Stale TLS Certificates

Investigating Precarious Third-Party Access to Valid TLS Keys

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Public-key crypto

TLS Certificate

Key challenge: linking cryptographic identity (public-key) with semantic identity

TLS certificate = cached attestation

TLS Certificate

Stale TLS certificates

Stale TLS Certificate

New TLS Certificate

Stale certificates arise from **certificate invalidation events**: changes to attested information (e.g., subject / issuer info) while certificate is still valid

Stale TLS certificates

Issuer Name: Certificate Authority XYZ

Subject Name: domain.com
Subject Public Key: 0400aefa6edef14a…

Validity: 2023-10-20 to 2024-11-19

Issuer Signature: 19574503953e…

Issuer Name: Certificate Authority XYZ

Subject Name: domain.com
Subject Public Key: 00c946d6e746f1…

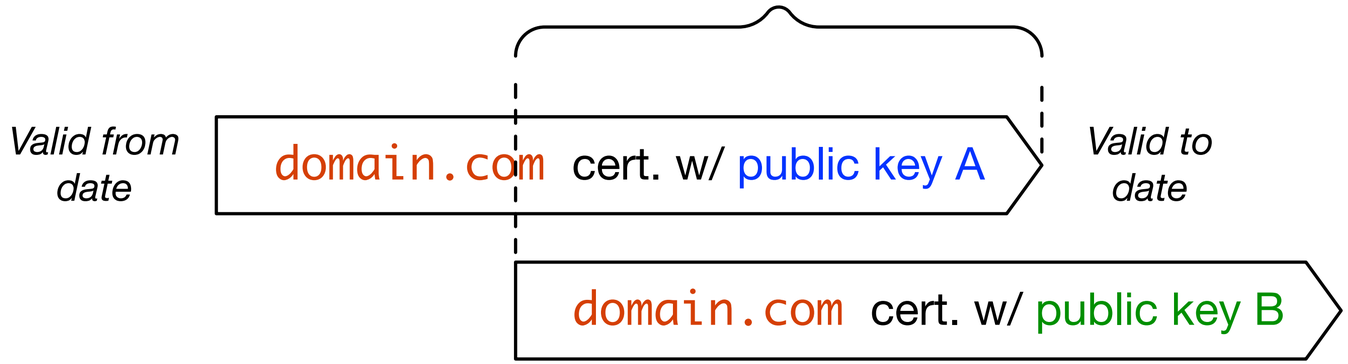
Validity: 2023-10-25 to 2024-11-24

Issuer Signature: 19574503953e…

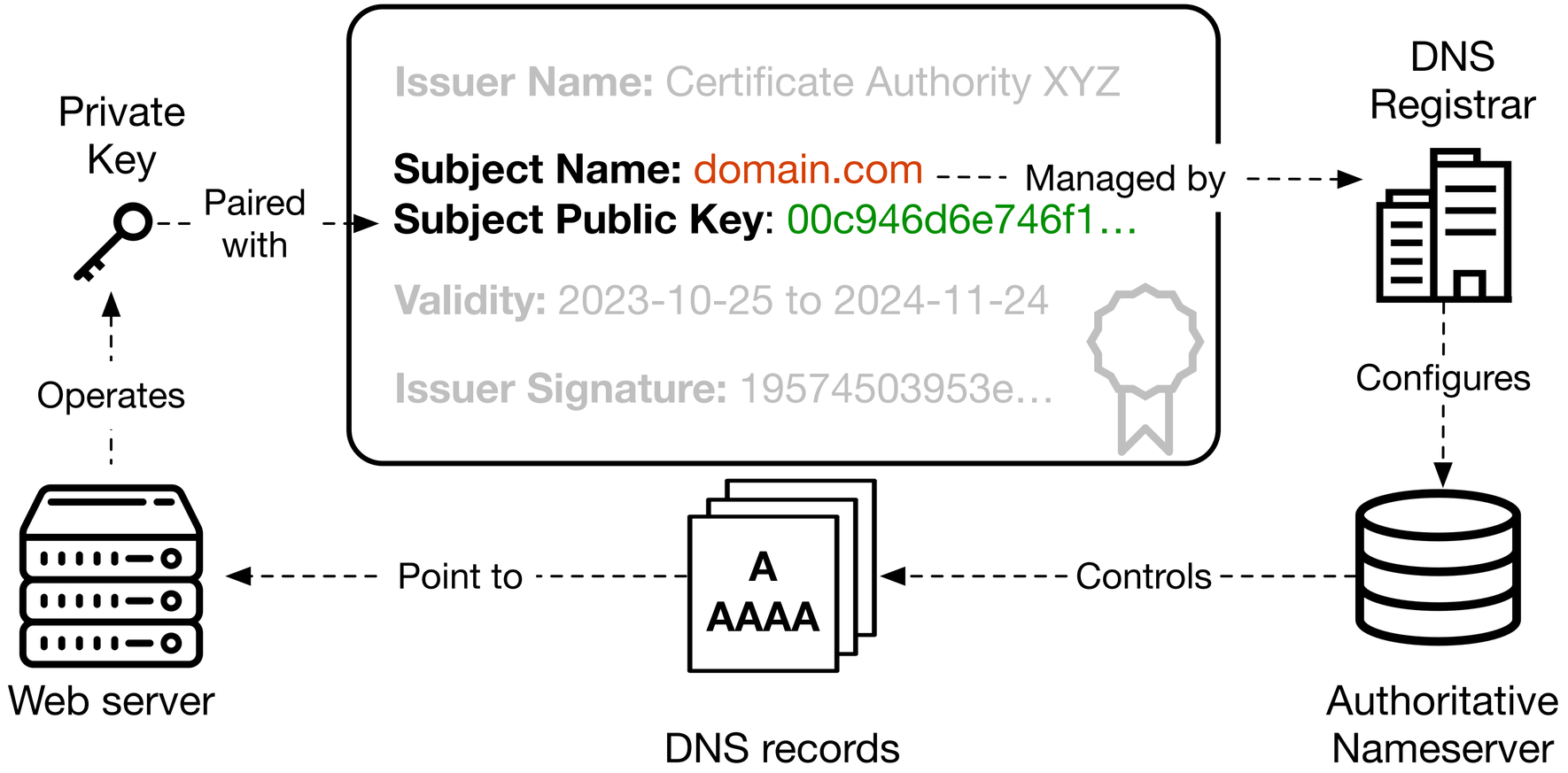
Stale TLS Certificate

Stale period

New TLS Certificate

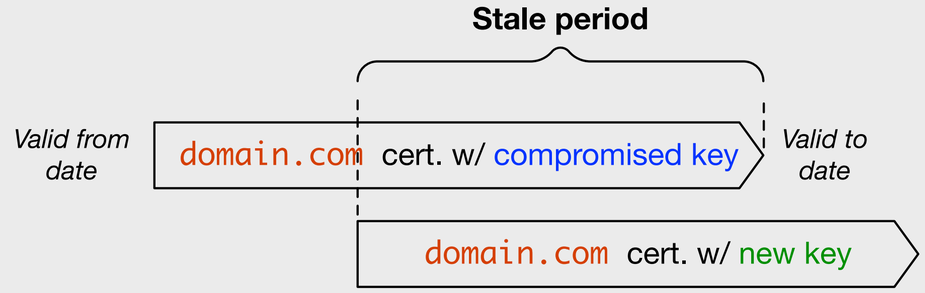


Domain-to-key operational gap

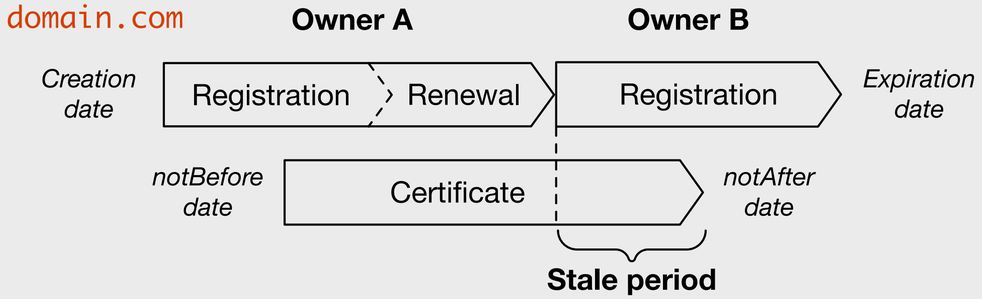


Third-party access to valid TLS keys

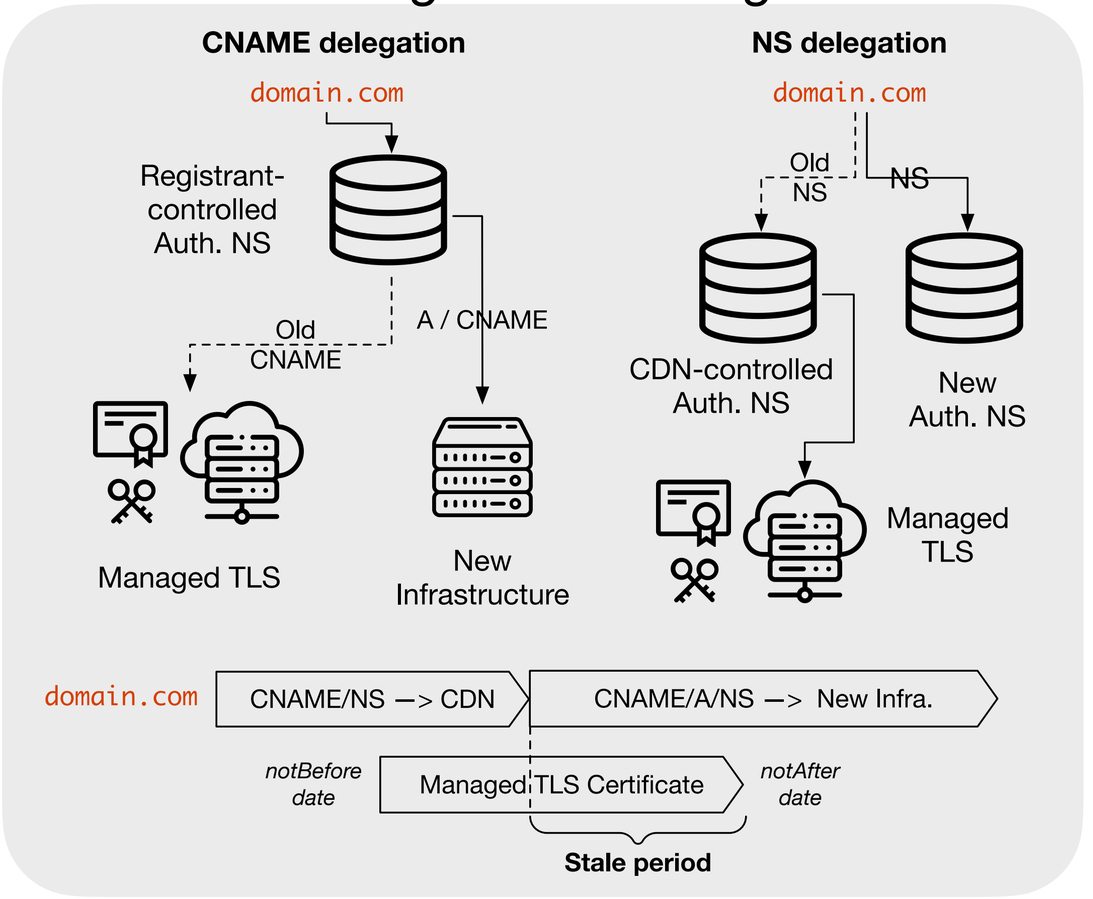
Compromised key change



Domain owner change



Managed TLS change



Revocation to the rescue?

Web browsers

Chrome has CRLsets primarily for “emergency situations”

Firefox OCSP checking fails open
OCSP Must-Staple fails closed, but low adoption

No revocation checking for most leaf certificate revocation

Non-browser TLS clients

openSSL, curl, API libraries, email servers, messaging clients

OpenSSL Cryptography and SSL/TLS Toolkit

curl://

OkHttp **LibreSSL** **GnuTLS**

Mbed TLS **BoringSSL**

Minimal-to-no revocation checking

Revocation is sparse and unreliable

Internet-wide staleness

5B TLS certificates

4B WHOIS records

27B DNS records

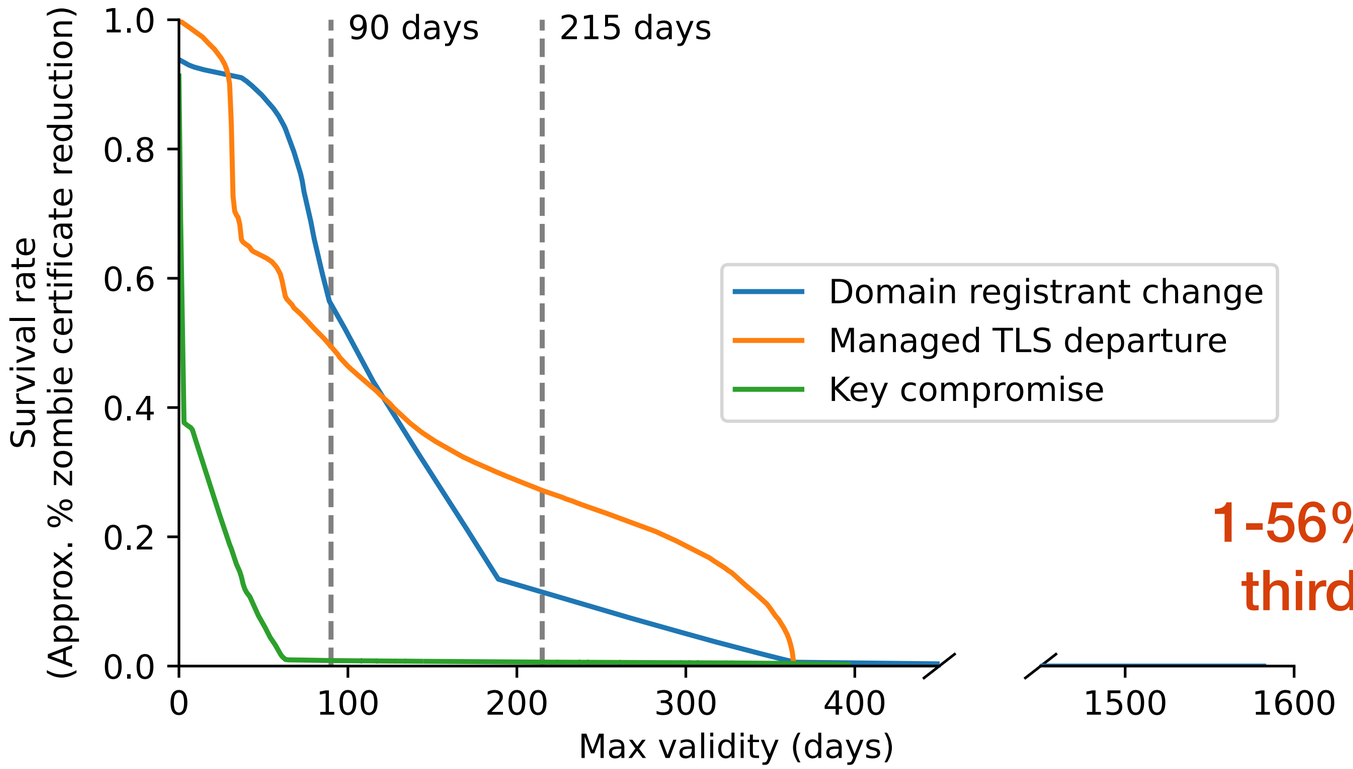
31M Revocations

Third-party Staleness	# certs / day	# FQDNs / day	#e2LD / day
Key compromise	493	787	347
Domain owner change	2,593	2,807	1,214
Cloudflare managed TLS change	9,495	18,833	7,722

Detected stale certs for over >4M e2LDs!

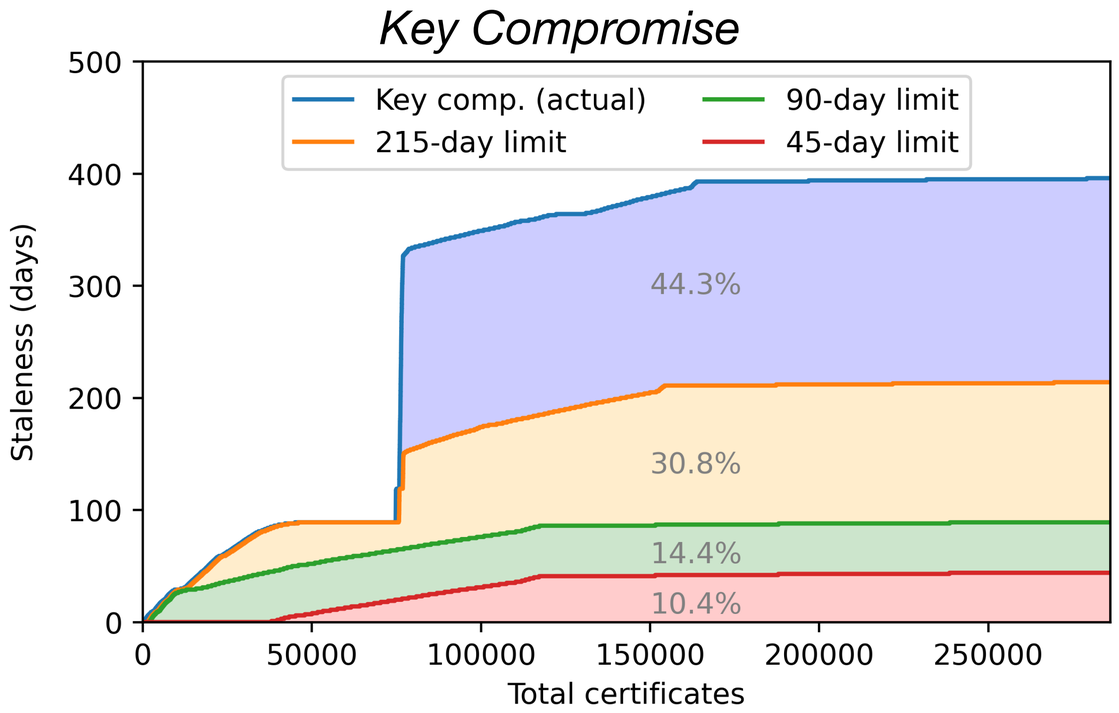
What can we do about it?

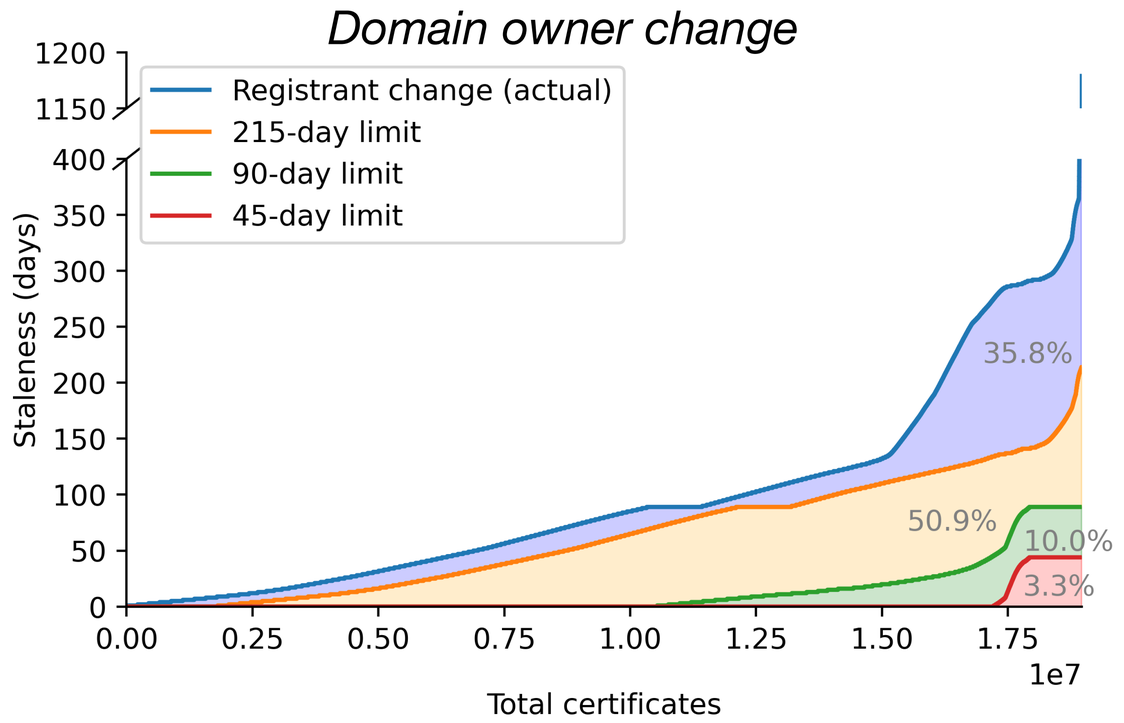
- Revocation is largely ineffective, and (unsurprisingly) poorly utilized
- Caching problem: reduce certificate lifetimes



90-day limit =
1-56% reduction in stale third-party certificates

Shortening certificate lifetimes





90-day limit =
75% decrease in time of third-party access to valid TLS keys

Conclusion

- TLS certificates are a caching mechanism to bind domain-to-key
- Stale TLS certificates —> third-party access to valid TLS keys for someone else's domain, enabling interception attacks
- This has affected at least 4 million domains since 2013
- Revocation (cache invalidation) is ineffective; reducing certificate lifetimes (cache duration) is a promising direction
- Alternative solutions: placing keys closer to names and reducing the domain-to-key operational gap

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