



NDSS Symposium 2023

Ghost Domain Reloaded: Vulnerable Links in Domain Name Delegation and Revocation

Xiang Li, Baojun Liu, Xuesong Bai, Mingming Zhang, Qifan Zhang,
Zhou Li, Haixin Duan, and Qi Li

Presenter: Xiang Li, Tsinghua University

March 1st, 2023

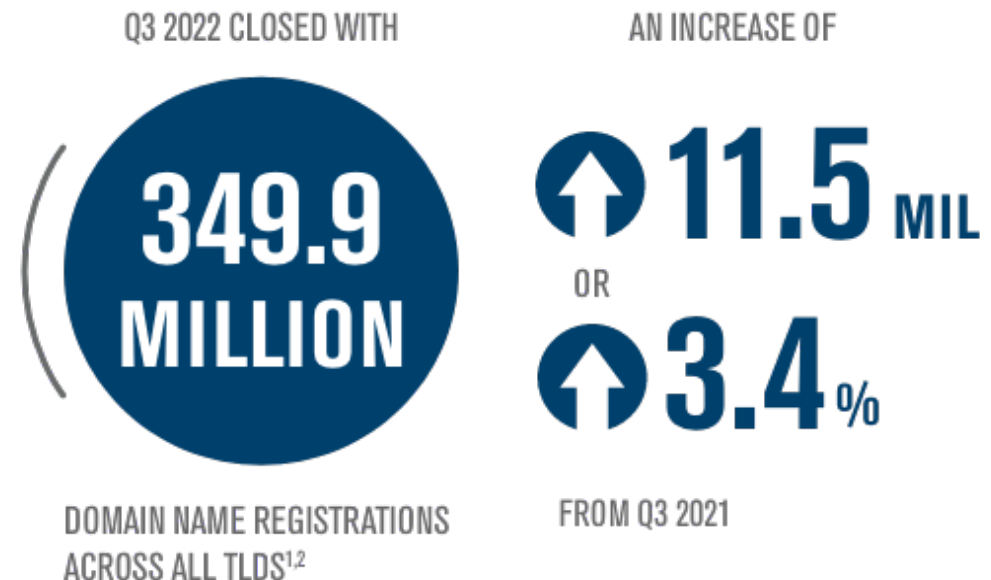
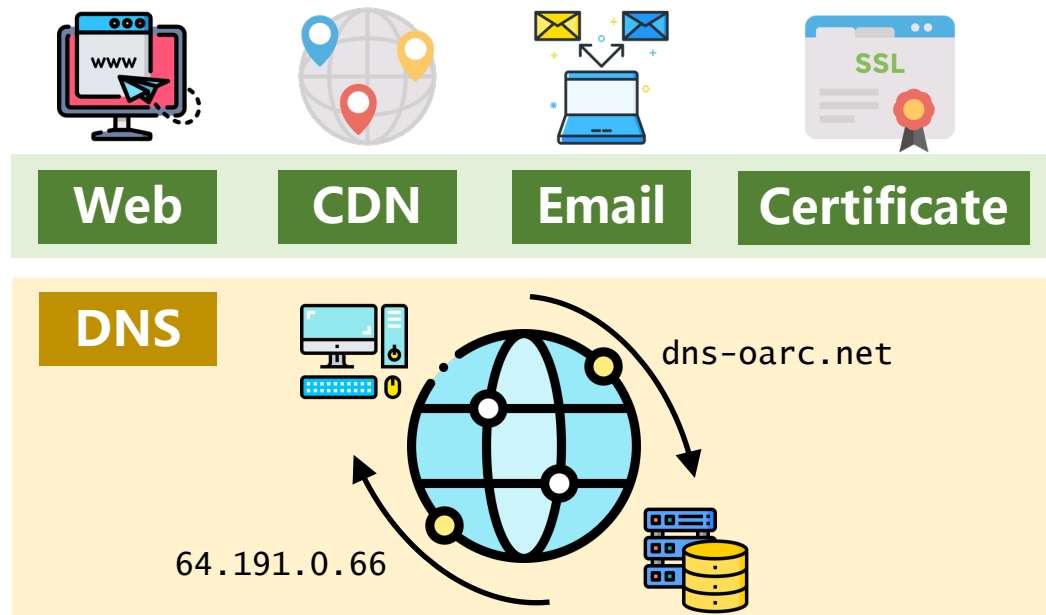




Domain Name

➤ Domain name system (DNS)

- Entry point of many Internet activities
- Security guarantee of multiple application services
- Domain names are widely registered



Domain Name Abuse

➤ Also abused by criminal activities

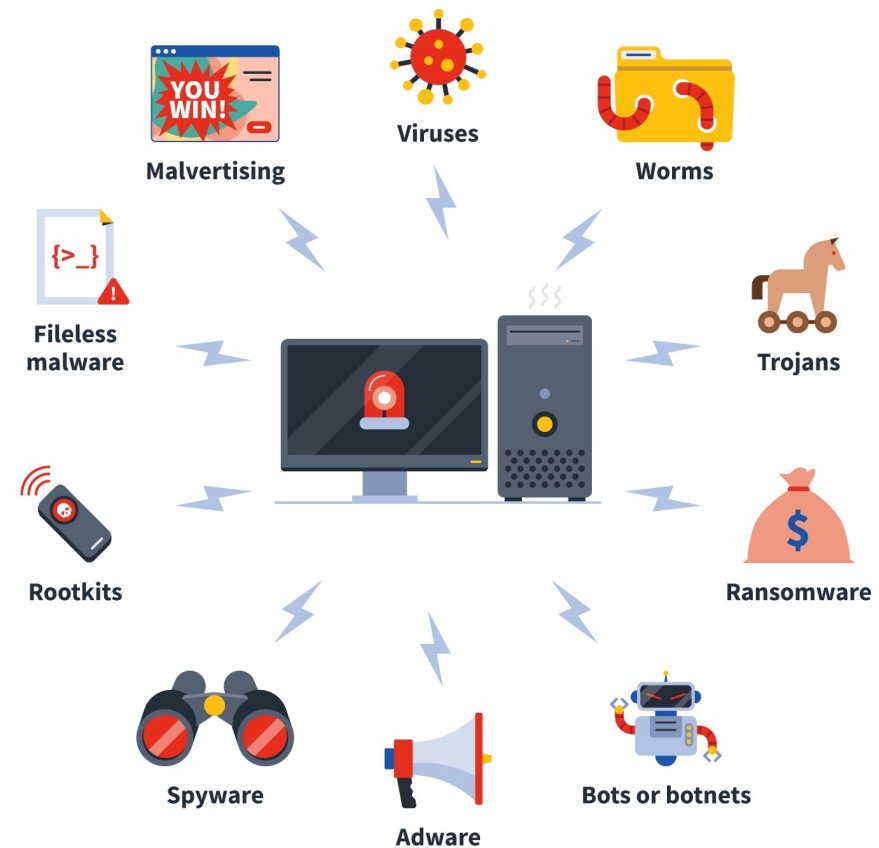
➤ Botnet, phishing, malware distribution



Cited from bleepingcomputer.com



Cited from scmp.com



Cited from norton.com



Domain Name Abuse

- **Also abused by criminal activities**
 - Botnet, phishing, malware distribution
- **ICANN Domain abuse activity reporting (DAAR)**
 - In January 2023
 - Check 215,555,155 domain names within 1,154 gTLDs

**659,813 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.

Cited from theregister.com



Cited from intelligentciso.com



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

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

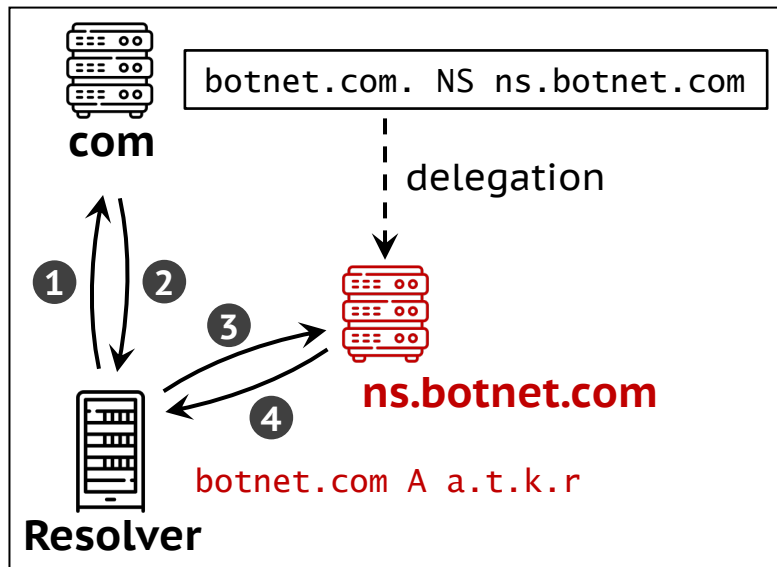
Domain Name Revocation

➤ Normal resolution

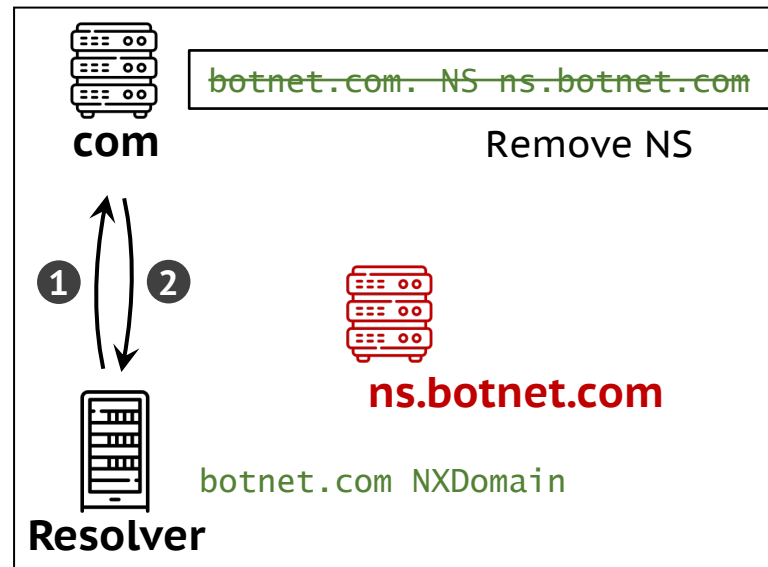
➤ Revocation

➤ Domain delisting

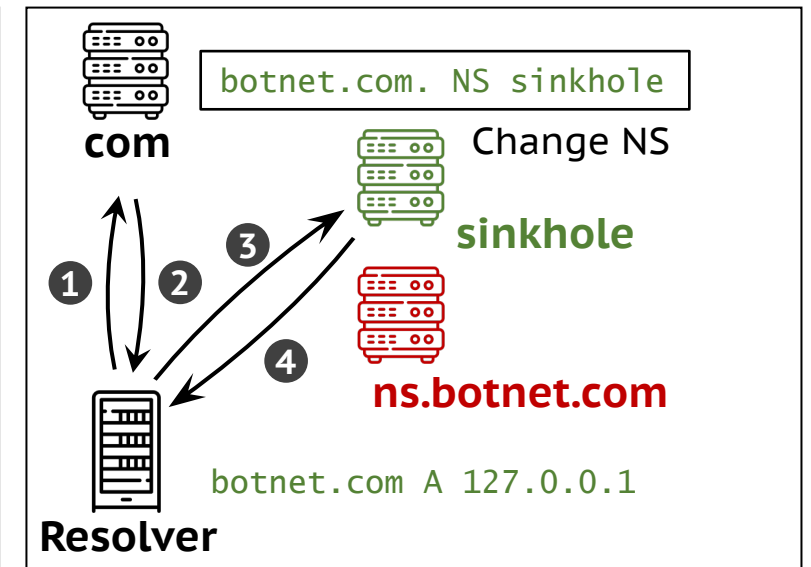
➤ Domain sinkholing



Normal resolution



Domain delisting



Domain sinkholing



**Does domain name revocation
function as desired?**

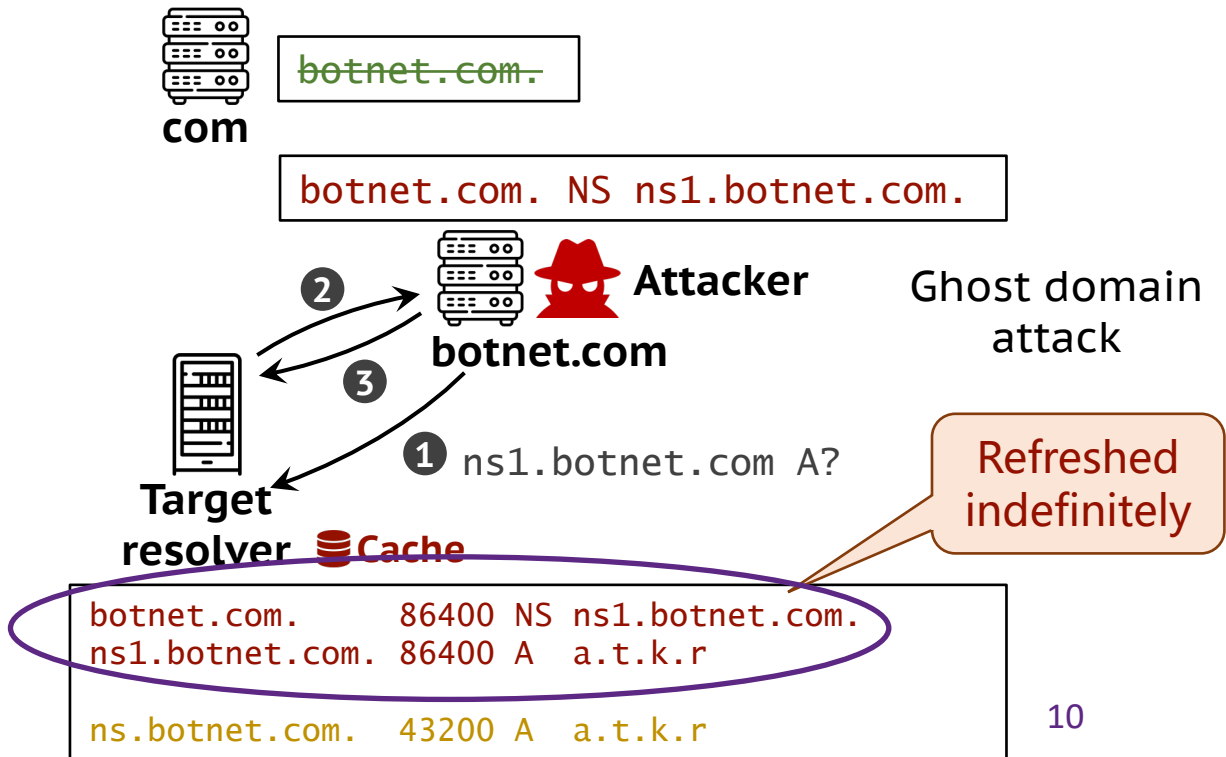
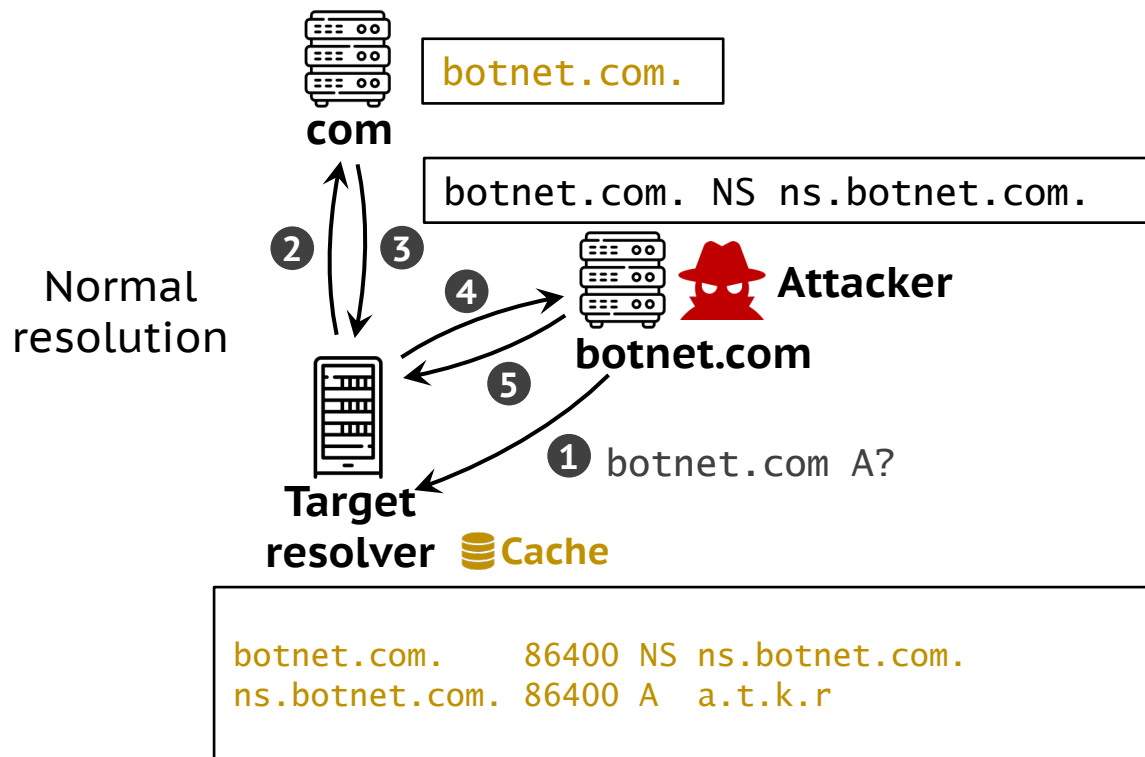
No. Ghost domain broke this guarantee.



Ghost Domain

➤ Ghost domain attack

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





**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

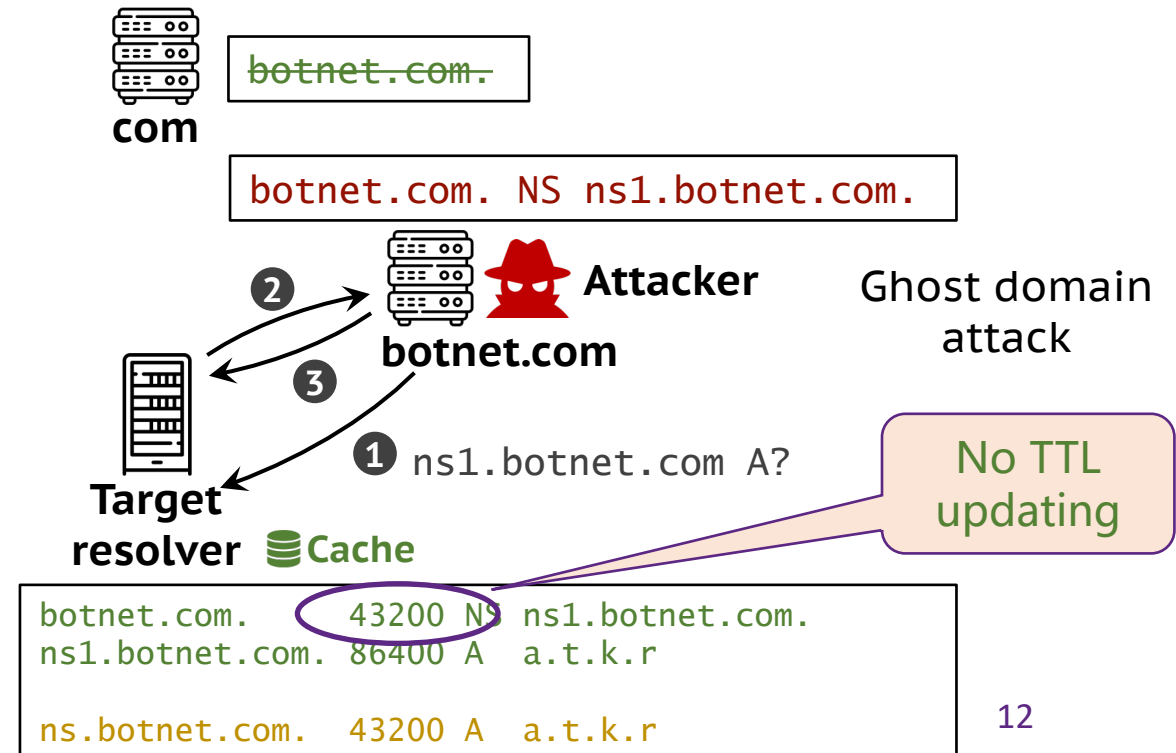
➤ Vulnerable software

➤ 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





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
- 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**



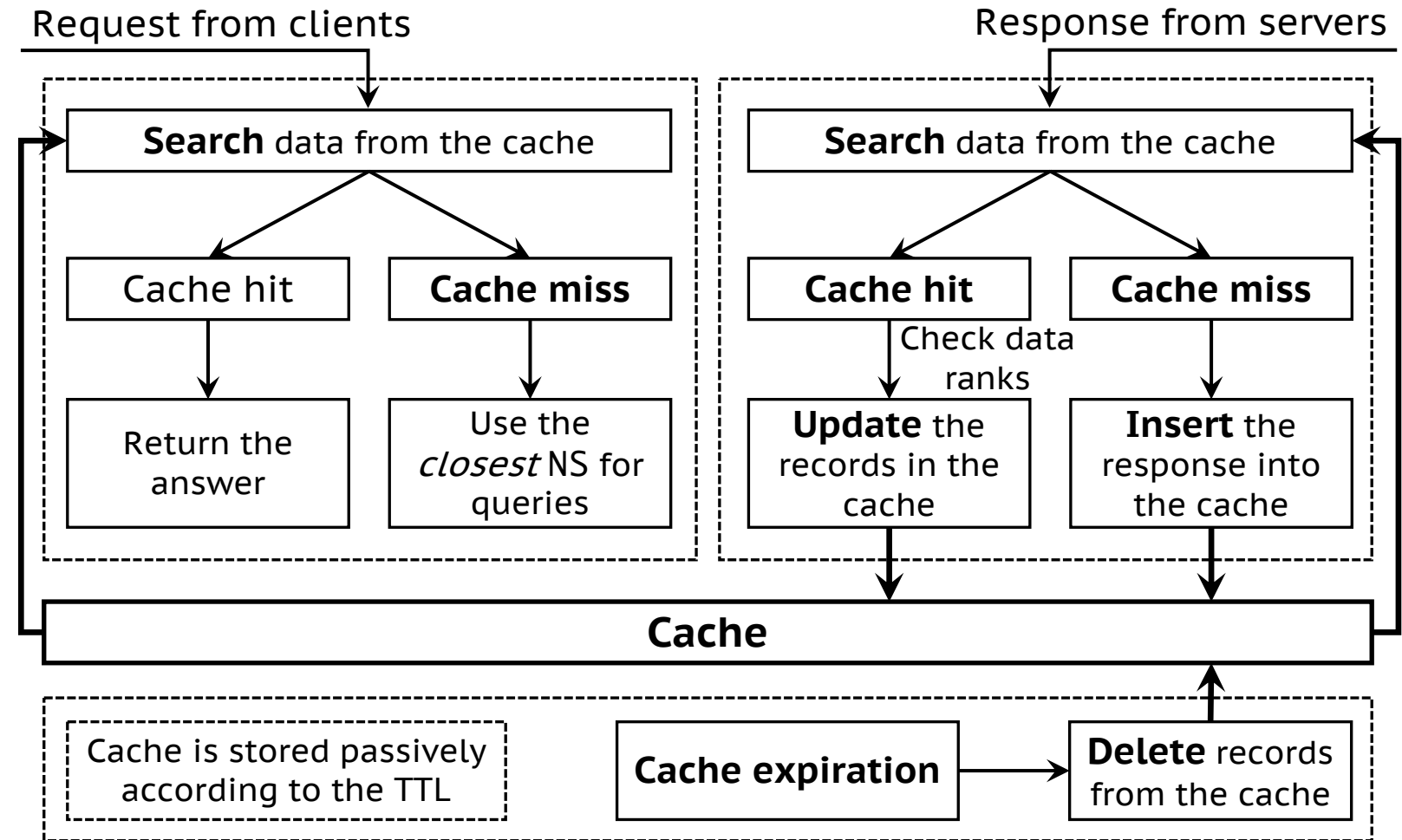
Why is domain name revocation still vulnerable?

We find that the entire attack surface
remains unclear now.

DNS Cache Operations



➤ Summary

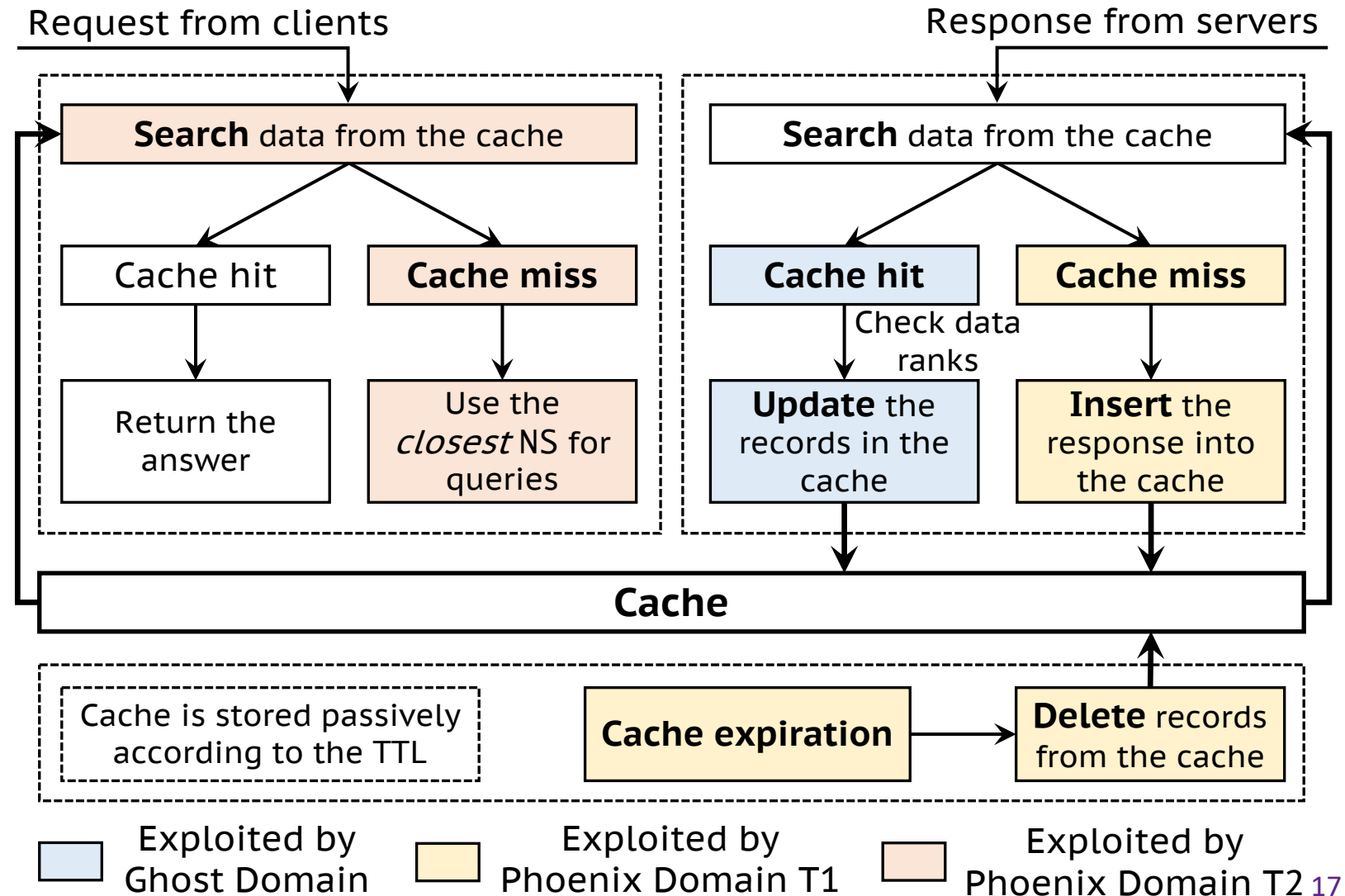


DNS Cache Operations



➤ Attack Surface

- Updating
- Insertion
- Searching





How does phoenix domain work?

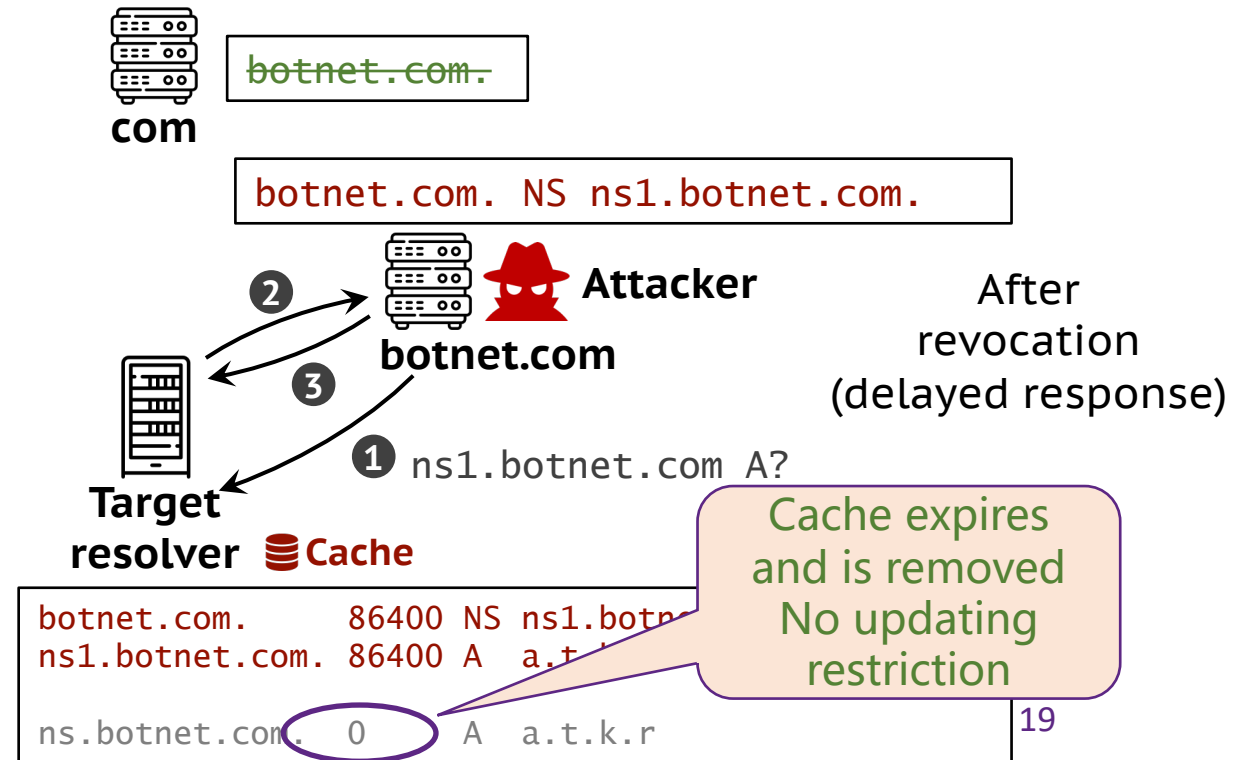
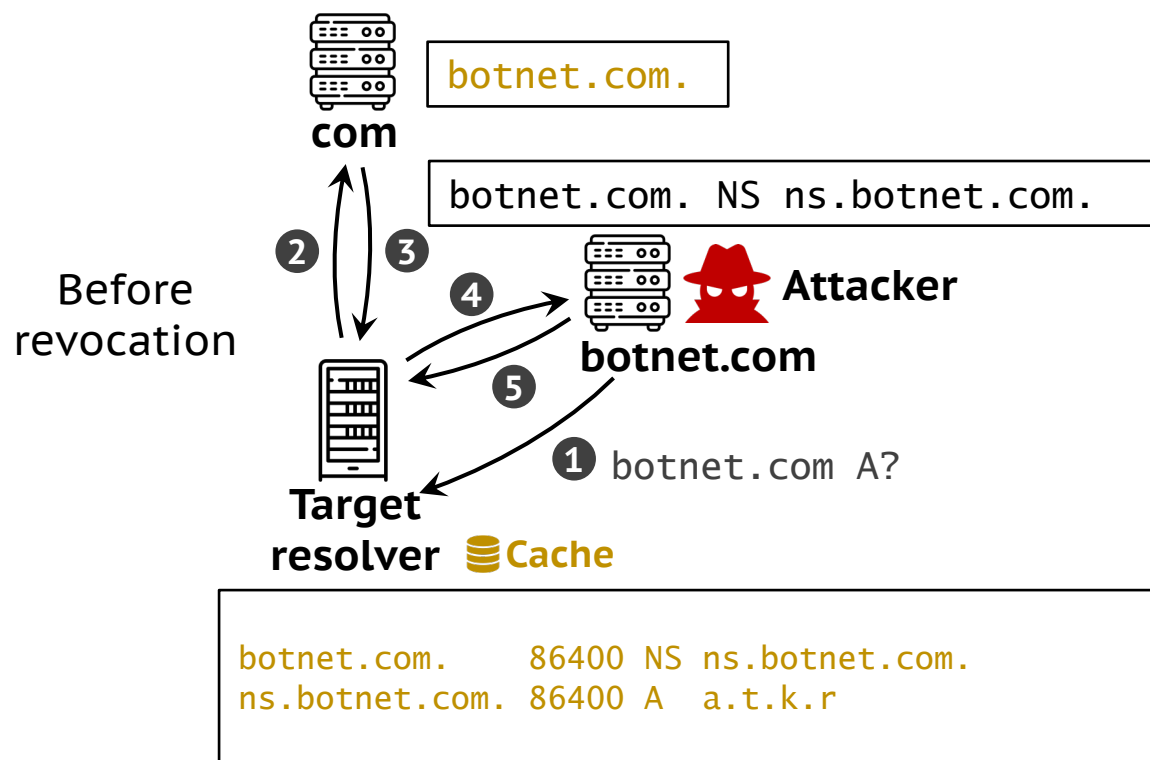
Two variations, two ways.



Phoenix Domain T1

➤ T1 attack

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



Phoenix Domain T1



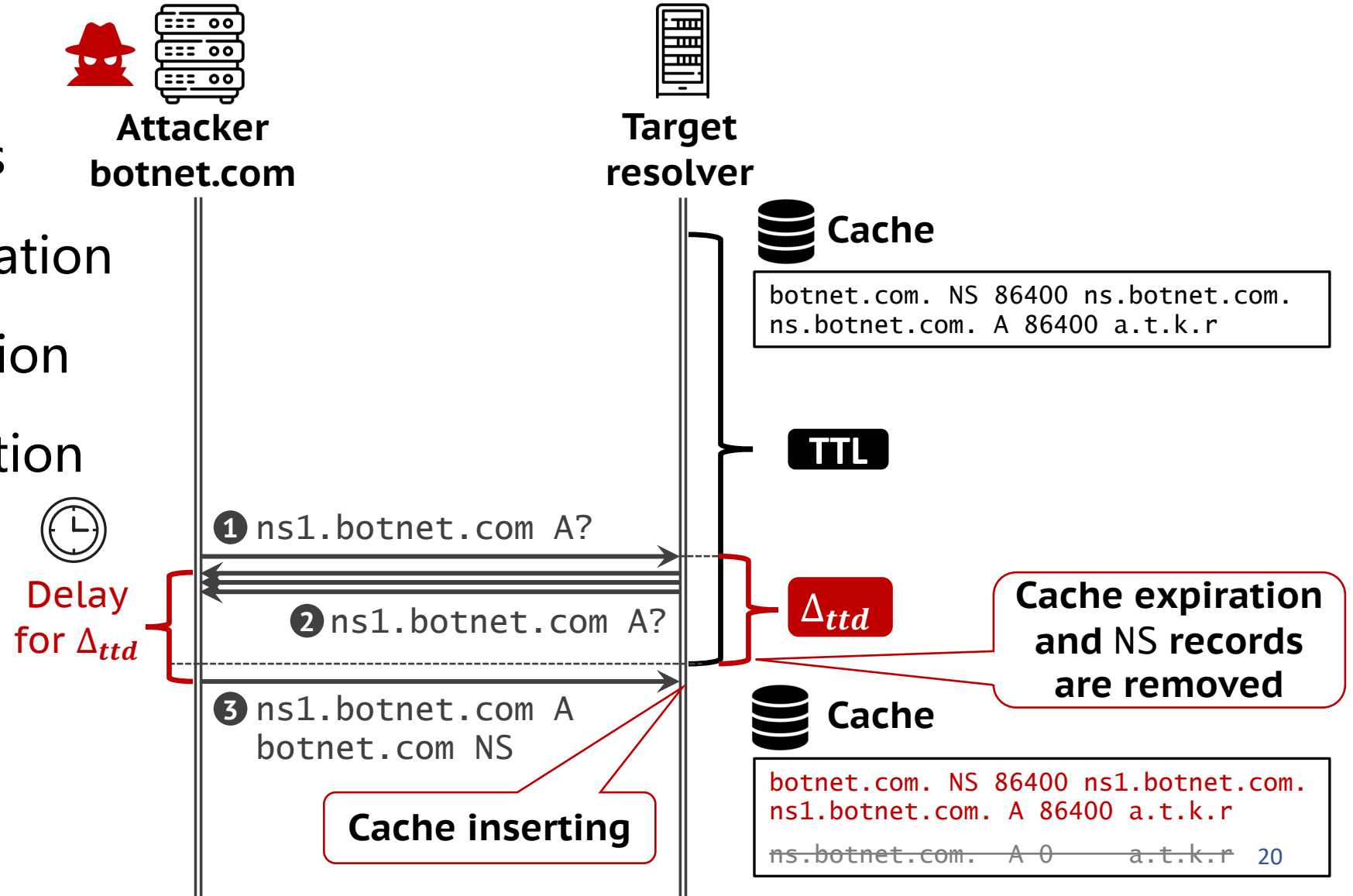
➤ T1 attack

➤ Attack steps

➤ Cache expiration

➤ Cache deletion

➤ Cache insertion

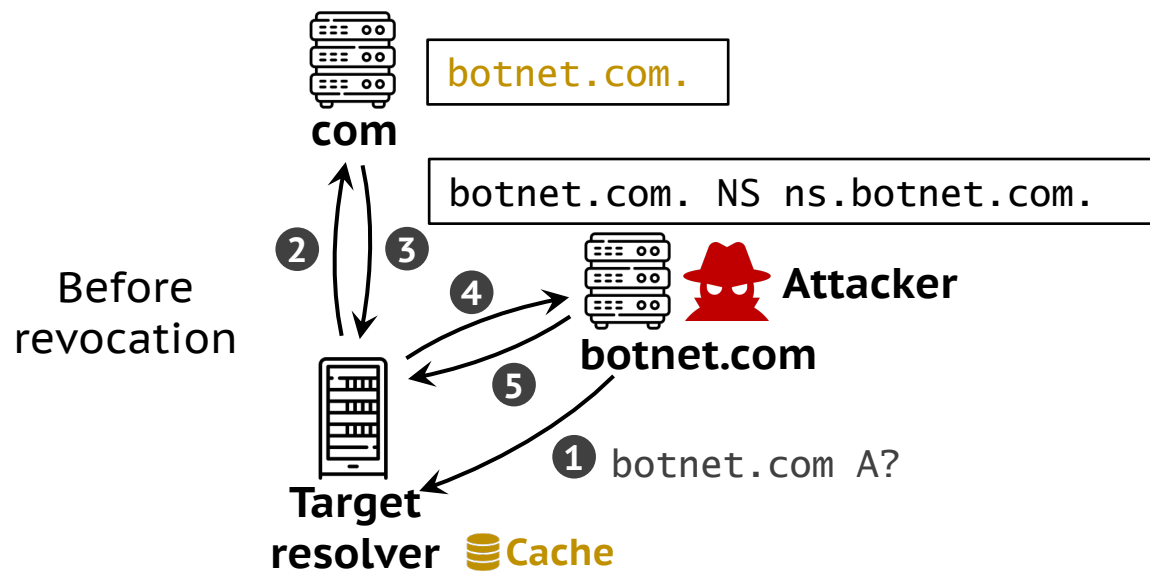




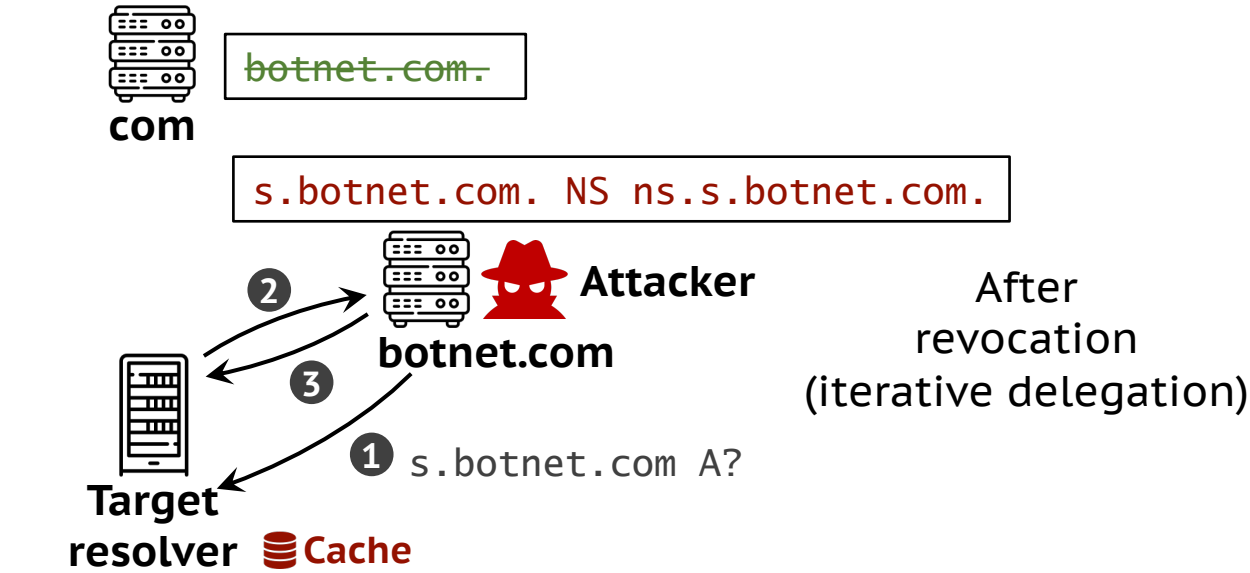
Phoenix Domain T2

➤ T2 attack

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



botnet.com.	86400	NS	ns.botnet.com.
ns.botnet.com.	86400	A	a.t.k.r



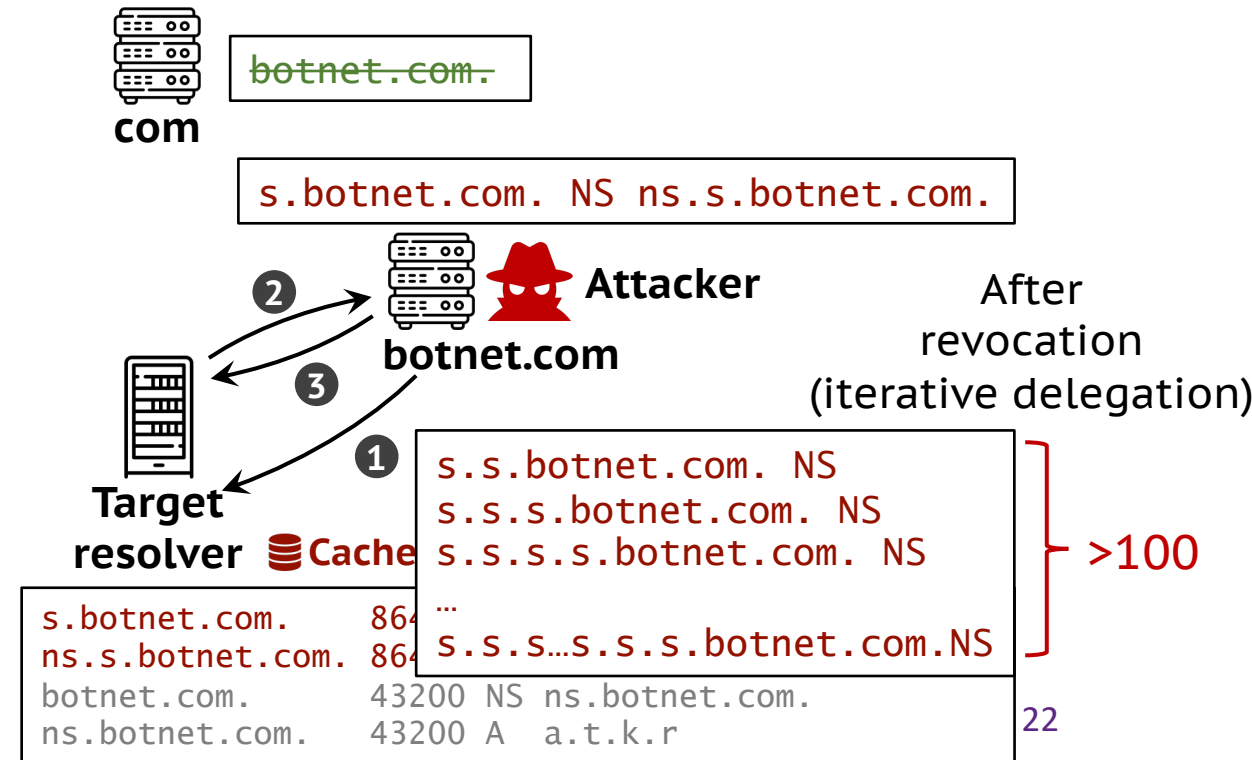
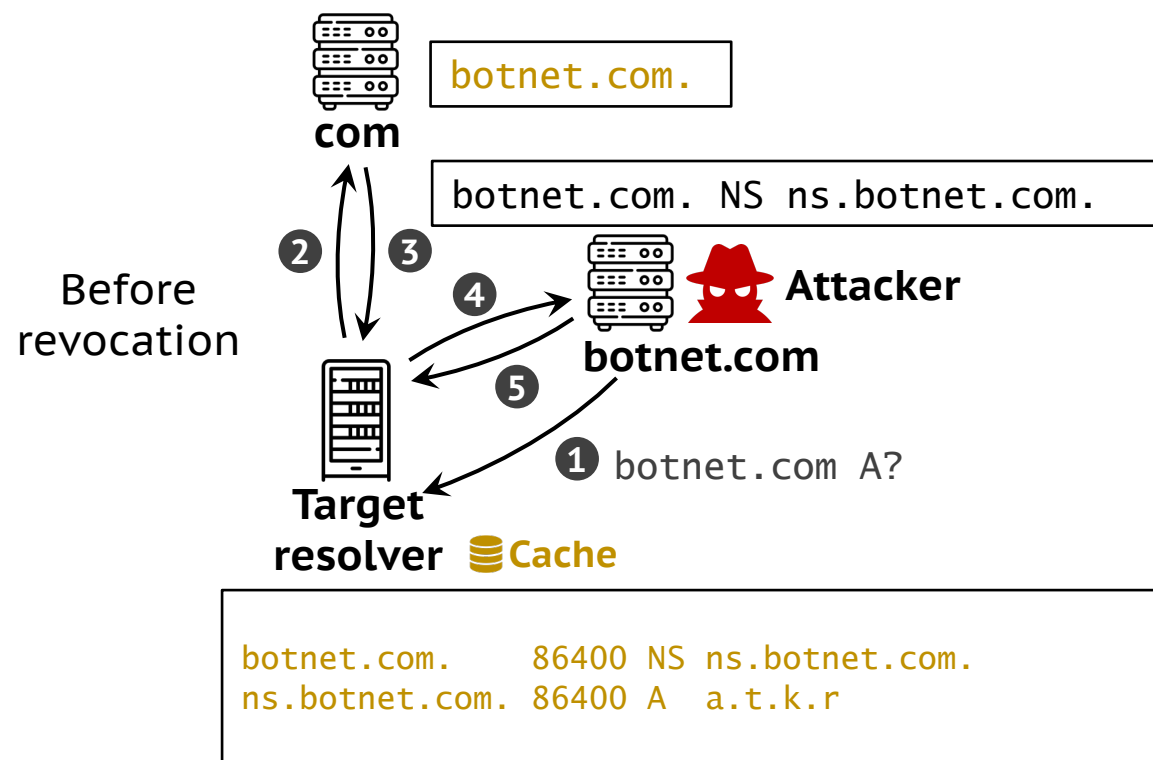
s.botnet.com.	86400	NS	ns.s.botnet.com.
ns.s.botnet.com.	86400	A	a.t.k.r
botnet.com.	43200	NS	ns.botnet.com.
ns.botnet.com.	43200	A	a.t.k.r



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

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

POWERDNS

Microsoft
DNS

MaraDNS

Simple DNS Plus

Technitium DNS Server



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



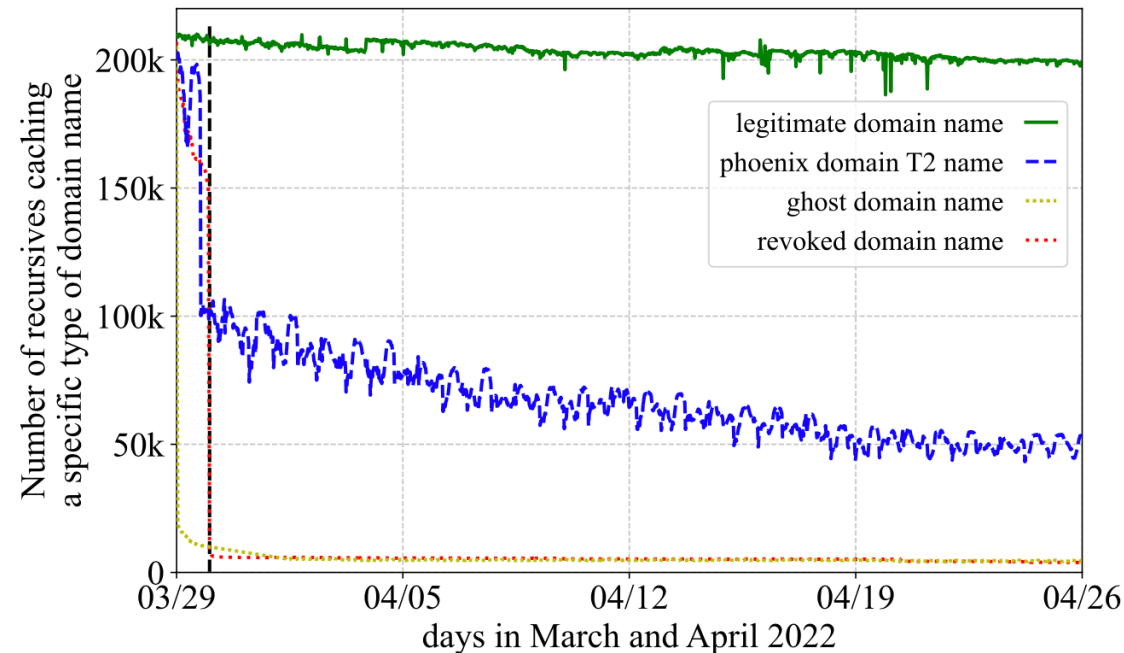
Region	Number	%	ASN	Number	%
USA	43,034	20.5%	4837	9,825	4.7%
China	25,152	12.0%	4134	5,988	2.9%
Russia	22,802	10.9%	3462	5,864	2.8%
Japan	13,421	6.4%	4713	5,134	2.4%
France	12,801	6.1%	8866	4,884	2.3%
Turkey	8,389	4.0%	9121	4,779	2.3%
Brazil	7,128	3.4%	16276	4,355	2.1%
Sweden	7,026	3.3%	209	3,937	1.9%
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

➤ Long-term experiments

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



Mitigation



➤ 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

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

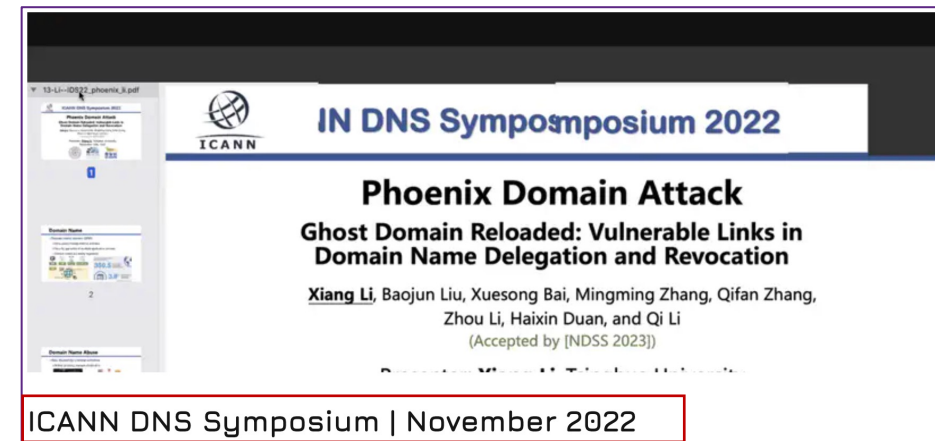
●: Fully valid. ◐: Partially valid. ○: Not valid.

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



Conclusion

- New phoenix domain attacks
- Two novel vulnerabilities
 - T1 (poor implementations)
 - T2 (de facto protocol standards)
- Comprehensive influence
- Detailed mitigation approaches
 - Our paper is added into an RFC draft
- Well acknowledged by the community



Thanks for listening!

Any question?

Xiang Li, Tsinghua University
x-l19@mails.tsinghua.edu.cn

