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Phoenix Domain Attack: Vulnerabilities in Domain Name Delegation and Revocation

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Presenter: **Xiang Li**, Tsinghua University

August 2023

Xiang Li (李想)

- **5th-year Ph.D. Candidate**
  - Tsinghua University (NISL Lab), UCI (visiting scholar)
  - Advisor(s): Prof. Qi Li and Haixin Duan
- **Research Area and Publication**
  - Network scanning, IPv6 security, DNS security, vulnerability discovery, and fuzzing
  - **Publications in total (12):** S&P ('24), NDSS ('23, '24), Security ('23a, '23b, '24), CCS ('23a, '23b), DSN ('21), VehicleSec ('23), SIGMETRICS ('23), IMC ('23)
  - **Publications as the 1st author (5):** S&P ('24), NDSS ('23), Security ('23), CCS ('23), DSN ('21)
  - **Publications under review (5):** S&P ('24a, '24b), NDSS ('24a, '24b)
  - **Industry Conferences:** IDS ('21, '22), DNS OARC (39, 40, 41), Black Hat (Asia '23, USA '23)
  - **CNVD/CVE:** 109/70.

Phoenix Domain Attack: Vulnerable Links in Domain Name Delegation and Revocation

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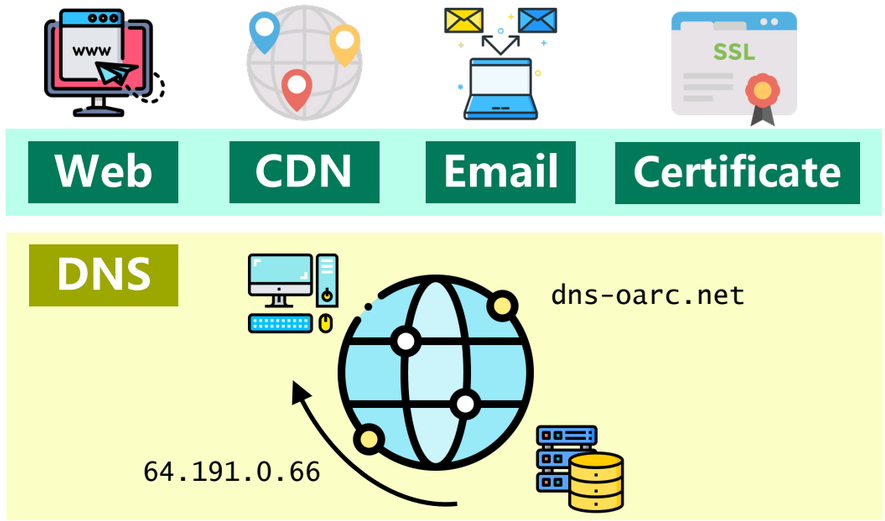
Exploitation Impact

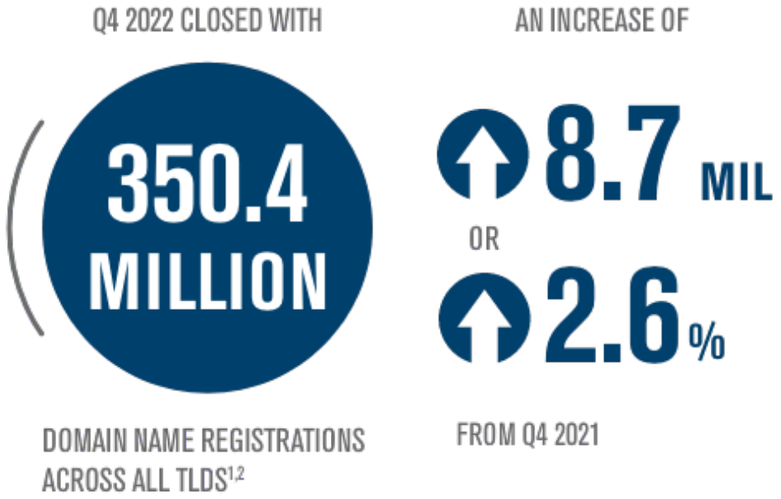
Even a domain expired or was removed,

Attackers could still use it for free with the Phoenix Domain Attack.

Domain Name

- **Domain name system (DNS)**
  - Entry point of many Internet activities
  - Security guarantee of multiple application services
  - Domain names are widely registered





verisign.com/dnib

Domain Name Abuse

- **Also abused by criminal activities**
  - Botnet, phishing, malware distribution

bleepingcomputer.com

scmp.com

norton.com

Domain Name Abuse

- **Also abused by criminal activities**
  - Botnet, phishing, malware distribution
- **ICANN Domain abuse activity reporting (DAAR)**
  - In July 2023
  - Check 217M domain names within 1.1K gTLDs

576K domains showing security threats

Domain Name Revocation

- **Fighting against malicious domain names**
- **Mechanism**
  - Domain name revocation
  - Operated by registries or registrars
  - Deleting or changing domain name registration (delegation)
- **Result**
  - Domains are no longer controlled by original registrants/attackers

Domain Name Revocation

- **Domain name seizure activity**
  - ❑ Best security practice
  - ❑ Widely adopted

Microsoft seizes Chinese dot-org to kill Nitol bot army

Takedown after infected new computers sold to victims

John Leyden

Thu 13 Sep 2012 // 15:01 UTC

Microsoft has disrupted the emerging Nitol botnet - and more than 500 additional strains of malware - by taking control of a rogue dot-org website. The takedown is the latest in Microsoft's war against armies of hacker-controlled PCs.

theregister.com

intelligentciso.com

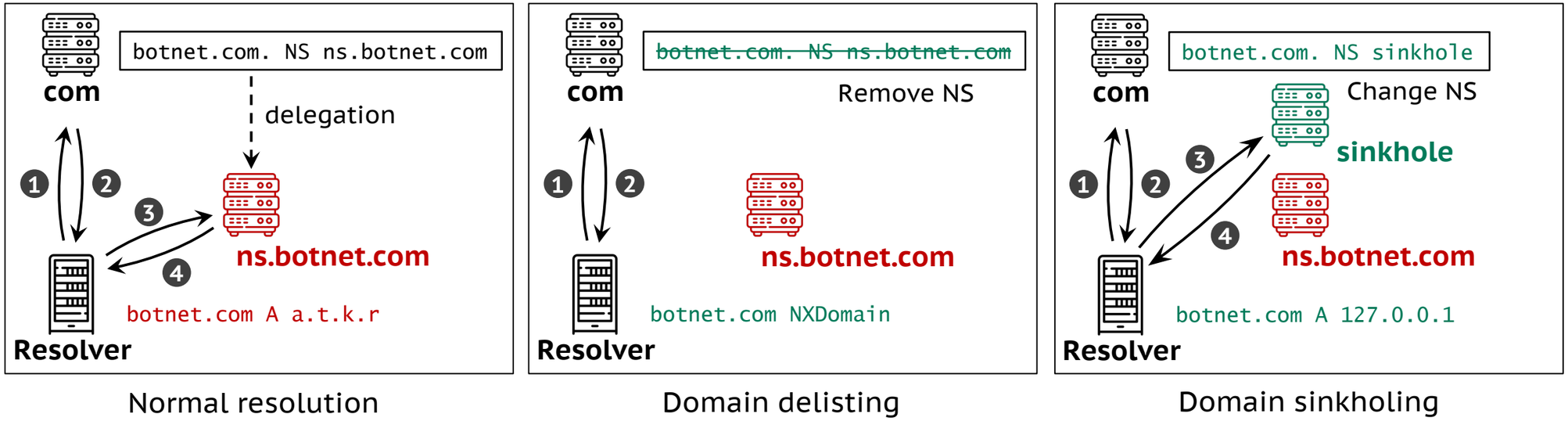
Question

How does domain name revocation work on domain name registration (delegation)?

It is the reverse process of **delegation**.

Domain Name Revocation

- **Normal resolution**
- **Revocation**
  - Domain delisting
  - Domain sinkholing



Normal resolution | Domain delisting | Domain sinkholing

Question

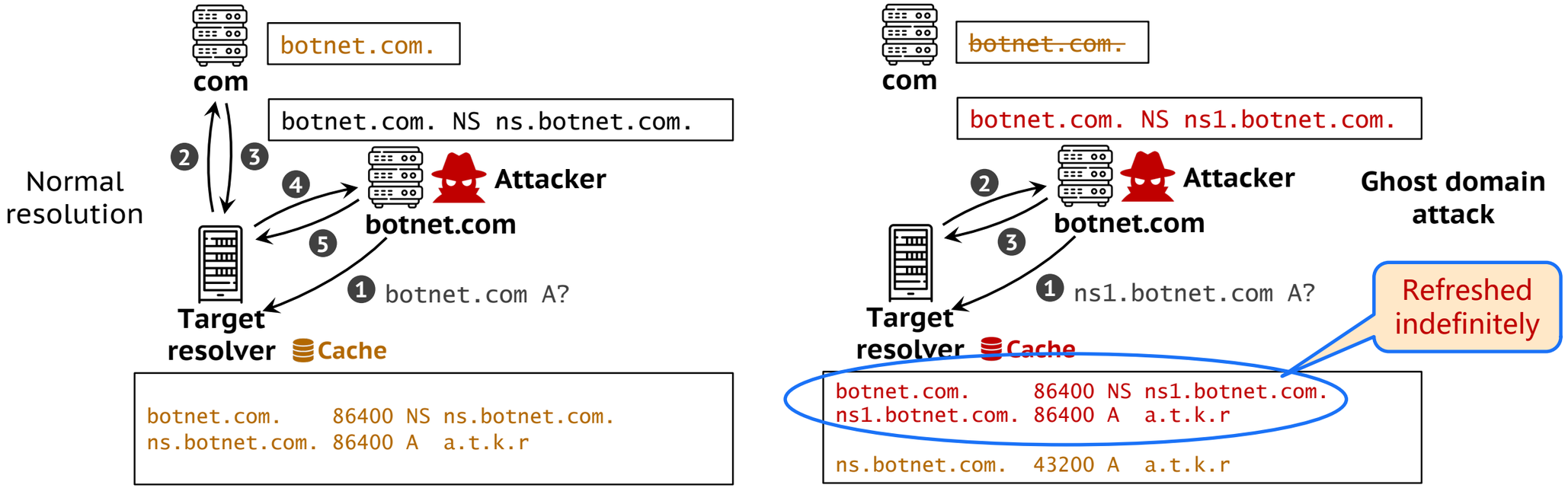
Does domain name revocation function as desired?

No. **Ghost domain** broke this guarantee.

Ghost Domain

➢ Ghost domain attack

- ❑ Proposed in NDSS 2012 by our NISL lab
- ❑ Making revoked domain names still resolvable on resolvers



Takeaway

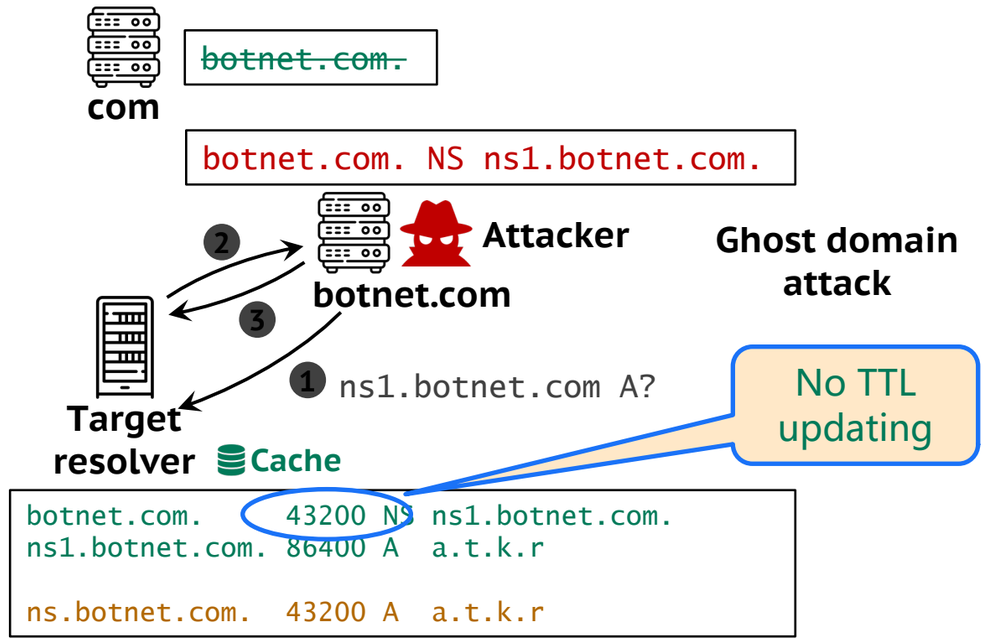
With ghost domain, even after revocation, malicious domains can still be resolvable.

Attackers can use it to evade **domain take-down** or **domain expiration**.

Ghost Domain

- **Vulnerable software**
  - Not all software: BIND, PowerDNS, etc.
- **Mitigation**
  - TTL field cannot be prolonged

DNS Vendor	Version	Vulnerable?
BIND	9.8.0-P4	Yes
DJB dnscache	1.05	Yes
Unbound	1.4.11	No
	1.4.7	Yes
PowerDNS	Recursor 3.3	Yes
MaraDNS	Deadwood-3.0.03	No
	Deadwood-2.3.05	No
Microsoft DNS	Windows Server 2008 R2	No
	Windows Server 2008	Yes



Question

10 years later, does domain name revocation work as desired after fixing ghost domain?

No. **Phoenix domain** still breaks this guarantee with a broader attack surface.

Phoenix Domain

- **What is phoenix domain**
  - Proposed by our NISL lab too
  - Published at NDSS 2023
  - Also making revoked domain names still resolvable on resolvers
  - Two new vulnerabilities in protocols or implementations
  - Two variations (**T1** and **T2**)
  - Affecting all DNS implementations

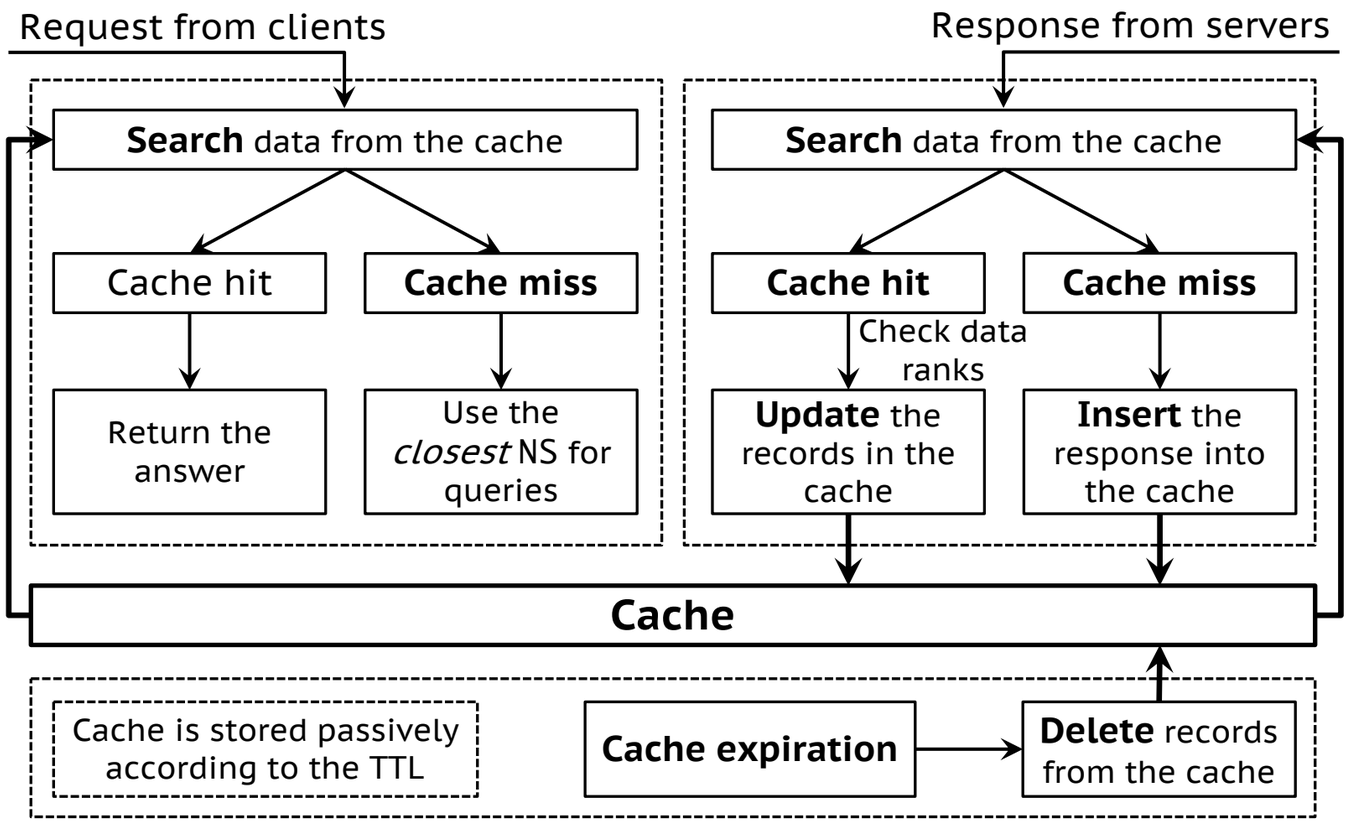
Question

Why is domain name revocation still vulnerable?

We find that the entire attack surface remains unclear now.

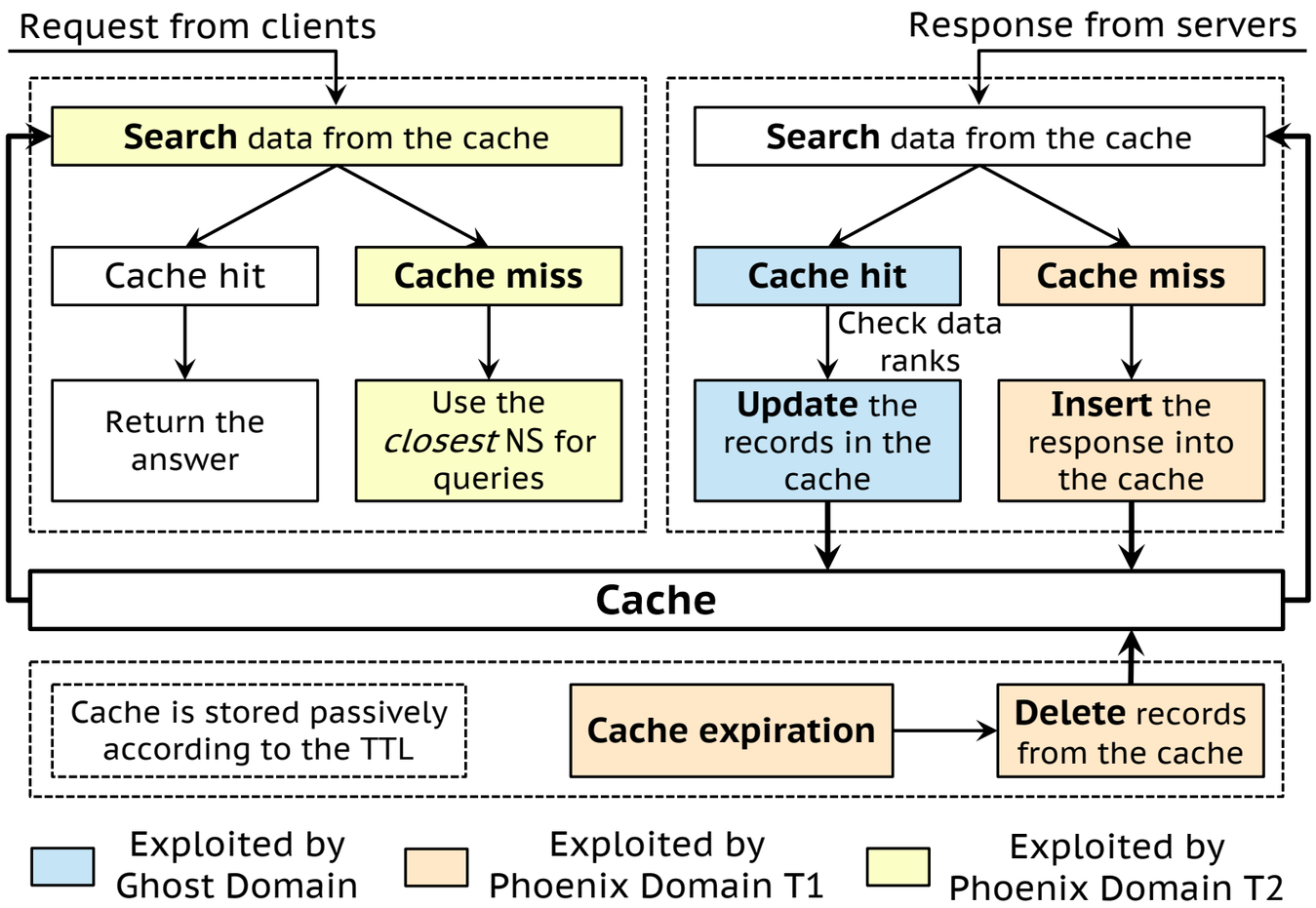
DNS Cache Operations

- Summary



DNS Cache Operations

- **Summary**
  - Updating
  - Insertion
  - Searching



Question

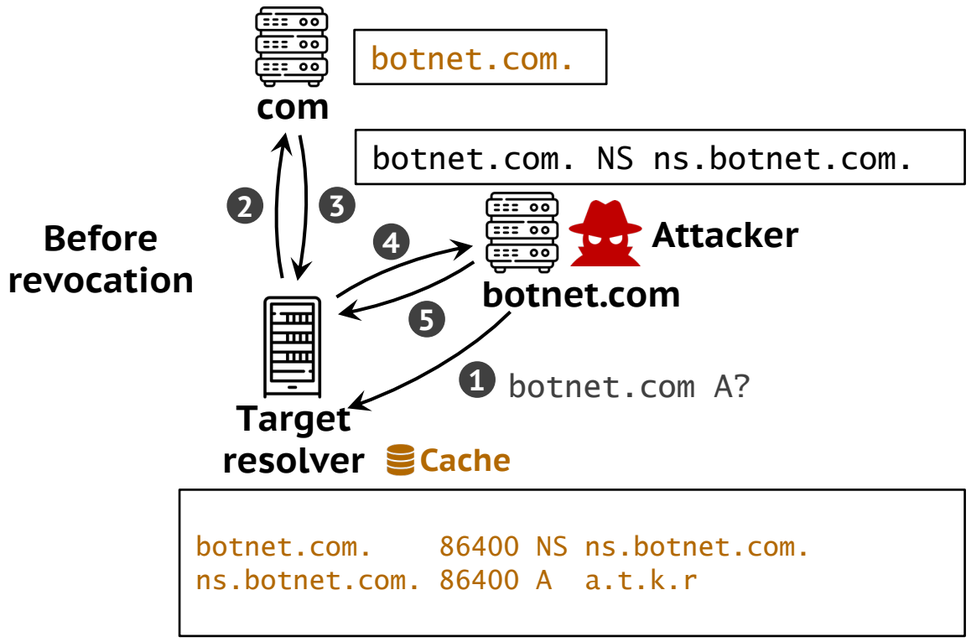
How does Phoenix Domain work?

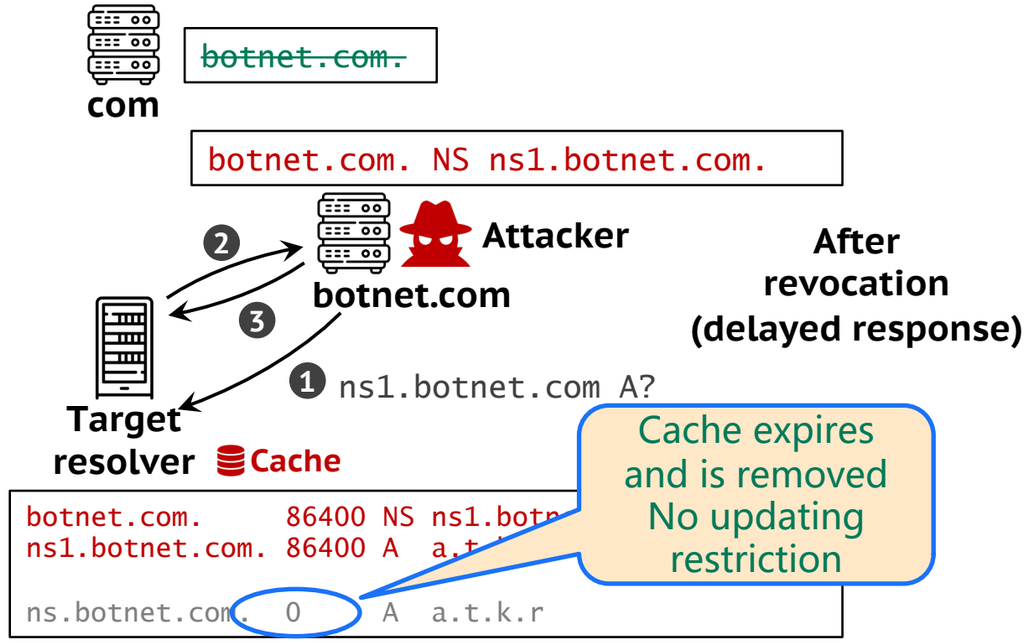
Two variations, two ways.

Phoenix Domain T1

➢ T1 attack

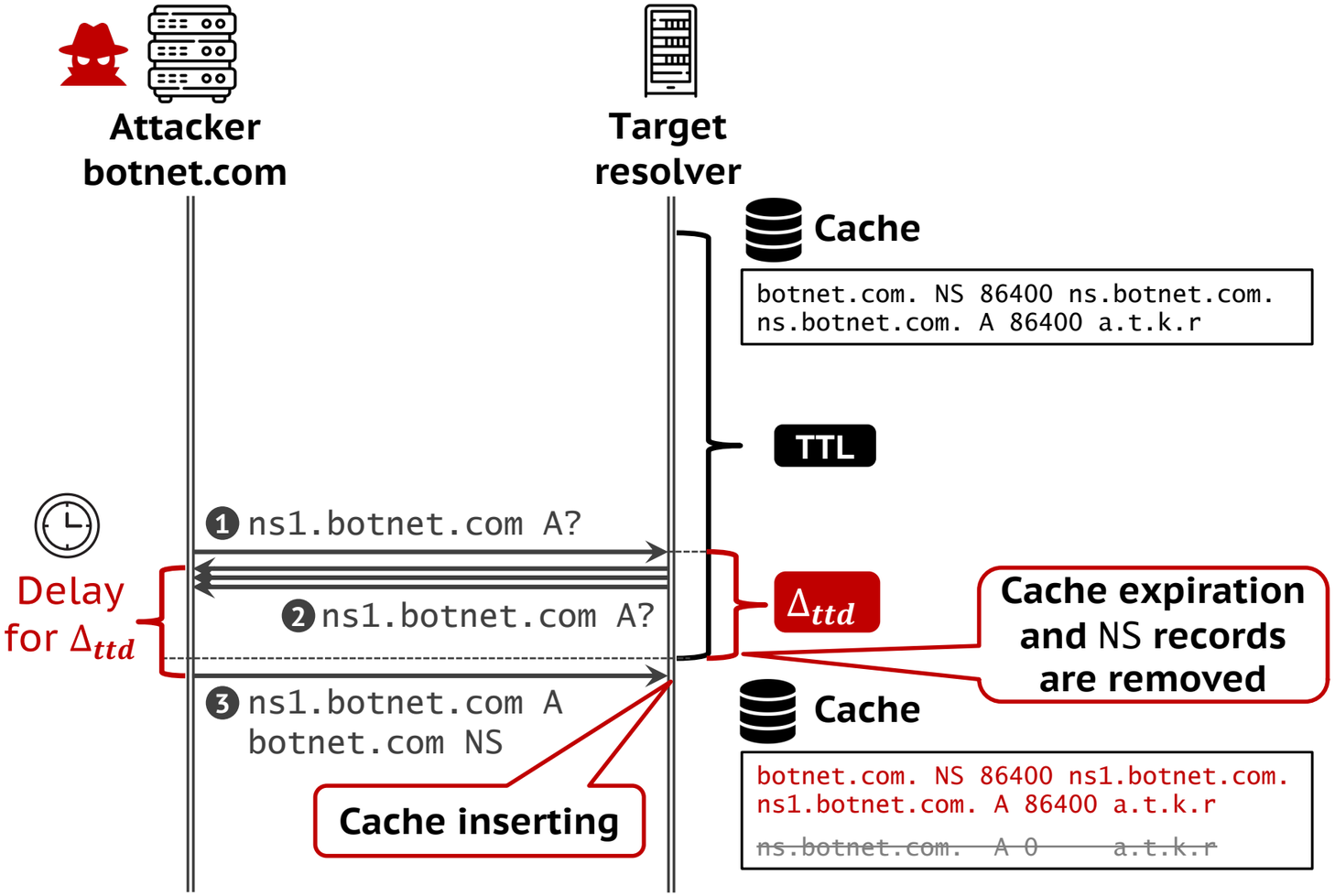
- ❑ Exploiting vulnerable cache insertion implementations
- ❑ Inserting new NS records when the old is about to expire





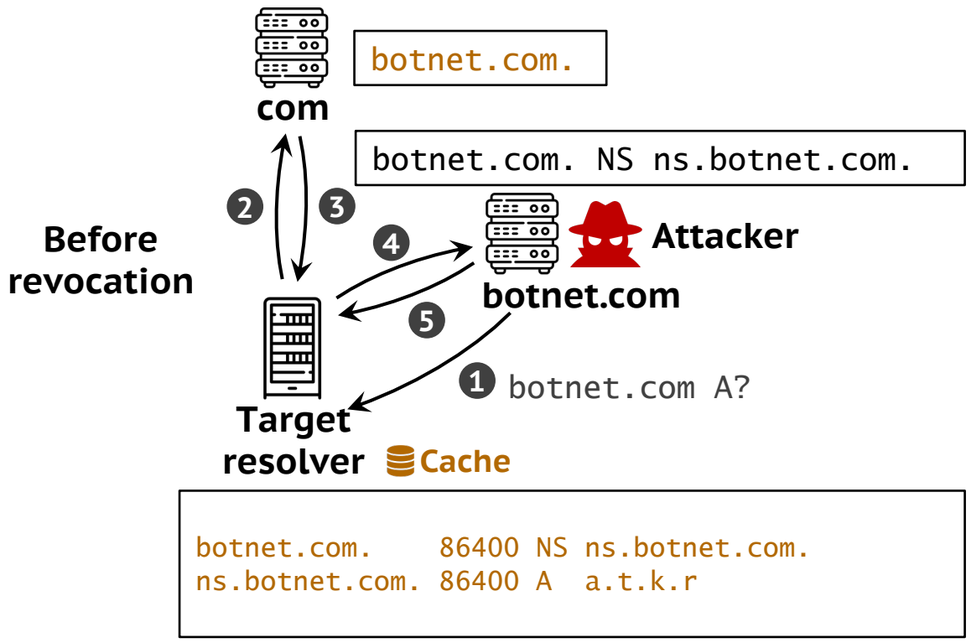
Phoenix Domain T1

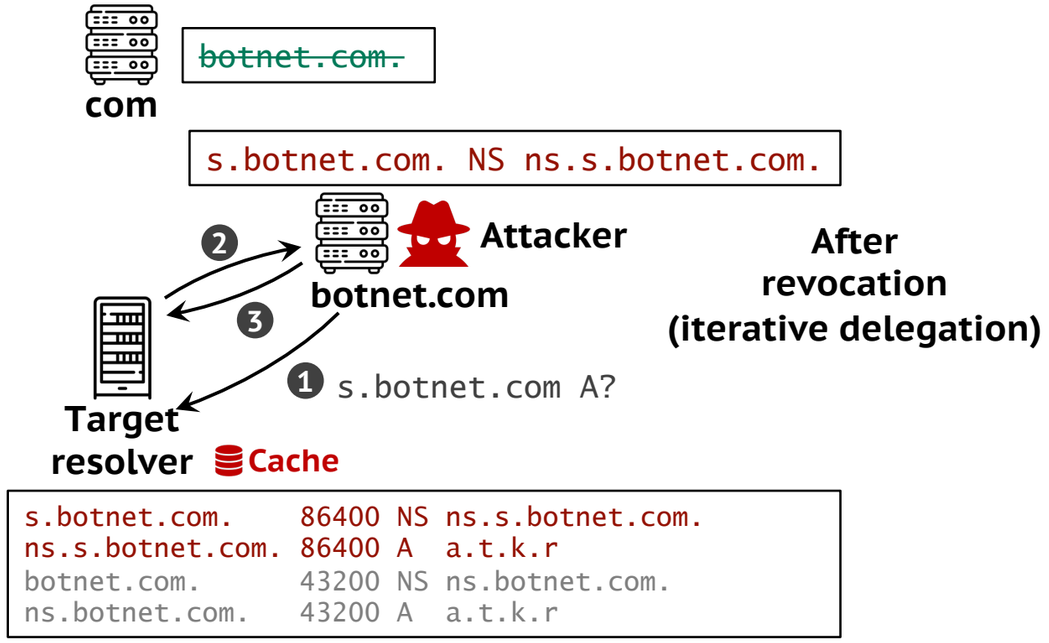
- **T1 attack**
  - ❑ Attack steps
  - ❑ Cache expiration
  - ❑ Cache deletion
  - ❑ Cache insertion



Phoenix Domain T2

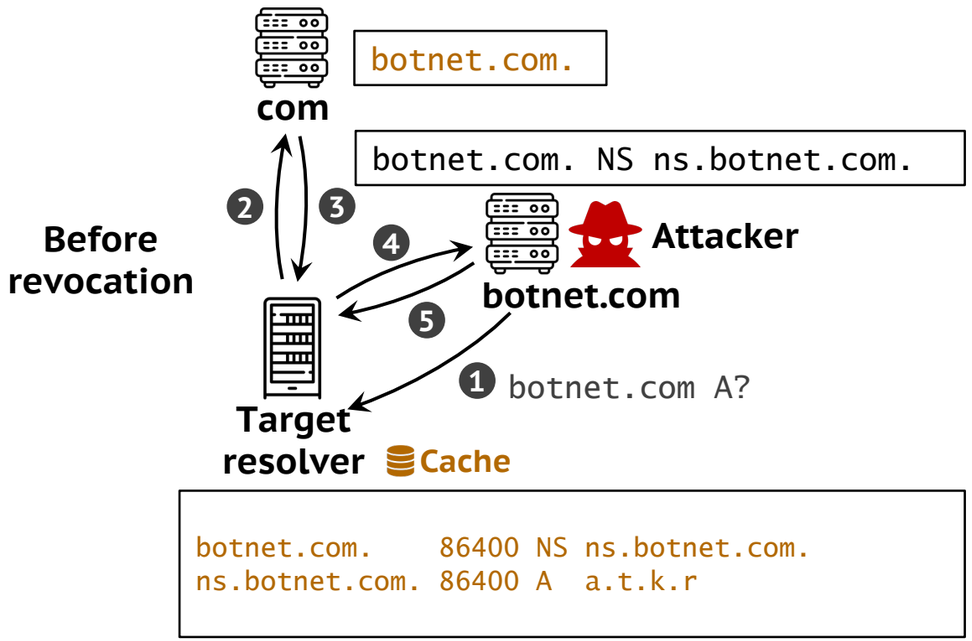
- **T2 attack**
  - Exploiting vulnerable cache searching operations
  - Inserting new NS records of subdomains

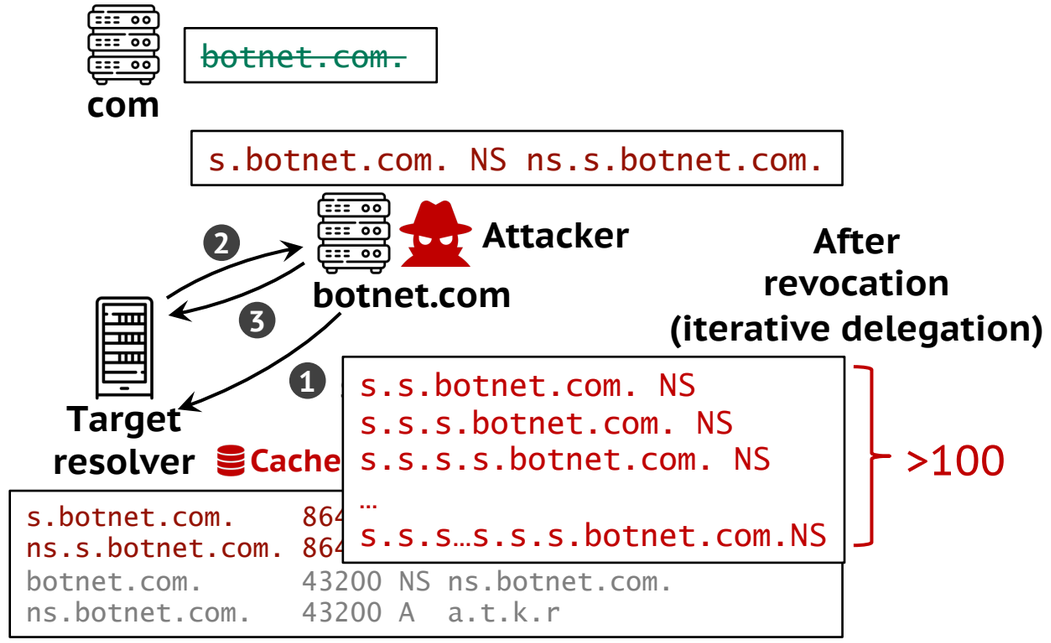




Phoenix Domain T2

- **T2 attack**
  - Exploiting vulnerable cache searching operations
  - Inserting **new NS records of subdomains**





Vulnerable Software

- **Phoenix domain T1**
  - BIND9, Knot, Unbound, and Technitium
- **Phoenix domain T2**
  - All tested 8 software are vulnerable (7 confirmed, 9 CVEs)

BIND 9 | KNOT RESOLVER | unbound | POWERDNS | Microsoft DNS | MaraDNS | Simple DNS Plus | Technitium DNS Server

CVE-2022-30250 CVE-2022-30251
CVE-2022-30252 CVE-2022-30254
CVE-2022-30256 CVE-2022-30257
CVE-2022-30258 CVE-2022-30698
CVE-2022-30699

Vulnerable Public Resolvers

- **Phoenix domain T1 and/or T2**
  - We test 41 public resolver vendors
  - All resolvers are vulnerable to T1 and/or T2
  - Such as Google, Cloudflare, Akamai, AdGuard, etc. (15 confirmed)

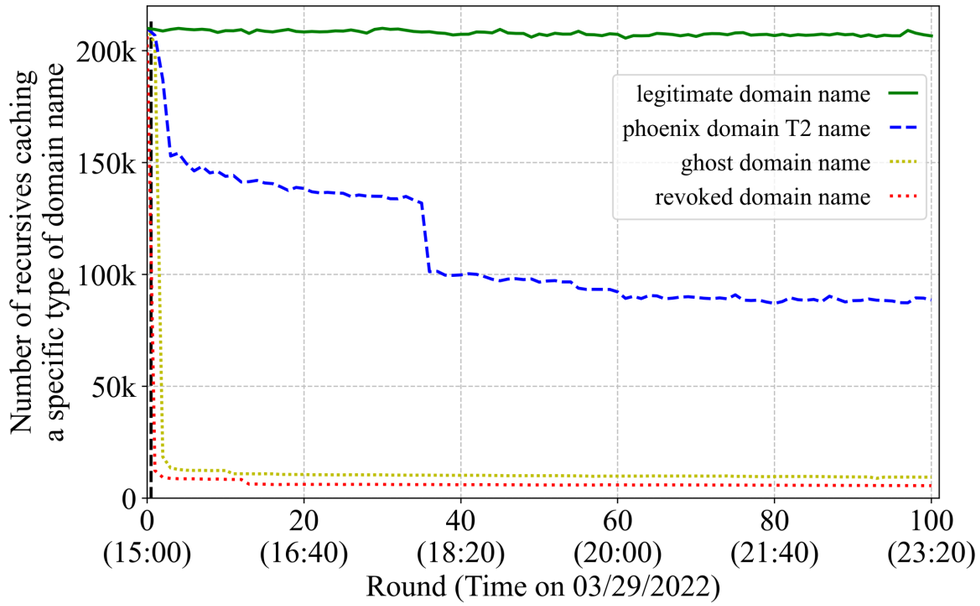
Vulnerable Open Resolvers

- **Recursive resolver list**
  - Through scanning, we collected 1.2M resolvers
  - 210k recursive resolvers are selected

Region	Number	%	ASN	Number	%
USA	43,034	20.5%	4837	9,825	4.7%
China	25,152	12.0%	4134	5,988	2.9%
Russia	22,802	10.9%	3462	5,864	2.8%
Japan	13,421	6.4%	4713	5,134	2.4%
France	12,801	6.1%	8866	4,884	2.3%
Turkey	8,389	4.0%	9121	4,779	2.3%
Brazil	7,128	3.4%	16276	4,355	2.1%
Sweden	7,026	3.3%	209	3,937	1.9%
Taiwan	6,869	3.3%	3215	3,735	1.8%
Ukraine	6,572	3.1%	12389	3,485	1.7%
Total 218 regions			**Total 11,274 ASes**		

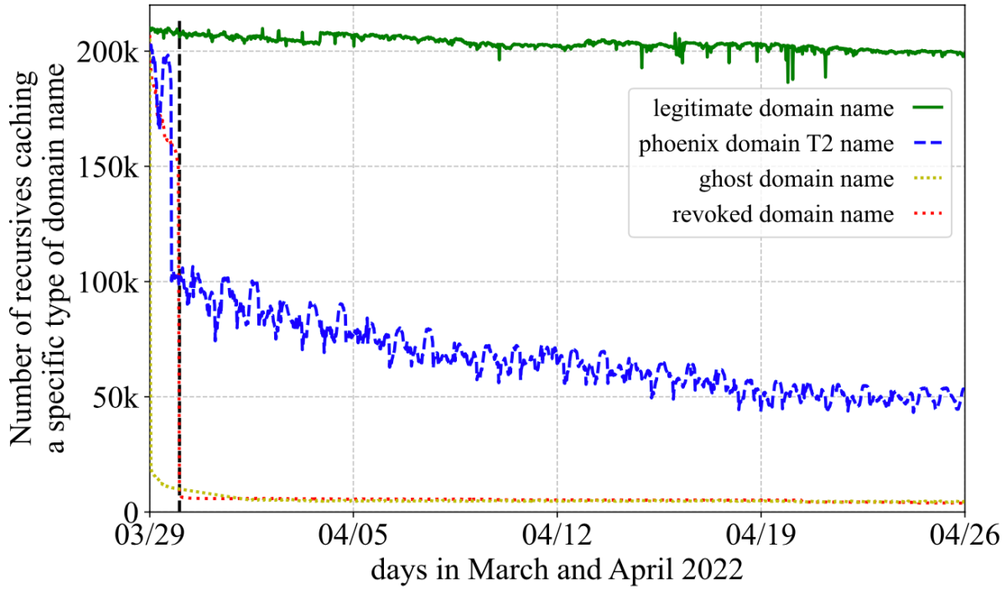
Experiments for T2

- **Short-term experiments**
  - Check how many labels are supported
  - 89% are vulnerable
  - After 100 rounds, 42% are vulnerable



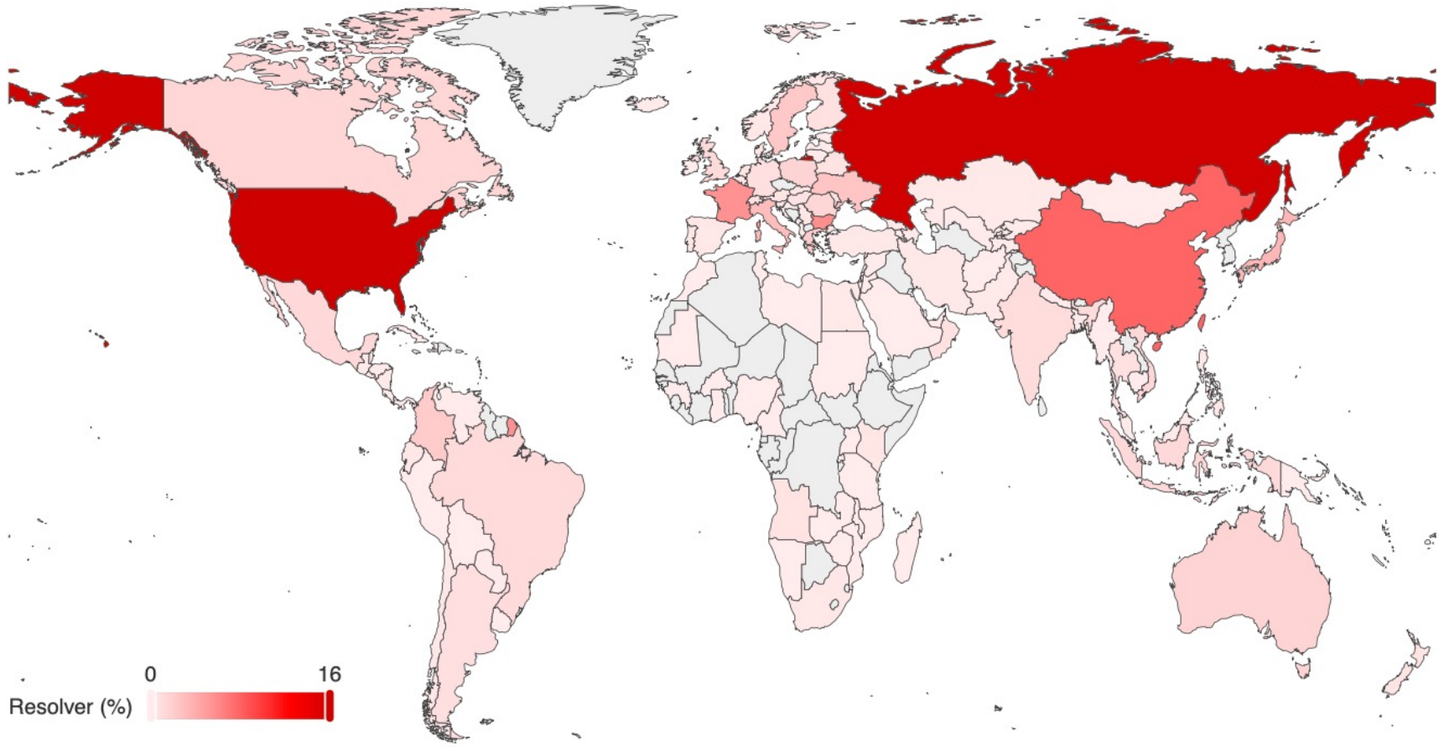
Experiments for T2

- **Long-term experiments**
  - Check how long phoenix domain can be alive
  - After one week, 40% are vulnerable
  - After one month, 25% are vulnerable



Experiments for T2

- **Geolocation of vulnerable resolvers**
  - USA, Russia, and China



Mitigation

- 6 approaches
- Discussing with RFC editors
- For example,
- **M1:** when NS RRs expire, querying upstream for NS
- **M2:** trust NS from the parent more than the child
- **M3:** use small TTL values

Delegation Revalidation by DNS Resolvers
draft-ietf-dnsop-ns-revalidation-03

Mitigation	T1	T2
M1: Re-validating delegation information	●	●
M2: Updating delegation data by parent-centric policies.	●	○
M3: Aligning the cache use-and-check operations	●	○
M4: Ignoring unsolicited DNS records	◐	◐
M5: Scrutinizing domain names with over many labels	○	◐
M6: Restricting the maximum cache TTL	○	◐

●: Fully valid. ◐: Partially valid. ○: Not valid.

Sound Bytes

- **The DNS RFCs and specifications are not clear to provide a deterministic definition for each operation, hence leaving a large attack window for ambiguous implementations.**
  - We should check the RFC's essential specifications.
- **The DNS implementations are not consistent across software, even for identical client queries.**
  - This inconsistency is likely to conceal possible risks, which should be thoroughly researched and evaluated.
- **The original DNS mechanism is insufficient to defend against several types of attacks.**
  - To improve it, we should propose new patches or redesign some structures.

Wrap-up

Thanks for listening!
Any question?

Xiang Li, Tsinghua University

x-l19@mails.tsinghua.edu.cn

Paper

Tool