The Design Space between CT and KT

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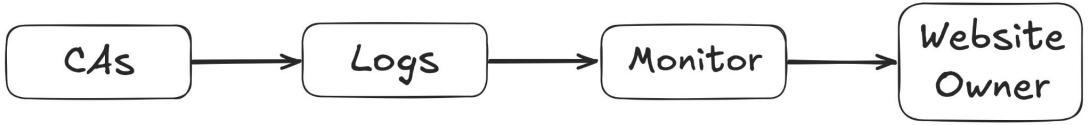
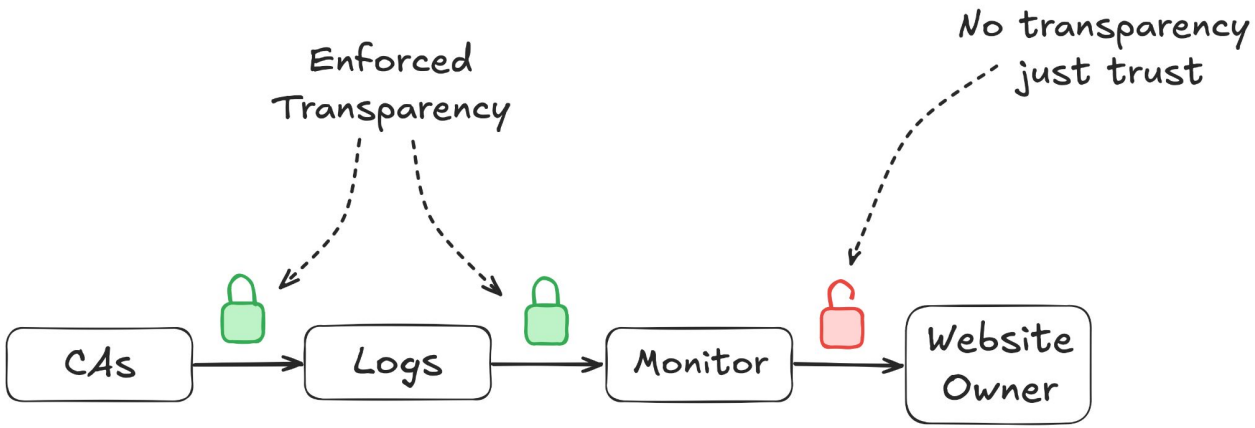
Certificate Transparency



Certificate Transparency: Pain Points



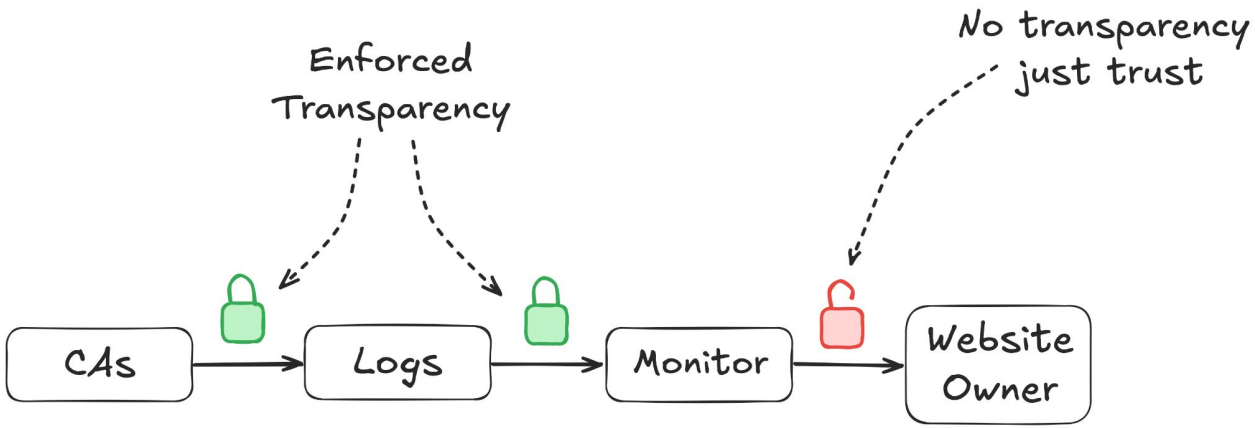
Certificate Transparency: Pain Points

crt.sh Certificate Search

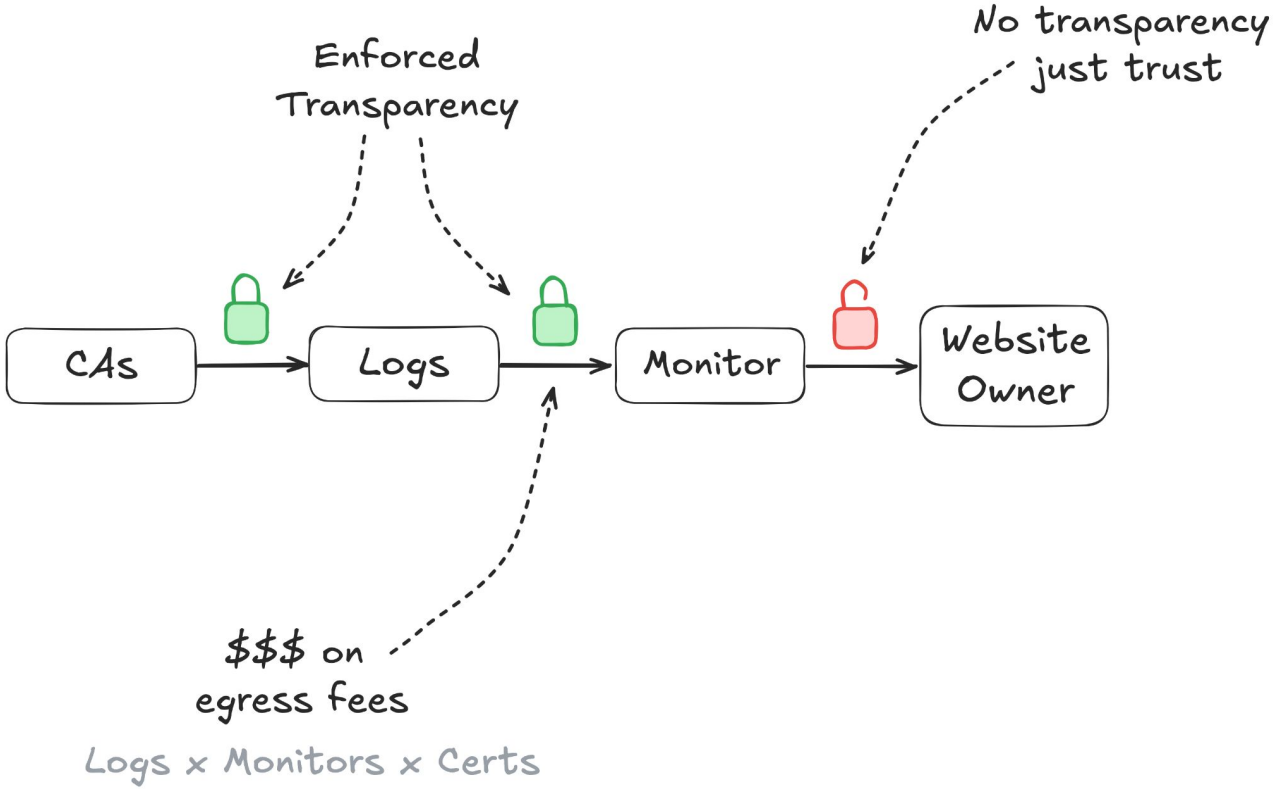
Enter an **Identity** (Domain Name, Organization Name, etc),
a **Certificate Fingerprint** (SHA-1 or SHA-256) or a **crt.sh ID**:

Search Advanced...

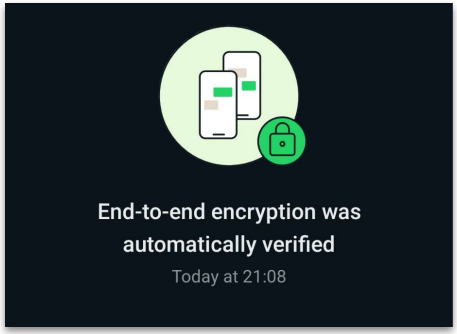
Certificate Transparency: Pain Points

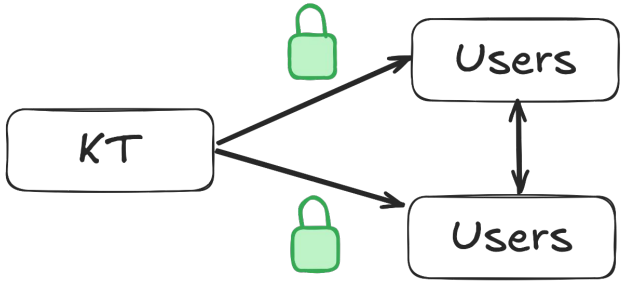


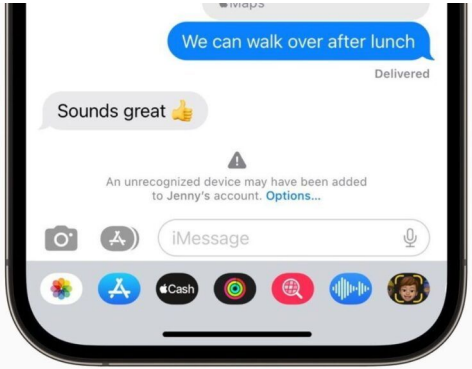
Certificate Transparency: Pain Points



Key Transparency







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The Space Between

Initial Question:

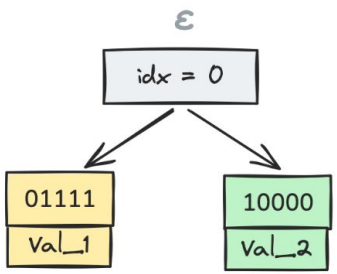
What ideas could be borrowed from KT and leveraged in a future CT system?

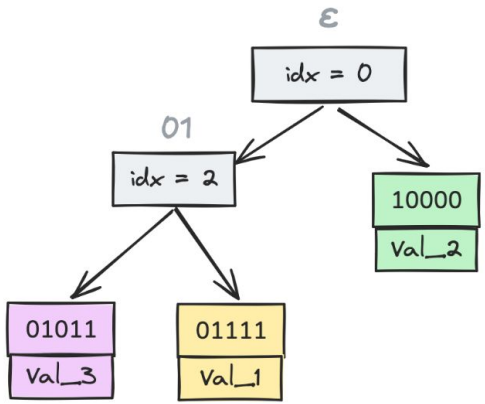
Observation:

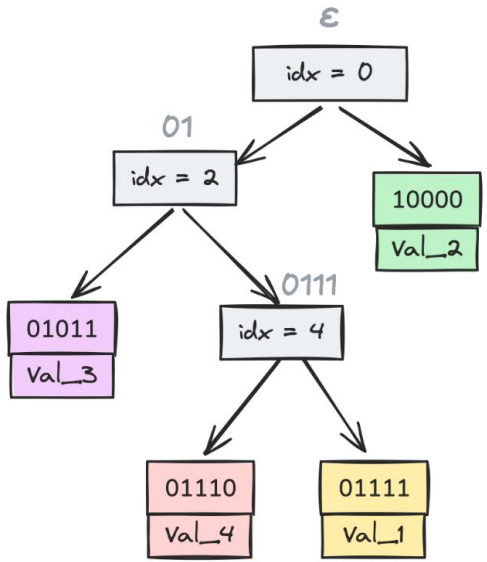
Websites, unlike users, don't need privacy.

The next 7 minutes: Sketching a design that sits between CT and KT.

Efficient Verifiable Maps: Merkle Patricia Tries








```
{
    01111  : Val_1,
    10000  : Val_2
}
```

```
{
    01111  : Val_1,
    10000  : Val_2,
    01011  : Val_3
}
```

```
{
    01111  : Val_1,
    10000  : Val_2,
    01011  : Val_3,
    01110  : Val_4
}
```

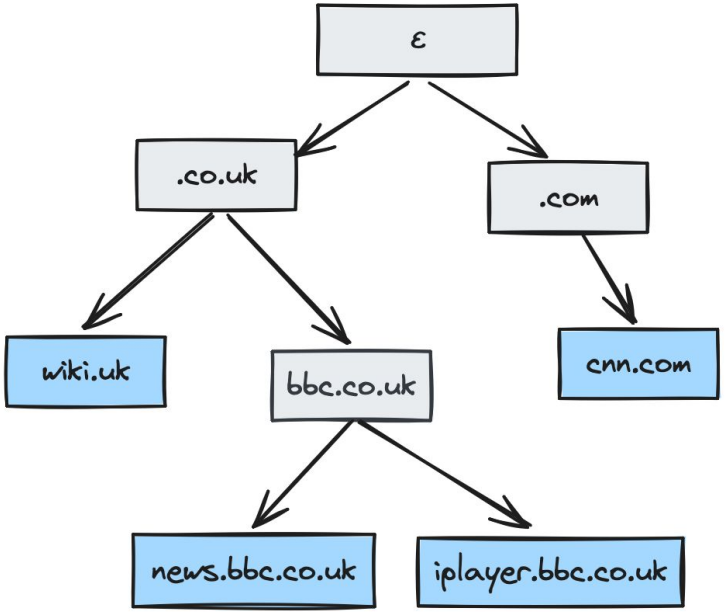
How do we key our MPT?

Key := Reverse Domain Name Notation

KT designs traditionally use a VRF to obscure user identities but we can use structured keys.

Benefits:

- Path length to root is proportional to number of eTLD+1s
- Subdomains have a shared path to the root (enables proof compression)



What to put in the leaves of our MPT?

A Hash Chain of Certificate Sets

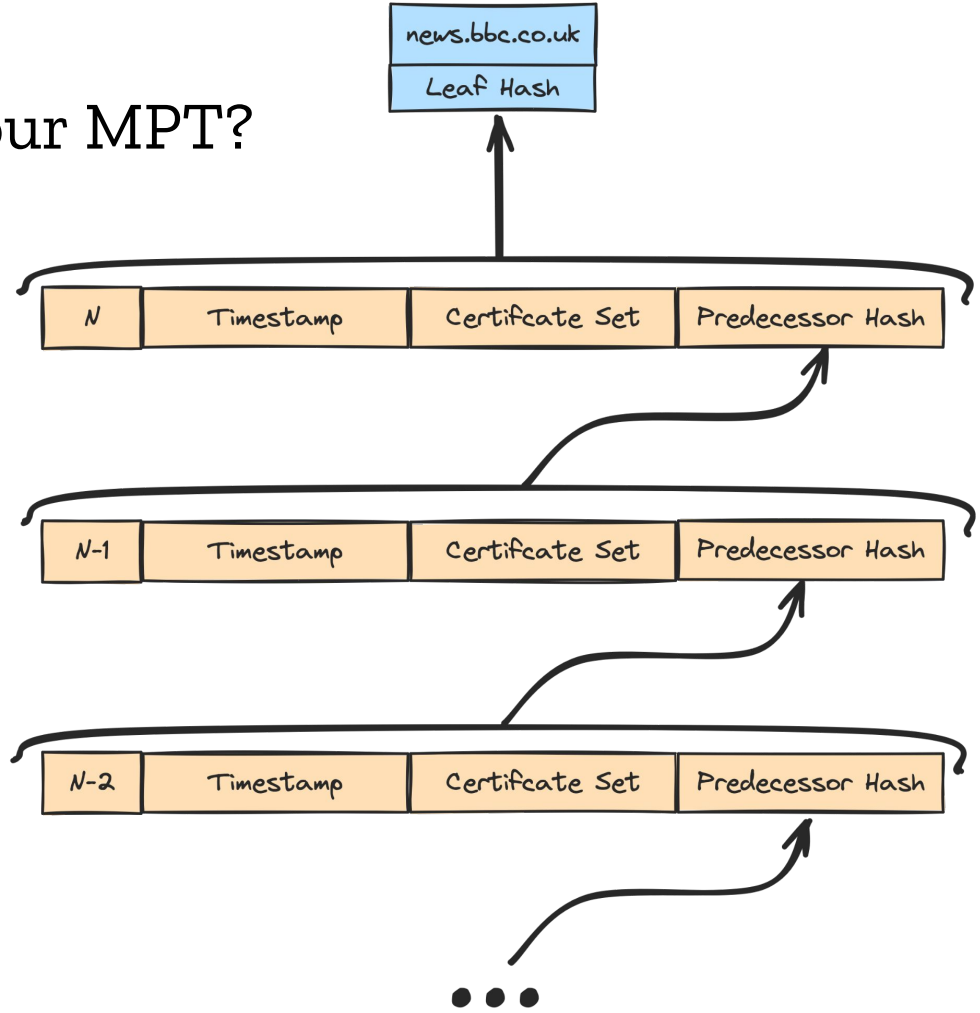
Leaf Values :=

Set of Valid Certs

+ Timestamp

+ SeqNo

+ Hash of Predecessor



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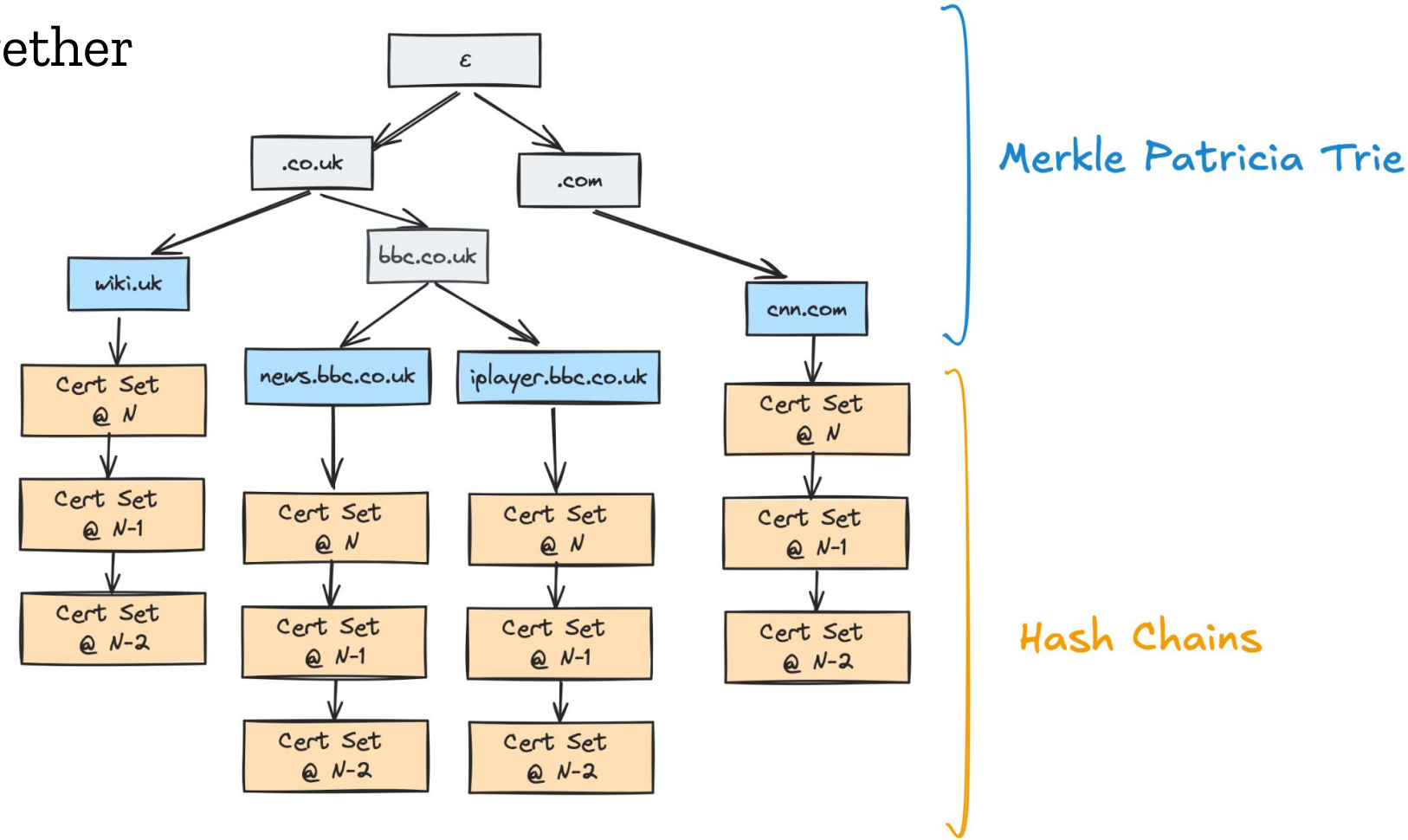
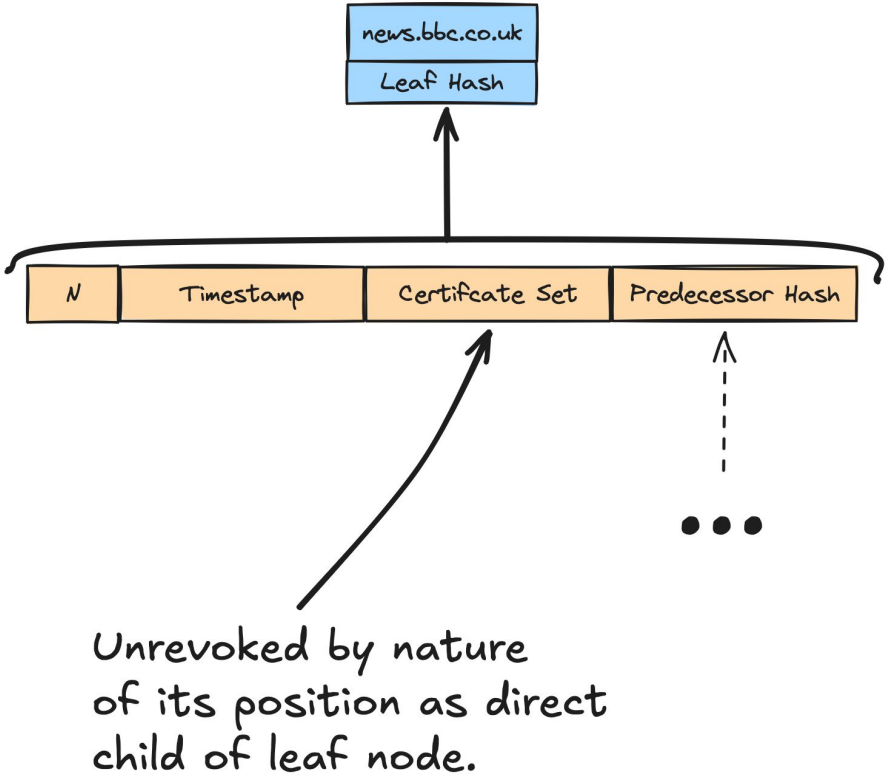
All Together



Revocation Transparency

- Revocation status maintained as a structural invariant.

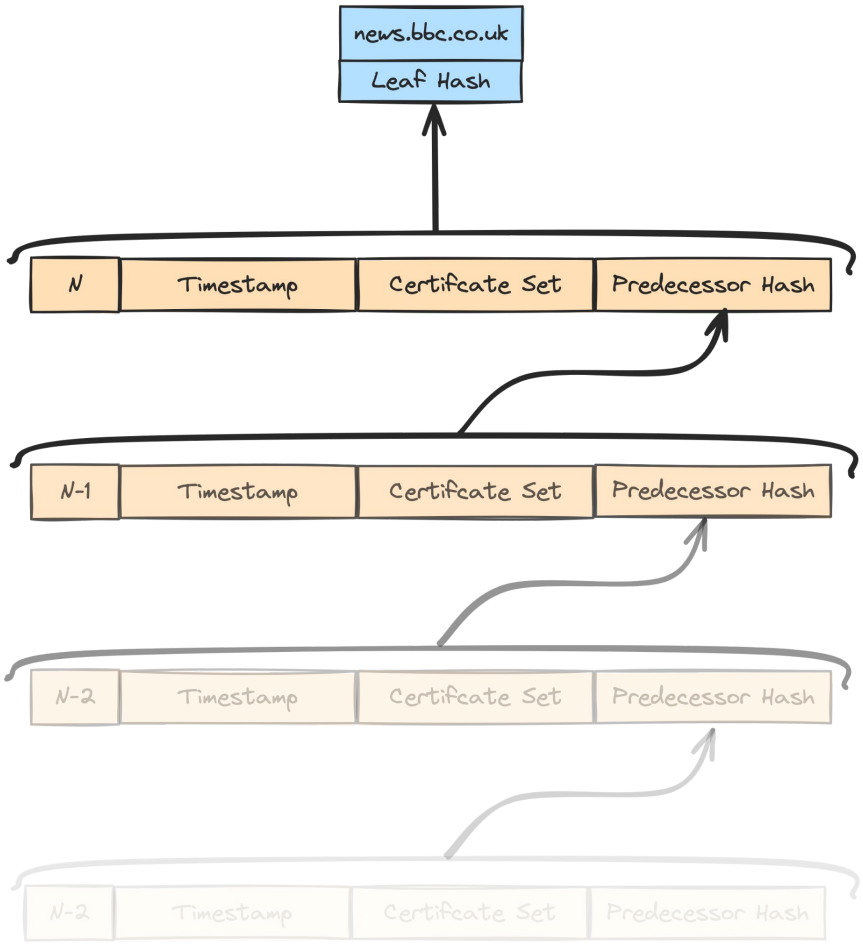
- When a certificate gets added or revoked, we
  - Insert a new node at the top of the hash chain
  - Update its path to the root through the MPT.



Graceful Expiry

- We can also gracefully forget old entries without having to update the tree.

- Log storage is proportional to number of active domains rather than total number of issued certificates.



Proof Lengths

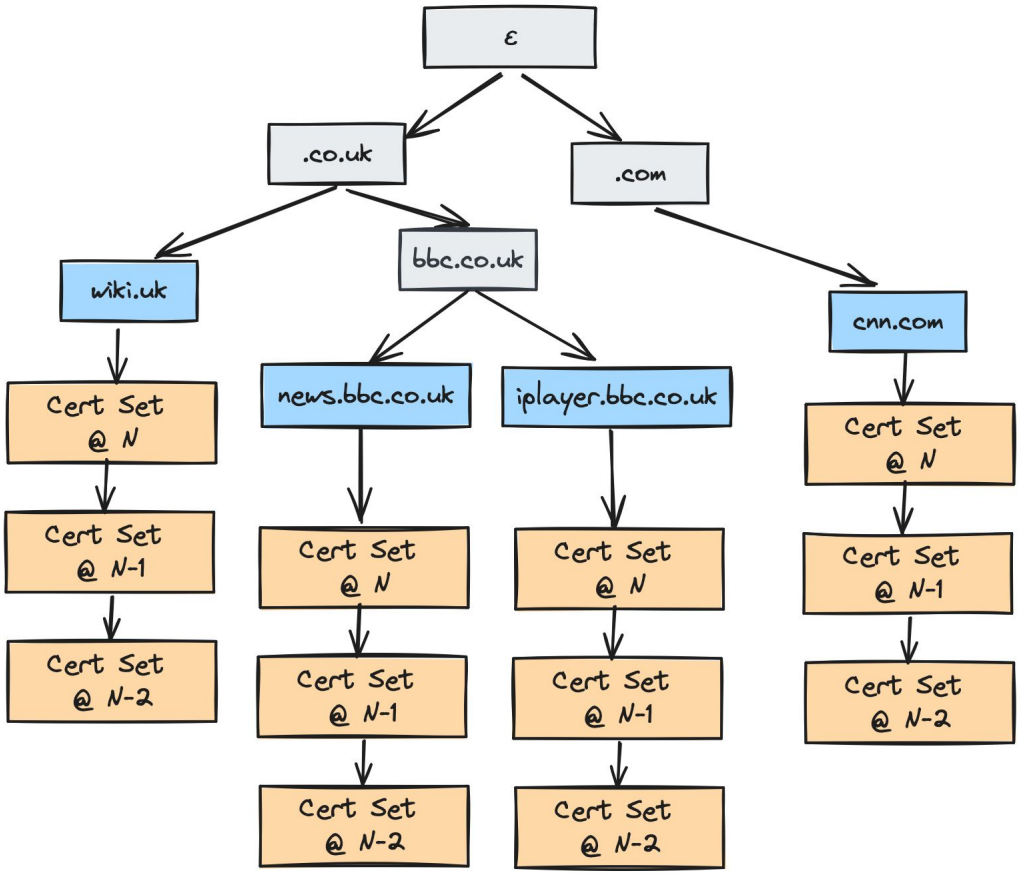
- **D** := | All eTLD+1s |
- **S** := | Site's Subdomains |
- **C** := | Site's Valid Certs |
- **E** := | Site's Expired / Revoked Certs |

Proof a certificate is not revoked (or absent):
Log **D** + log **S** + log **C**

Proof of Certificate History:
Log **D** + log **S** + **C** + **E**

Privacy Preserving KT solutions:

- Tree size scales a multiple of all certificates.
- Proof lengths are 3 x Log (|Tree size|)



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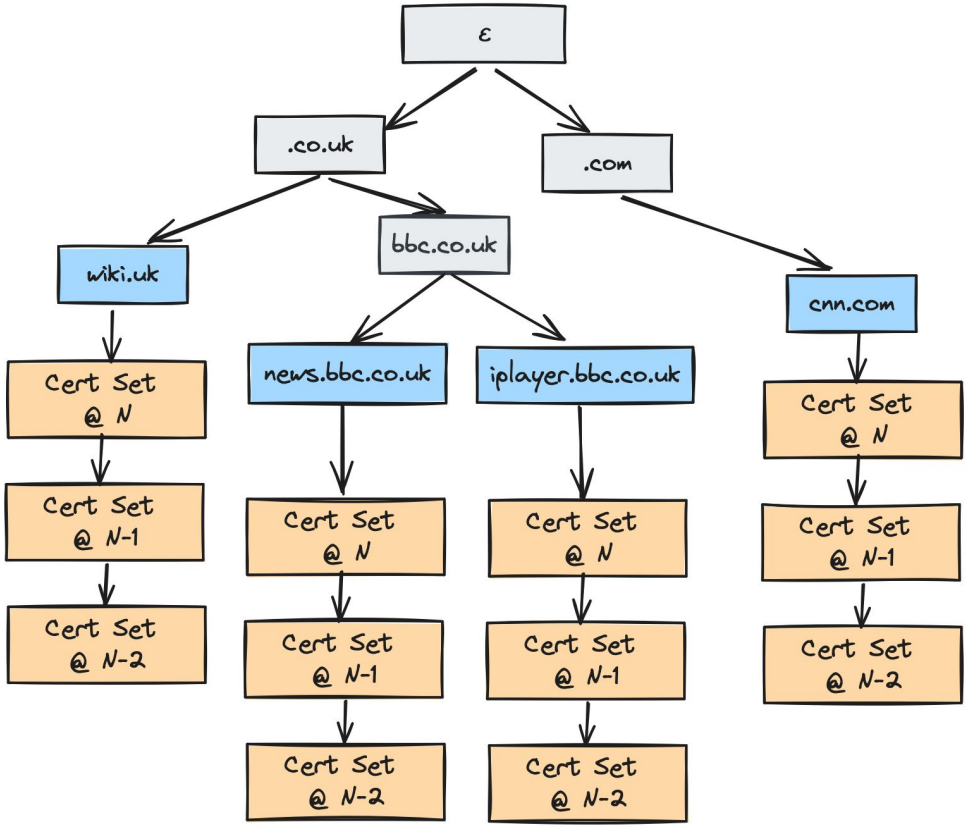
Observations

- Cheap E2E proof that a given certificate is present and unrevoked, e.g. in an MTC-style design.
- Enables succinct proofs of all certificates issued for a given domain and its subdomains.
- Lower egress costs - can use a quorum of auditors rather than general public monitors.
- Storage costs grow proportional to valid certificates, not total issued certificates.



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Thoughts

- KT-like designs might help solve challenges in the CT ecosystem.
- Loosening the privacy constraint of KT unlocks a rich design space with opportunities for much greater efficiencies.
- **Ideal Monitoring Story?** `certbot --certificate-report *.example.com`
- Did this sketch pique your interest? Do you know of other work in this area? **Come say hi!**

Credits: Kevin Lewi in particular, but also many conversations at HACS & RWC 2024, including Bas Westerbaan, Sophie Schmieg, Esha Ghosh, Alexander Scheel, Kevin Milner, Richard Barnes, and Brendan McMillion.

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