

## 1. How come does this even work?

- This is to show they suffered little pressure

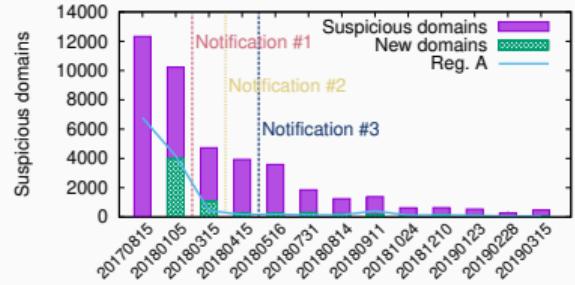
## 2. Why so many of these webshops?

- it's unlikely there are that many counterfeiters
- *Domains are cheap and disposable*
- automation heavily used
- 10 down does not even make a difference

## 3. Why 6K were registered with only one registrar?

- API for automatic registration & good price

*Take downs were effective, in partnership with our registrars*



- Later they changed strategy, we had a new system
- See PAM2020 [3]

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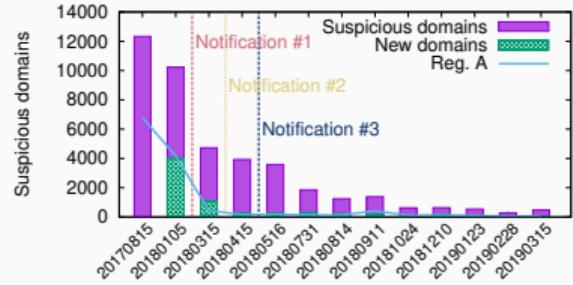
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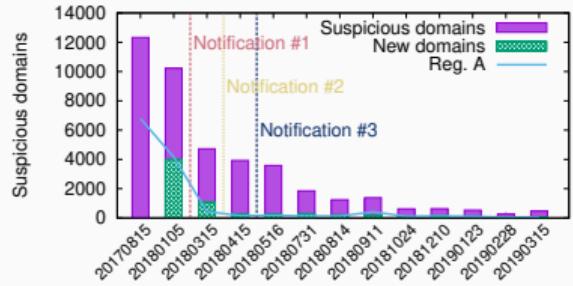
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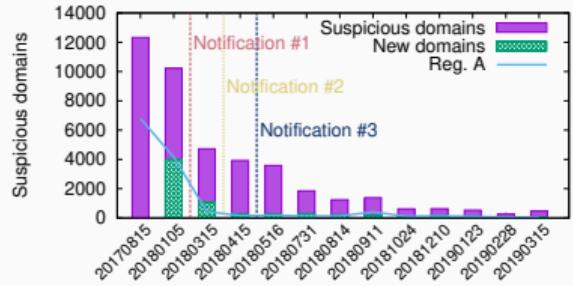


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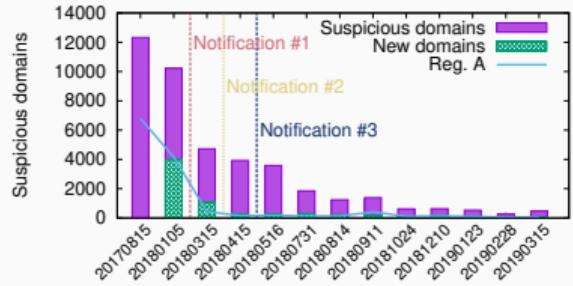


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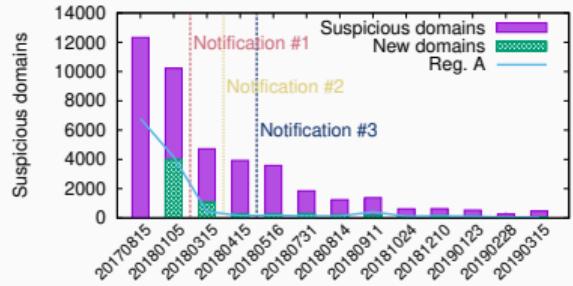


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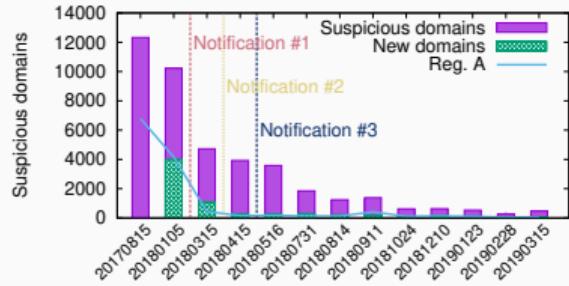


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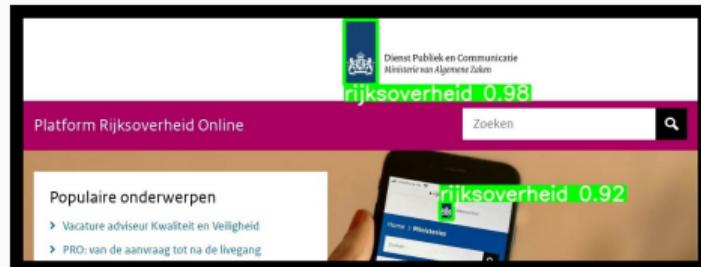
Logo Misuse

E-gov DNS

Wrap-up

# From text to logo detection: LogoMotive

- My colleagues did a study evaluating misuse of Dutch government logo
- It became a **brand protection** service
- See **PAM2022 [2]** paper



# Detecting logos misuse with ML

Pagina's

Volg ons

Home  
Problemen  
Vragen  
Nieuws

Video's  
Quizzen  
Over ons

Facebook  
Twitter  
Instagram  
YouTube  
Vimeo

Privacyverklaring  
Cookieverklaring  
Responsible disclosure  
Disclaimer  
Digitoegankelijkheid

Een initiatief van:  
**rijksoverheid 0.98 rijksoverheid 0.98**

Ministerie van Economische Zaken en Klimaat  
National Cyber Security Center  
Ministerie van Justitie en Veiligheid  
ECP  
Platform voor de Intermediairs Samenwerking

Mede mogelijk gemaakt door:

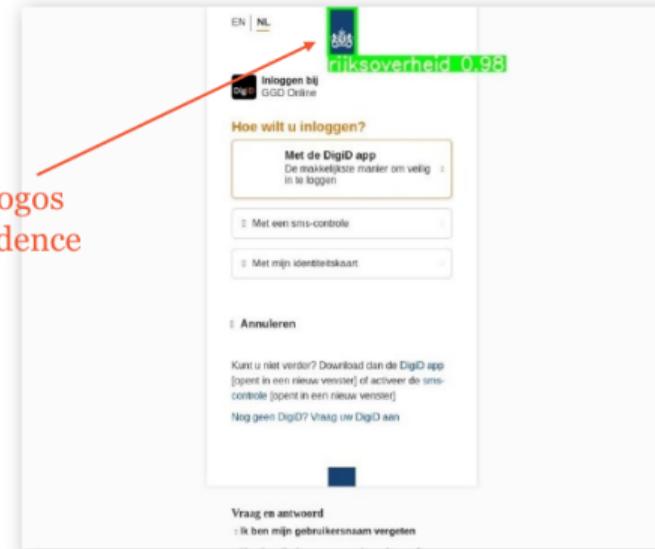
kpn vodafone zego sidn 0.97 T... Google

Microsoft PHILITIE thuiswinkel 0.95 thuiswinkel.org DENMARK M SIC

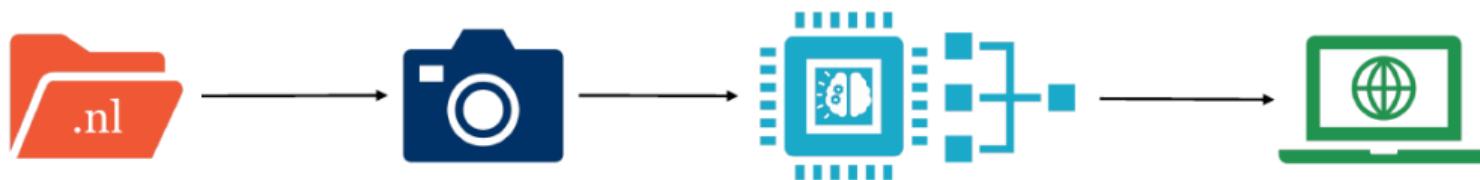
NLDigital FRAUDE-HUDEFEST.nl ACM ConsuWijzer Co-financed by the European Union Connecting Europe Facility

veilig internetten.nl

Detected logos with confidence



# How does LogoMotive work?



List of 6.2M+ .nl  
domain names

Automatically visit  
and screenshot  
websites

Apply logo detection  
to the screenshots

Upload results to  
online dashboard

# Generating training datasets

- We've used **Yolo** for image recognition
- It requires labeled data
- So we've generated it

	Value
Screenshots generated	64,893
Synthetic training samples	100,000
training set	95,000
validation set	5,000

**Table 1:** Datasets used for training and validation.

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GGD



JugdHulp is Gezinsovereen. Opgroei en opleiden huis' is de taak. Netwerken van gezinsovereen willen de hulp aan jugd en gezinse lokal organiseren.

Actuele berichten [home]  
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Gezinsovereen  
Publicaties & Blogs

Breed & Geduld  
Agenda  
Onderzoek  
Gezinsovereen  
Naar een nieuwe jugdhulp

Over Gezinsovereen  
Werken en leven in een gezinsovereen



## Minder actief?

Ik ben nu veel minder actief met 'gezinsovereen'. De site hou ik nog wel in de lucht. Uitstaard wil ik...



Bijeenkomst voor pleg- en gezinshuis-ouders Zeist, De Bilt, Bunnik, Utrechtse Heuvelrug en Wijk bij Duurstede

Op 17 april organiseert de regio Zuid-Oost Utrecht een netwerkbijeenkomst voor pleg- en gezinshuisouders uit de gemeenten Zeist, De Bilt...

Bijeenkomsten om landelijke en regionale plegzorgontwikkelingen met elkaar te verbinden

In mei en juni 2019 organiseert de NVP vier bijeenkomsten voor plegouders, verspreid over Nederland. Op deze bijeenkomsten horen we...

Minister wil intensivering Actieplan Plegzorg

Om de dagelijkse praktijk van pleggezinnen te verbeteren, wil minister Hugo de Jonge een intensivering van het Actieplan Plegzorg. Dat...



## Versterk pleggezinnen

In de uitzending van De Monitor van zondag 3 februari was te

## Random screenshot

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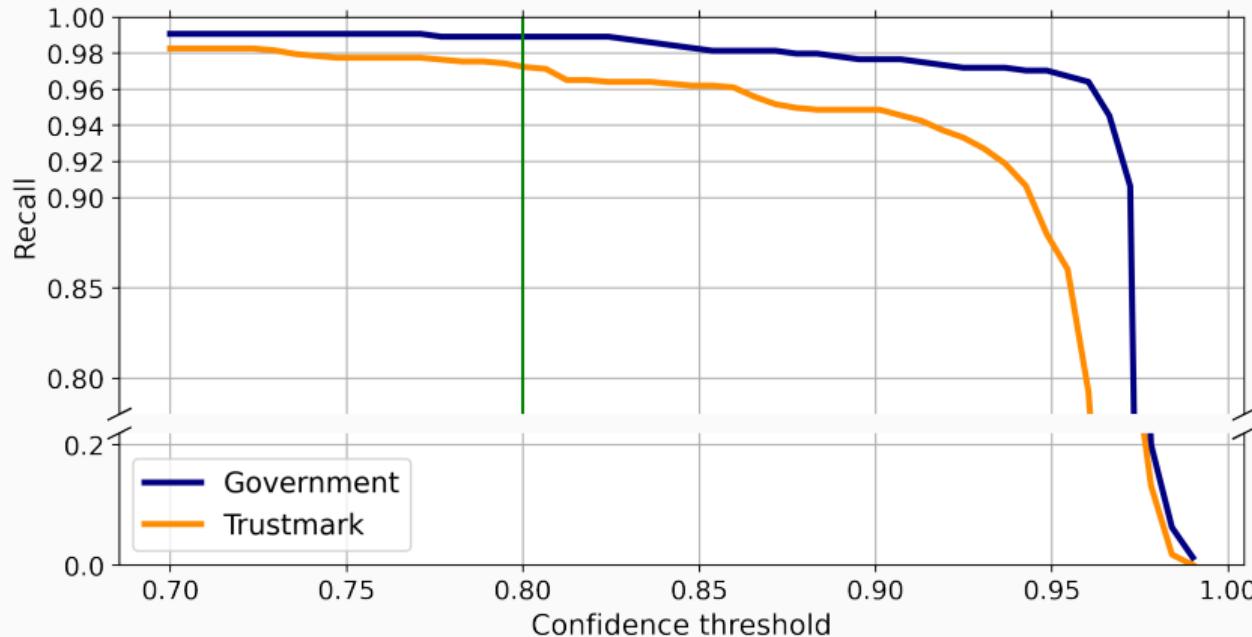


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## Resulting datapoint

# Evaluating the model



**Figure 4:** Recall performance of LogoMotive at confidence thresholds. The vertical line denotes our chosen threshold.

# Results

Label	Full-Zone	Newly-Registered
Total	12862 (100.00%)	53
Without gov. logo (FP)	1164 (9.05%)	0 (0.00%)
With gov. logo (TP)	11698 (90.95%)	53 (100.0%)
Benign	10595 (82.37%)	32 (60.38%)
Government impersonation	151 (1.17%)	17 (32.09%)
Phishing	3 (0.02%)	3 (5.66%)
Potential threat	73 (0.57%)	9 (16.98%)
Other (false endorsements, satire, etc.)	75 (0.58%)	5 (9.43%)
Government domains	952 (7.40%)	4 (7.55%)
In portfolio	636 (4.94%)	2 (0.00%)
Not in portfolio	316 (2.46%)	2 (3.77%)
Added	109 (0.85%)	1 (1.89%)
Pending	207 (1.61%)	1 (1.89%)

**Table 2:** Manual validation results for government impersonation case study.

## On the paper

- See PAM2022 [2] paper for more details
- There was a second case study
- It became a brand protection service

# You can also DIY!

You don't need private data:

## 1. Get DNS zone files

- Sweden's .se is **open**
- ICANN **CZDS** has all gTLDs, and .com,  
.net, and .org
- Ask your country ccTLD

## 2. Get an open-source crawler

- **Mercator** from DNSBelgium

## 3. Figure out problems

- Detect X impersonation



# Outline

Counterfeit webshops

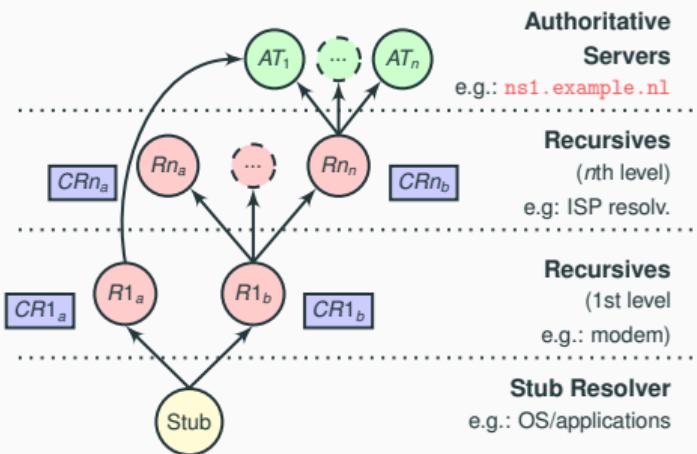
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Wrap-up

# DNS Servers and DNS infrastructure

- Two main types of DNS servers
- If authoritative server fails, zone becomes unreachable
- (previous example covered contents, this is infrastructure)



# E-gov

- Governments increasingly use Internet for communication with citizens (e-gov)
- E-gov provide crucial services

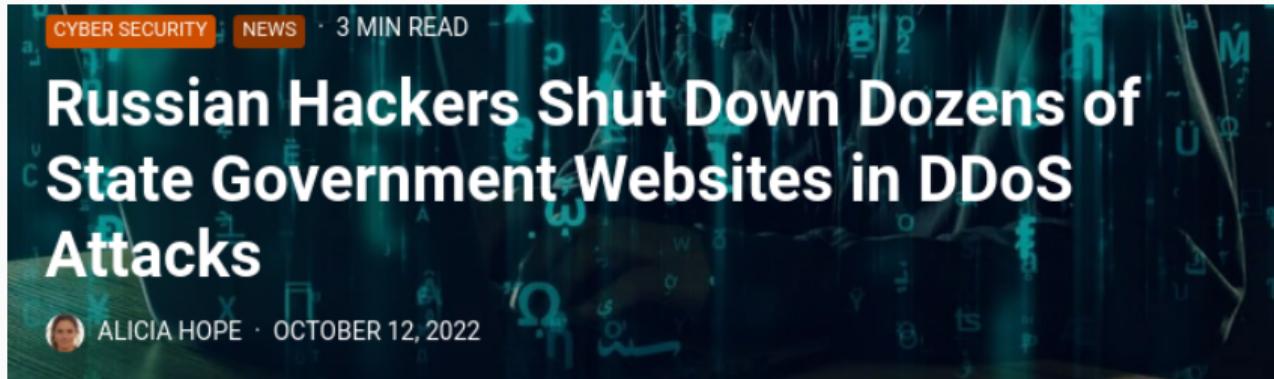


The screenshot shows the 'Municipal services' section of the Delft website. At the top, there's a banner with a photo of people at a service counter. Below it, the breadcrumb navigation shows 'Home > Municipal services'. The main content area is divided into three columns:

<b>Make or cancel an appointment</b> Make an appointment before you visit the municipality <a href="#">Read more</a> →	<b>Moving to Delft from abroad</b> Register in person, documents you should bring to your appointment <a href="#">Read more</a> →	<b>Reporting a change of address</b> Moving house to or within Delft, deregister in your old municipality <a href="#">Read more</a> →
<b>Marriage and partnership</b> Booking a date and location, notification (Intended marriage), marriage registrars <a href="#">Read more</a> →	<b>BRP extract</b> Municipal Personal Records Database, official document certifying registration <a href="#">Read more</a> →	<b>Proof of sponsorship / private accommodation</b> Expecting someone from abroad, list of countries citizens need visa <a href="#">Read more</a> →
<b>Certificate of good conduct (VOG)</b> Proof of good conduct, Integrity and Screening Agency <a href="#">Read more</a> →	<b>Address verification procedure</b> Someone else registered at your address, steps the council take <a href="#">Read more</a> →	<b>Leaving the Netherlands</b> Deregister and inform the appropriate authorities, check General Practitioner <a href="#">Read more</a> →

**Figure 5: Delft (local government) residents e-gov**

# When e-gov breaks



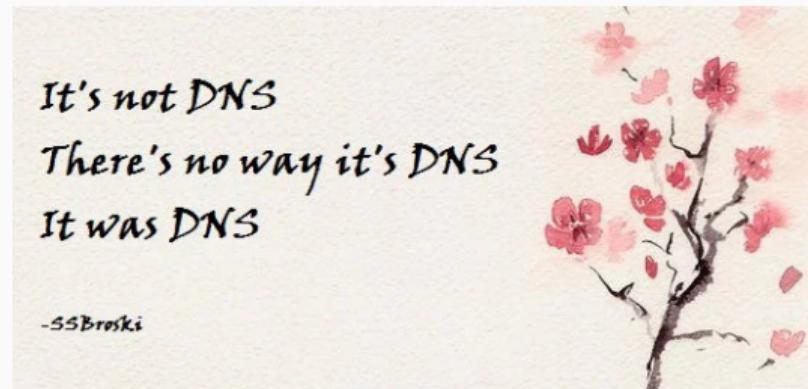
source: CPO Magazine

*“Russian hackers took responsibility for a wave of cyber attacks that knocked dozens of state government websites offline.*

*Several states, including Colorado, Connecticut, Kentucky, and Mississippi, were impacted by the politically-motivated cyber attacks ...”*

# E-gov is fully dependent on DNS

- E-gov provide crucial services
- Internet as core communications fabric of modern societies.
- E-gov is fully dependent on DNS



**Figure 6:** A haiku about DNS.  
Source: [Cyberciti](#)

# DNS Engineering for resilience

- DNS has been designed for resilience
  - multiple layers of redundancy
- Deploying those features is not easy/cheap
- Configuration errors may go unnoticed
  - system will still work
  - until it breaks



Source: Unsplash

# Research Question

Are e-gov DNS servers configured following best-practices for robustness?

*Approach: Internet measurements*

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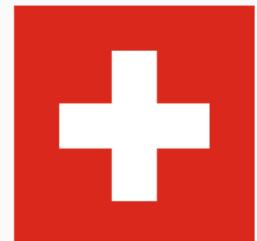
# Our contribution

1. E-gov DNS infrastructure evaluation for four countries
  - using active measurements
2. A comparative analysis among them
3. Recommendations for improvement

The Netherlands



Switzerland



Sweden



United States



# Datasets

Country	Netherlands	Sweden	Switzerland	United States
	.nl 	.se 	.ch 	.gov 
e-gov domains (SLD)	602	614	3971	7972
Population	17.4M	10.4M	8.7M	332.9M

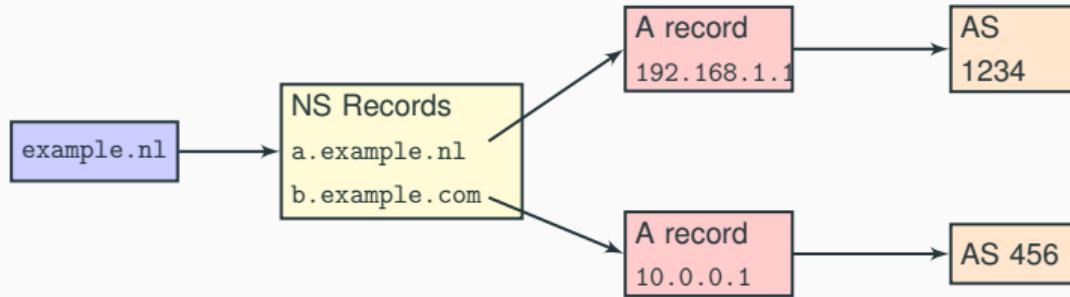
# Results: single points of failure (SPoF)

- Don't put all your eggs in one basket
  - We will look into diff basket types

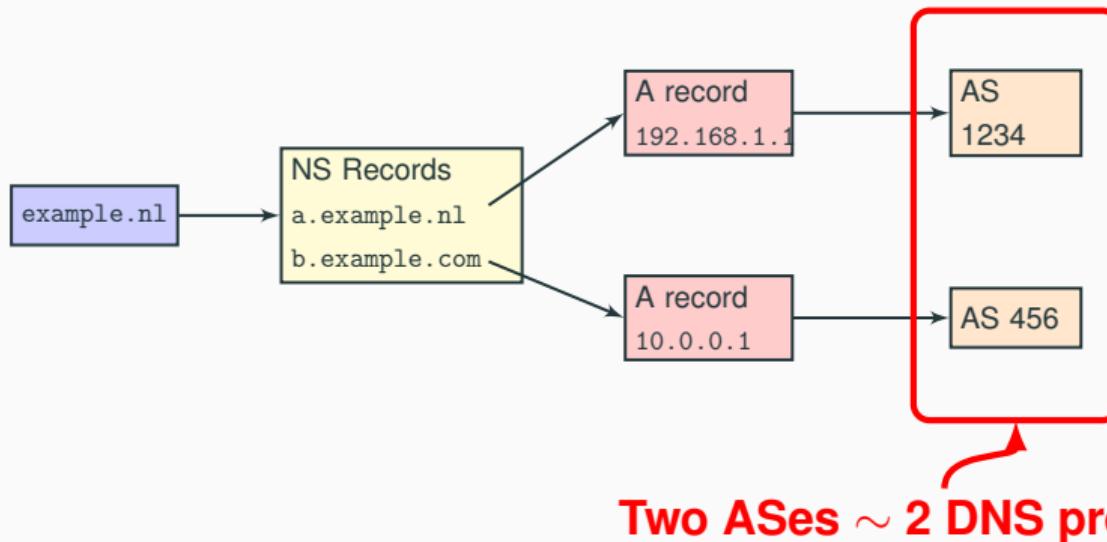


Source: Unsplash

# First SPOF: single DNS providers



# First SPOF: single DNS providers



# First SPOF: single DNS providers

	Netherlands	Sweden	Switzerland	United States
second-level domains				
Responsive	602	614	3971	7972
single provider(v4/v6)	601	609	3546	7911

- US: ~ 80% single DNS provider

# “But this is a bogus metric!”

- “I’ll put everything in the **cloud**”
- But even clouds occasionally fail:
  - Dyn 2016
  - AWS Route 53 - 2019
- Even [Amazon.com](#) does not use AWS for DNS:
  - pdns1.ultradns.net.
  - ns4.p31.dyneed.net.
  - ns2.p31.dyneed.net.
  - pdns6.ultradns.co.uk.
  - ns1.p31.dyneed.net.
  - ns3.p31.dyneed.net.



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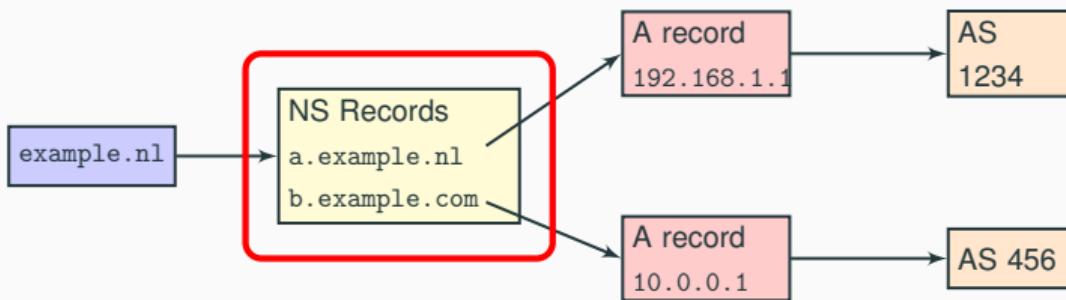
# DNS centralization: who are these DNS providers

Netherlands		Sweden		Switzerland		United States	
ASN	e-gov	ASN	e-gov	ASN	e-gov	ASN	e-gov
Transip	112	Loopia	47	Infomaniak	278	GoDaddy	1215
CLDIN	39	Tele2	23	Swisscomm	115	Cloudflare	909
QSP	28	Microsoft	21	Novatrend	100	Amazon	676
Solvinity	8	Telia	21	Abraxas	97	Akamai	334
SSC-ICT	8	Telia	19	Metanet	91	Tiggee	316

**Table 3:** Top 5 DNS providers for e-gov domains

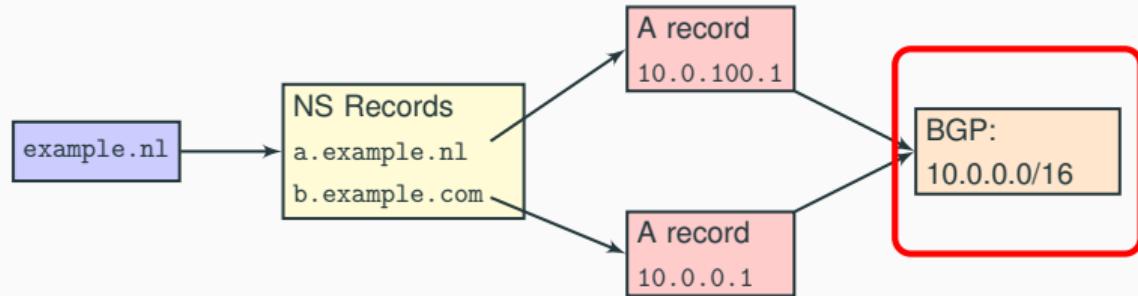
Most DNS providers are local

## Second SPoF: single DNS server



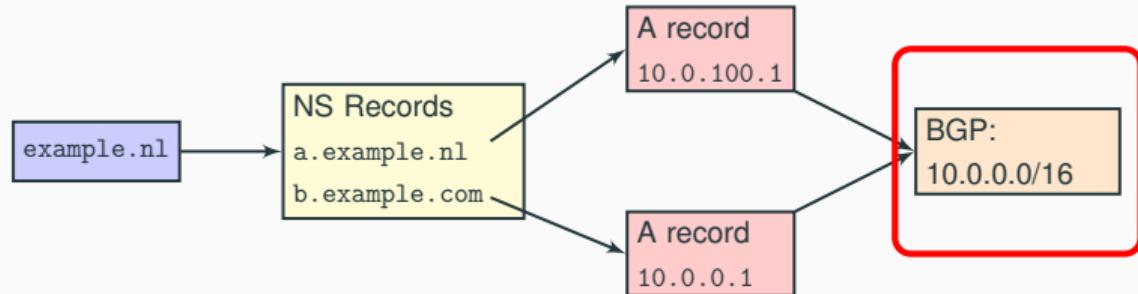
- RFC1034 (35 years old!) mandates at least two NS records
- We found 6 .gov domains that did have a single NS record
- We notified the .gov registry, 3 fixed it (2023-05-09)

## Third SPoF: BGP prefixes



- If two DNS servers share the same prefix, they are not topologically diverse
  - they share the same infrastructure
- We map the IP addresses of each NS to their prefixes

# Third SPoF: BGP prefixes

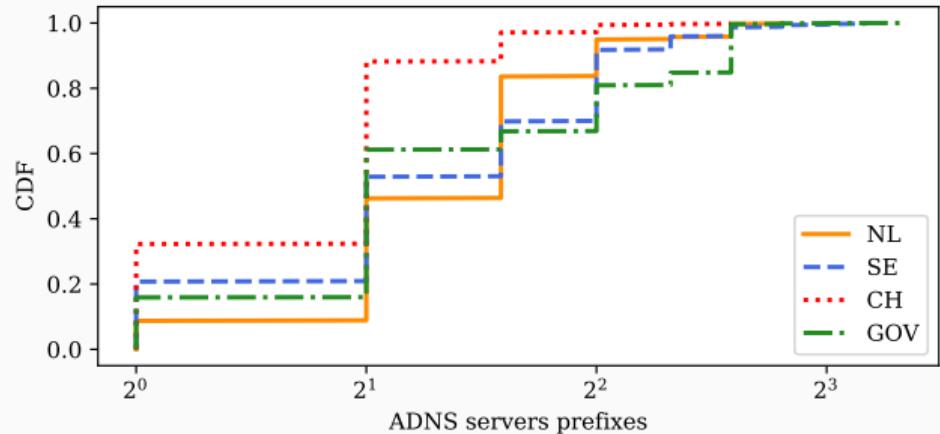


**One BGP prefix = same location**

- If two DNS servers share the same prefix, they are not topologically diverse
  - they share the same infrastructure
- We map the IP addresses of each NS to their prefixes

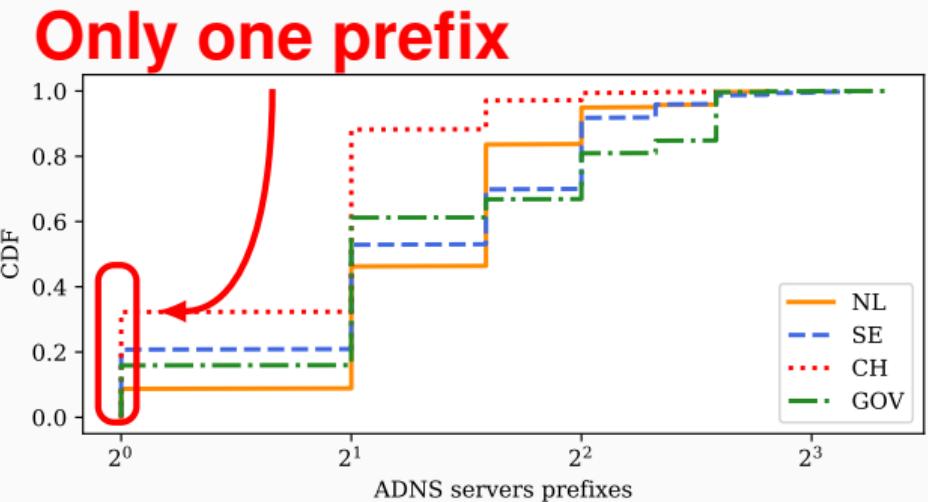
# Third SPoF: BGP prefixes

- Switzerland: 1/3 e-gov domains have a single prefix
- NL, SE, US: < 20%

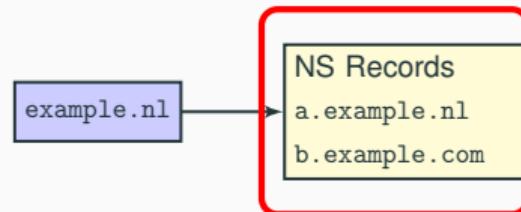


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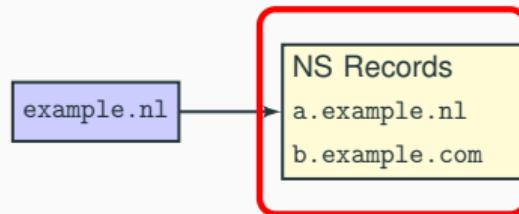


## Fourth SPoF: Number of TLDs



- NS records depend on top-level domains (TLDs)
- Having more than one TLD protect you fail TLD failures
  - Warning: it's TLDs for NS records, not the domains themselves

## Fourth SPoF: Number of TLDs

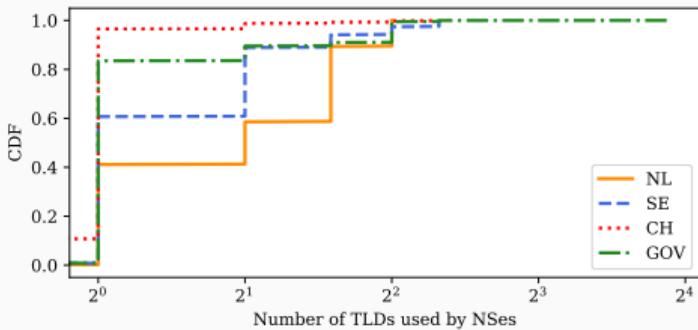


**Two TLDs: .nl and .com**

- NS records depend on top-level domains (TLDs)
- Having more than one TLD protect you fail TLD failures
  - Warning: it's TLDs for NS records, not the domains themselves

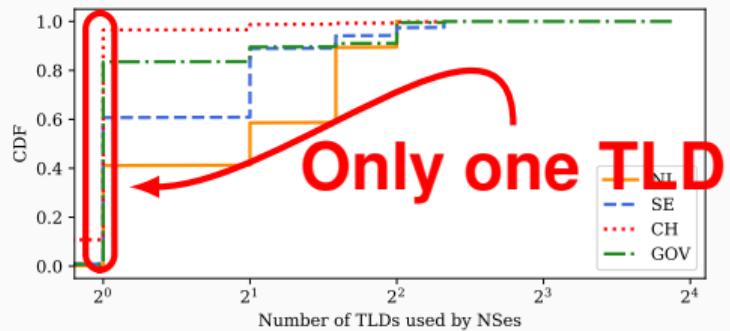
## Fourth SPoF: Number of TLDs

- Switzerland e-gov mostly uses only one TLD
- Netherlands is the most diverse
- All four countries can diversity still



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# TLD dependency

	Netherlands	Sweden	Switzerland	United States
				
1	170 (.nl)	483 (.se)	609 (.ch)	2507 (.com)
2	69 (.net)	100 (.net)	190 (.com)	1541 (.net)
3	26 (.com)	82 (.com)	150 (.net)	894 (.gov)
4	12 (.eu)	14 (.info)	19 (.org)	485 (.org)
5	4 (.be)	8 (.org)	12 (.de)	302 (.us)

**Table 4:** Most used TLD by e-gov ADNS severs.

- Most use their own TLD, then .com and .net

# Extra features that improve resilience (RFC9199)

## 1. IP Anycast

- Covered in [Moura16b](#)

## 2. DNS Time-to-live (TTLs)

- covered in [Moura18b](#), [Moura19b](#)

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Request for Comments: 9199  
Category: Informational  
ISSN: 2070-1721

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USC/Information Sciences Institute  
M. Davids  
SIDN Labs  
March 2022

Considerations for Large Authoritative DNS Server Operators

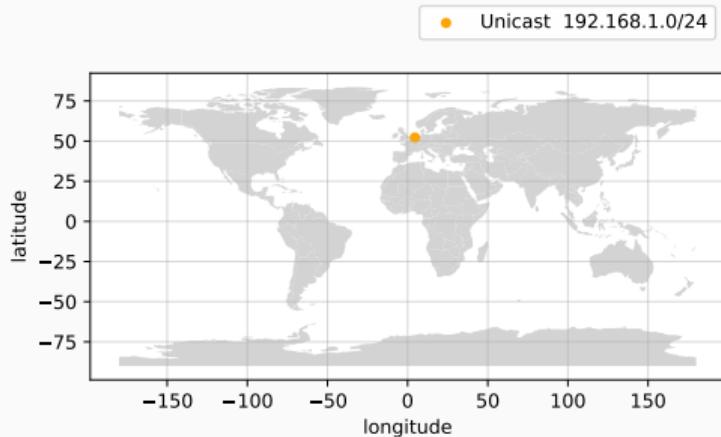
### Abstract

Recent research work has explored the deployment characteristics and configuration of the Domain Name System (DNS). This document summarizes the conclusions from these research efforts and offers specific, tangible considerations or advice to authoritative DNS server operators. Authoritative server operators may wish to follow these considerations to improve their DNS services.

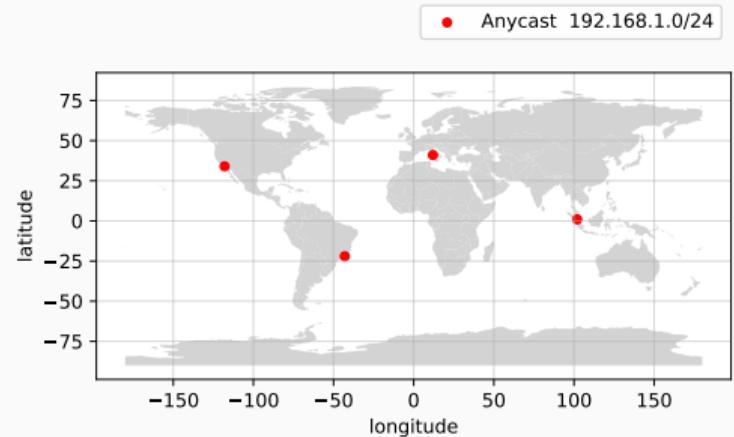
Both summarized in [RFC9199](#)

# IP anycast

Unicast



Anycast

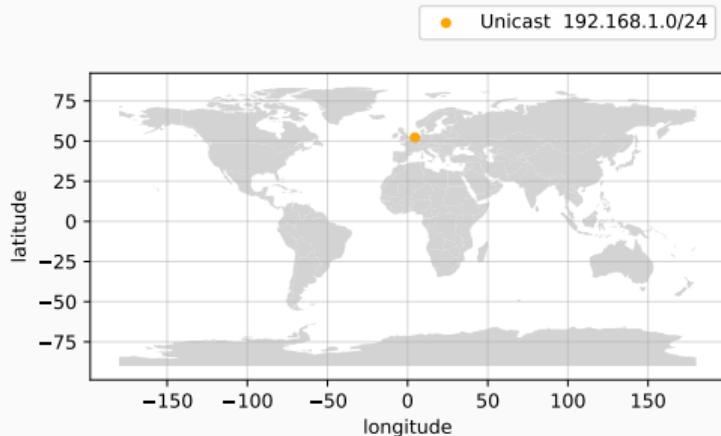


- One location
- All traffic to it
- Multiple locations
- Traffic distributed among them

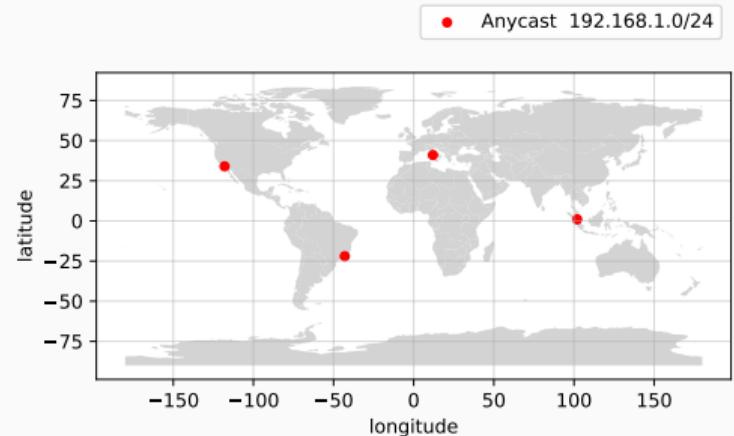
Anycast is more resilient to DDoS ([Moura16b](#))

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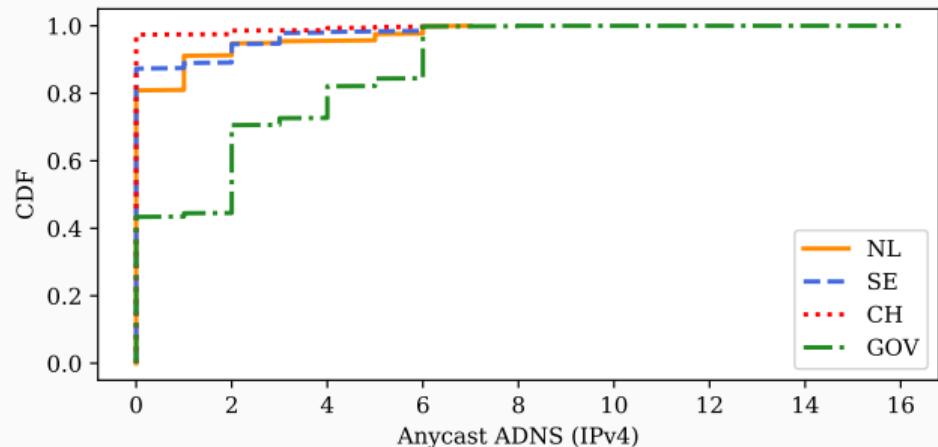


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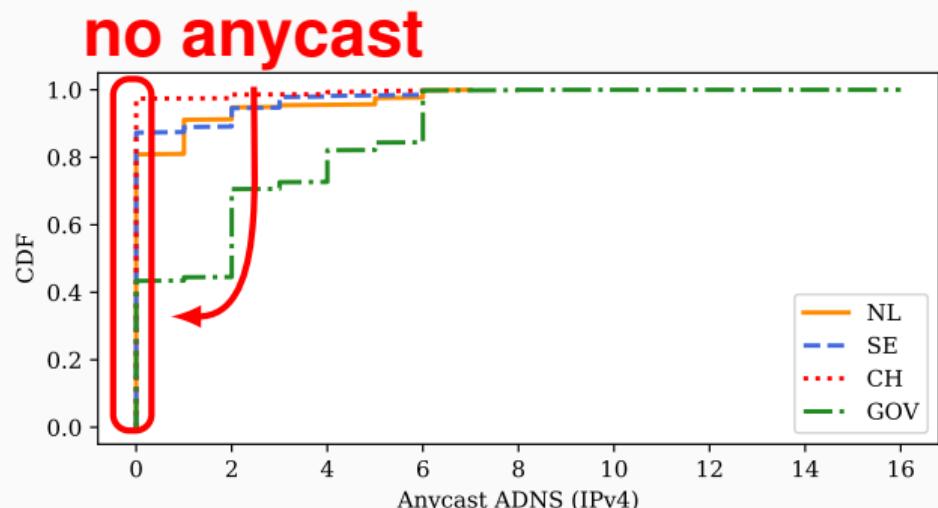
# IP anycast adoption on e-gov

- Good: 58% US .gov domains have anycast
- Not so good: very few Swiss e-gov domains have anycast
- Sweden and the Netherlands have around 20% of anycast servers



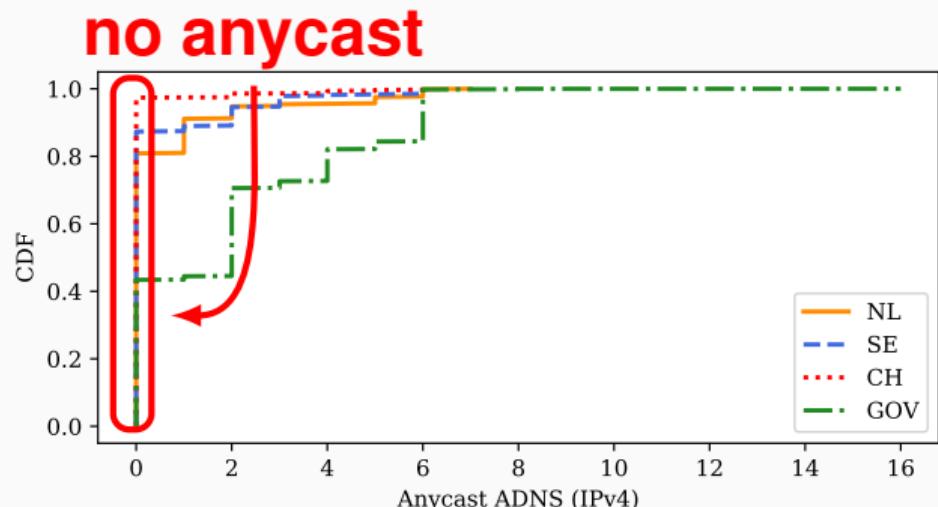
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# DNS time-to-live (TTL)

- TTLs control how long DNS records should stay in resolver's cache
- Last resort when everything else fails ([Moura18b](#))
- Current recommendations: use at least a couple of hours TTL



Source: Unsplash

# DNS time-to-live (TTL)

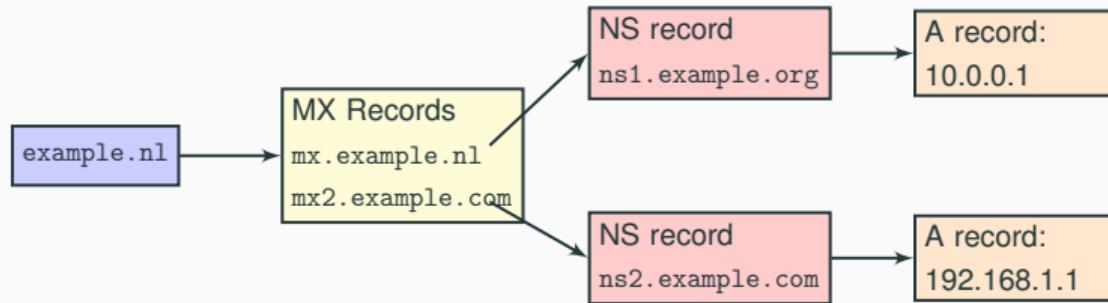
	Netherlands	Sweden	Switzerland	United States
				
NS TTL				
Median	10800	3600	3600	10800
A/AAAA TTL				
Median	3047	3600	3600	28800

# E-gov e-mail DNS

- So far we've looked into E-gov DNS for **web**
- E-mail is also an important e-gov service
- Now we turn to measure the resilience of e-gov DNS for e-mail



# E-gov e-mail DNS



- For e-mail we first retrieve their MX records, and proceed as previous

# E-gov e-mail DNS

Country	Netherlands	Sweden	Switzerland	United States
	.nl 	.se 	.ch 	.gov 
e-gov domains (SLD)	602	614	3971	7972
Outlook	164 (39%)	205 (37%)	425 (22.1%)	2243 (41%)

- E-gov E-mail uses mostly Microsoft regardless of the country
- Why? Maybe they seek for more traditional solutions
  - more in the [paper\[PDF\]](#)

# Recommendations for e-gov DNS

- **Diversify:** more DNS providers, more NS records, more prefixes, different TLDs for NS records
- **Deploy** anycast for more robust services
- **Reconsider** low TTL values



*Robust (1900 years old) infrastructure  
in Segovia, Spain. Src: Wikipedia*

# Lessons

- Many e-gov domains are not following the recommendation for robust services
- This creates unnecessary risk
- We hope our findings prompt the responsible operators to improve the redundancy and resilience of e-gov DNS



*Robust (1900 years old) infrastructure  
in Rome, Italy. Src: Wikipedia*

Full paper: [Sommese22a](#)

# Outline

Counterfeit webshops

Logo Misuse

E-gov DNS

Wrap-up

# Wrap-up

Slides:

- DNS offers great opportunities for research
  - both in contents and infrastructure
- I hope these examples motivatate folks
- Contact:
  - [giovane-moura.nl](http://giovane-moura.nl)
  - [giovane.moura@sidn.nl](mailto:giovane.moura@sidn.nl),  
@tudelft.nl



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