What's in a Name?
Exploring CA Certificate Control

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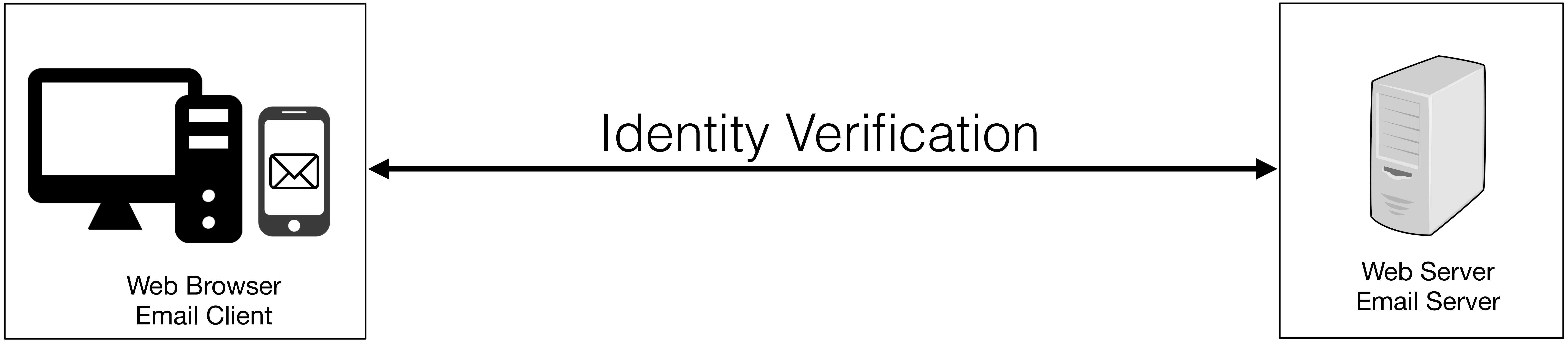
CA/Browser Forum, October 13th

Authentication

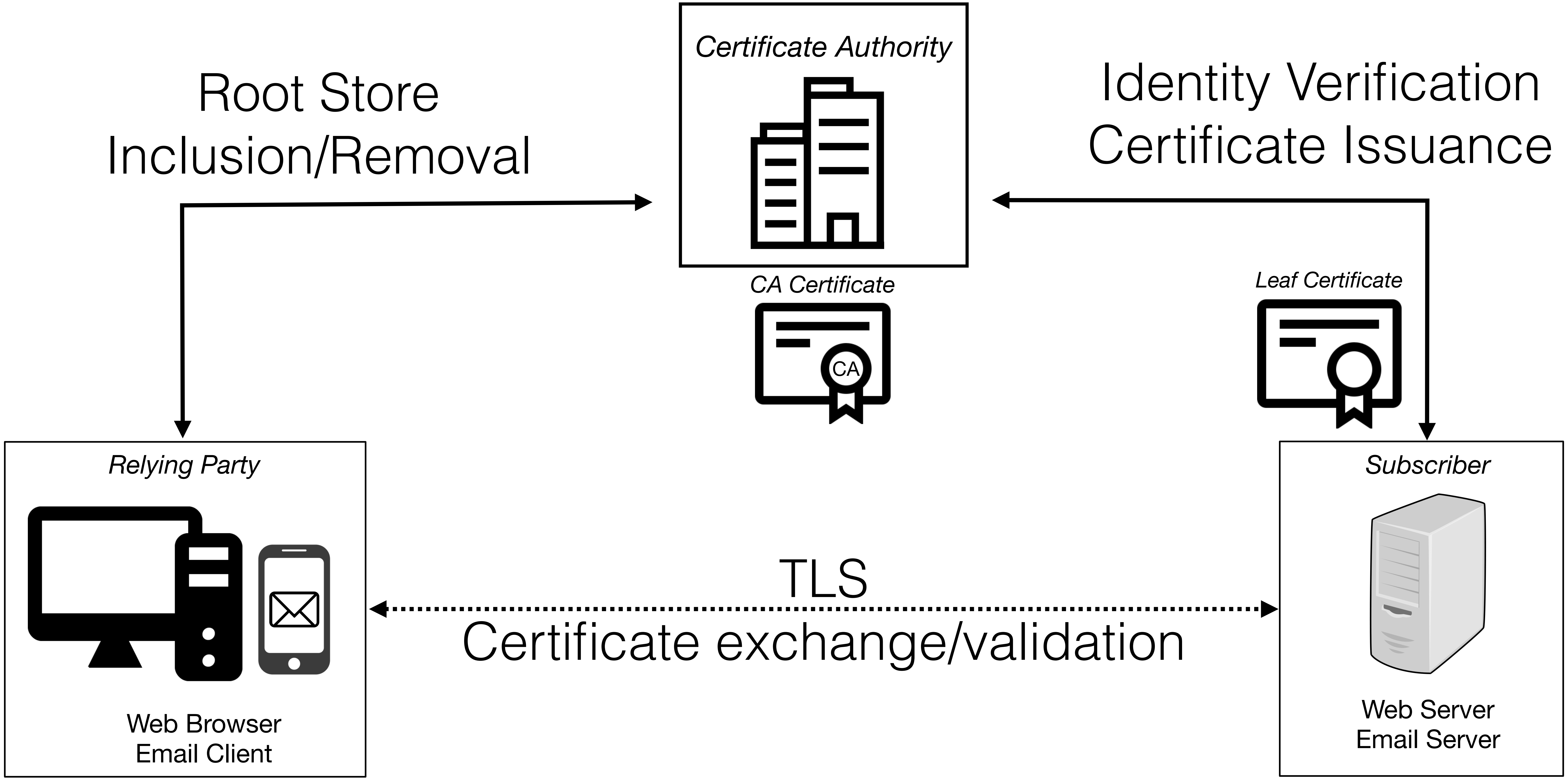


Identity Verification

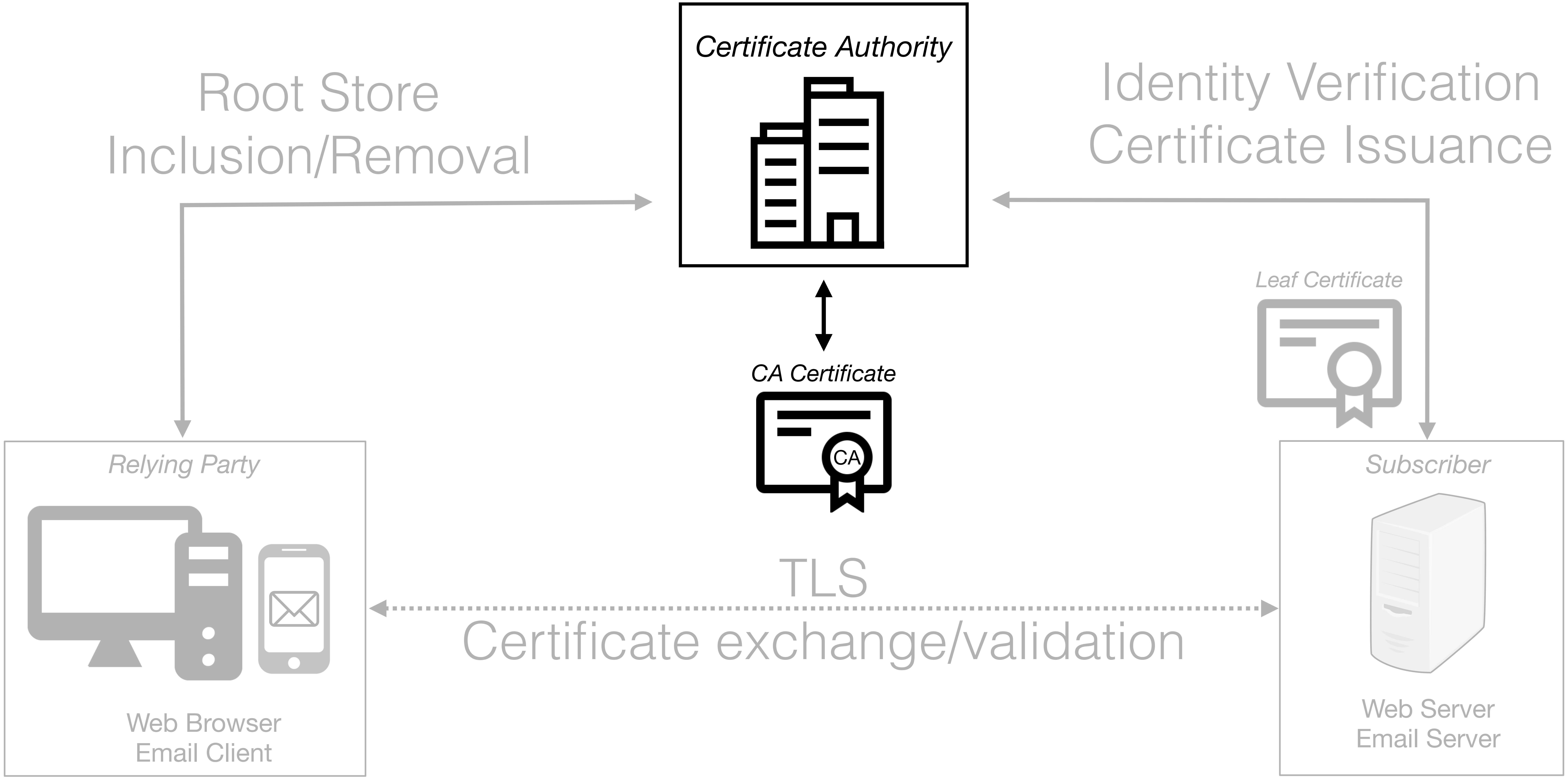
Web Browser
Email Client

Web Server
Email Server

Delegated Authentication



Delegated Authentication



Symantec Distrust

- From 2009-2017 Symantec was responsible for over a dozen issues[1] that prompted removal from browser root stores
- Difficult to determine which root CA certificates Symantec operated!

```
commonName          = UTN-USERFirst-Client Authentication and Email
orgUnitName         = http://www.usertrust.com
orgName             = The USERTRUST Network
localityName        = Salt Lake City
stateOrProvinceName = UT
countryName         = US
```

Comodo Root #1

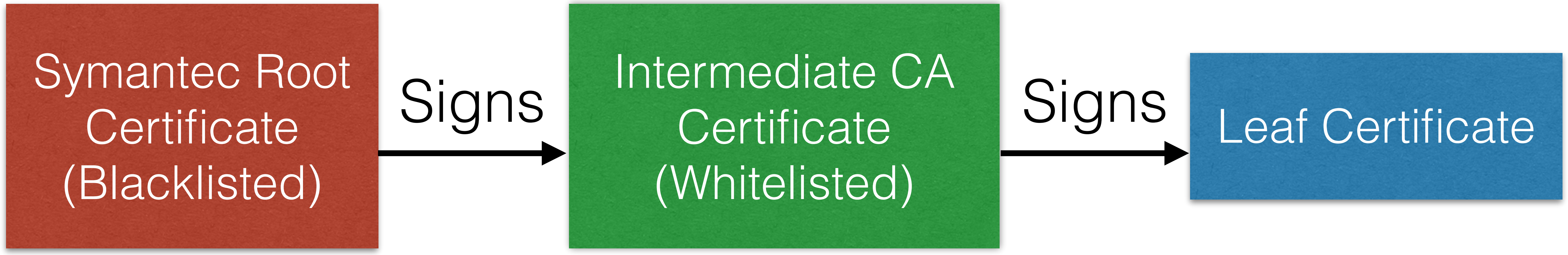
```
commonName          = UTN-USERFirst-NetworkApplications
orgUnitName         = http://www.usertrust.com
orgName             = The USERTRUST Network
localityName        = Salt Lake City
stateOrProvinceName = UT
countryName         = US
```

Symantec Root #2

[1] https://wiki.mozilla.org/CA:Symantec_Issues

Symantec Distrust

- From 2009-2017 Symantec was responsible for over a dozen issues[1] that prompted removal from browser root stores
- Difficult to determine which root CA certificates Symantec operated!
- Needed to whitelist independently-operated intermediate CAs
  - 6 Apple Intermediates
  - 1 Google Intermediate


Symantec Root Certificate (Blacklisted)
Signs
Intermediate CA Certificate (Whitelisted)
Signs
Leaf Certificate

[1] https://wiki.mozilla.org/CA:Symantec_Issues

Takeaways

1. TLS authentication trust occurs at the level of CAs (a.k.a. CA certificate operators), not CA certificates.

2. There are no guarantees that the identity in a CA certificate reflects the operator of the CA certificate.

3. Intermediate CA certificates may have separate operators that are independent of their root CA operator.

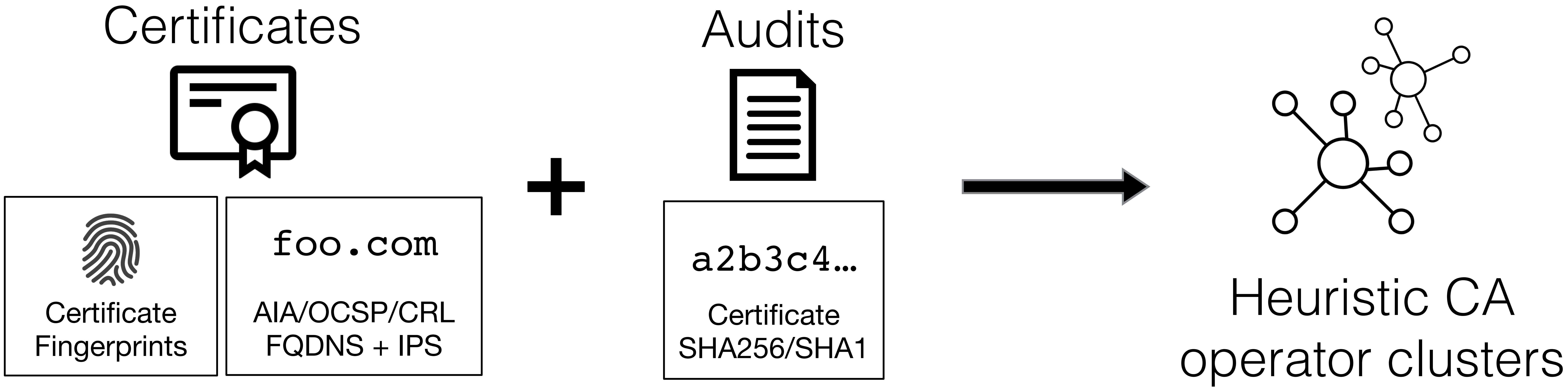
Previous Work

- No prior work on this general problem
- Mozilla-organized Common CA Database (CCADB)
    - CCADB “owner” has intentional administrative focus - for CAs to upload policies and audits
    - E.g. Several Let’s Encrypt certificates (cross-signs) were “owned” by IdenTrust, despite being operated by Let’s Encrypt

Approach

How can we determine the *operator* of a CA certificate / issuer?

1. Measure CA operational features to detect CA certificates with shared CA operators



Certificates

Certificate Fingerprints

foo.com

AIA/OCSP/CRL FQDNS + IPS

+

Audits

a2b3c4…

Certificate SHA256/SHA1

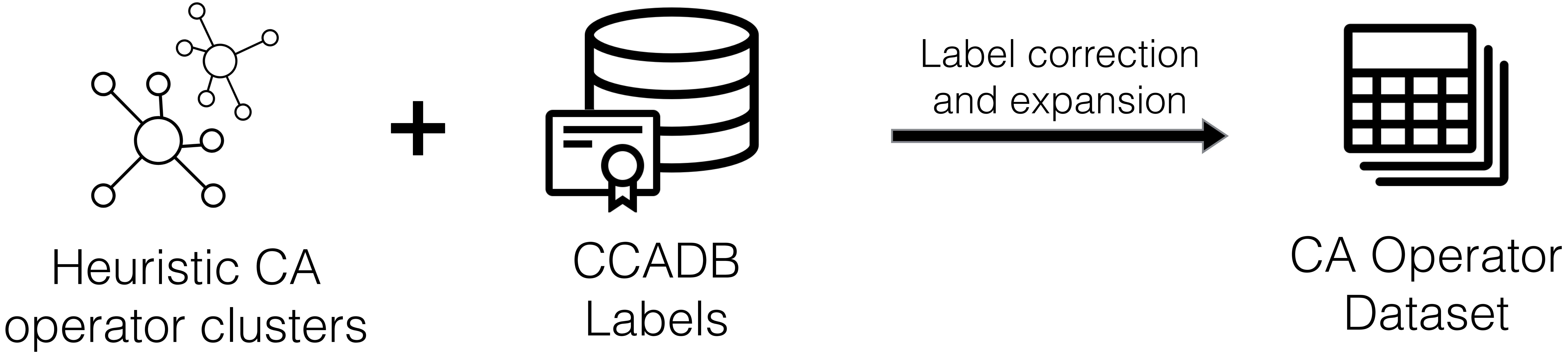
Heuristic CA operator clusters

Approach

How can we determine the *operator* of a CA certificate / issuer?

1. Measure CA operational features to detect CA certificates with shared CA operators

2. Carefully apply CCADB to label CA operator clusters



Heuristic CA operator clusters + CCADB Labels → Label correction and expansion → CA Operator Dataset

Certificate Fingerprints

Novel method to detect artifacts of issuance software/configuration

Goal: distinguish certificate entropy caused by issuance software from all other certificate entropy (e.g. serial number, public key value, subject name)

Insight: certificates are structured as an ordered tree (ASN.1 format), and issuance infrastructure controls the structure/order of tree

Certificate Fingerprints

```
Certificate root
   TBS certificate
      Validity
         datetime:start
         datetime:end
      Subject
         Field
            oid:commonName
            string:name
         Field
            oid:organizationName
            string:name
      Extensions
         Extension
            oid:keyUsage
         Extension
            oid:basicConstraints
   Signature
      oid:sha256WithRSAEnc.
      bytes:signatureValue
```

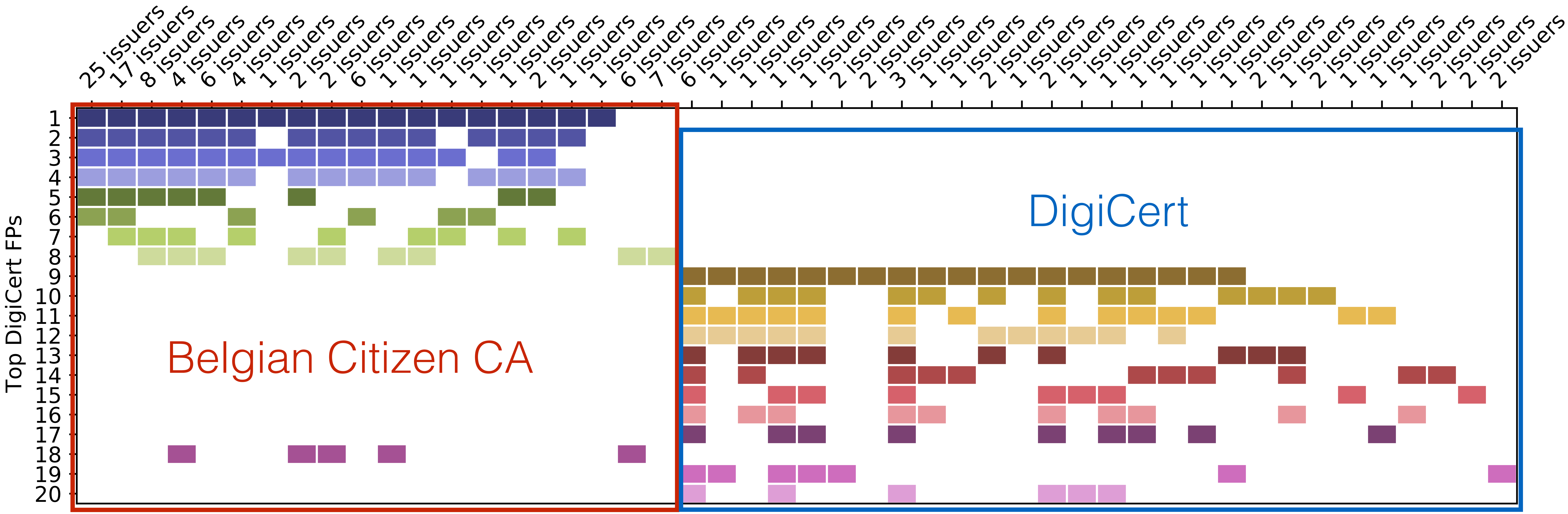
Issuance software-independent entropy:
validity, subject names, signature

Issuance software-dependent entropy:
type and order of subject fields / extensions

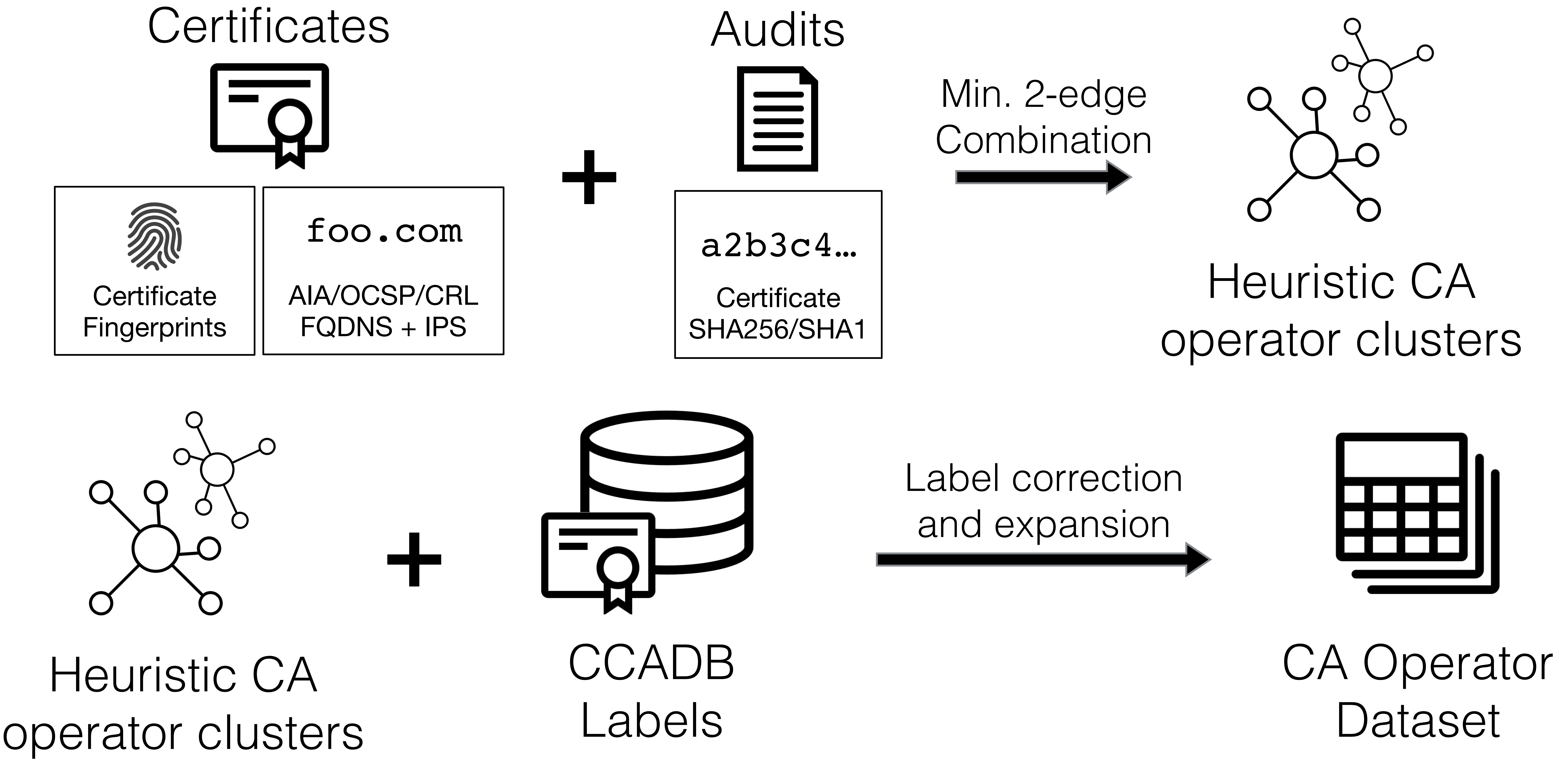
Fingerprint = structure of certificate, ignoring all leaf node values beside enumerable OID

Certificate Fingerprints

CA issuers grouped by *issuance profile,* which is the set of issued FPs



Pipeline



Certificates

Certificate Fingerprints

foo.com

AIA/OCSP/CRL FQDNS + IPS

+

Audits

a2b3c4…

Certificate SHA256/SHA1

Min. 2-edge Combination

Heuristic CA operator clusters

Heuristic CA operator clusters

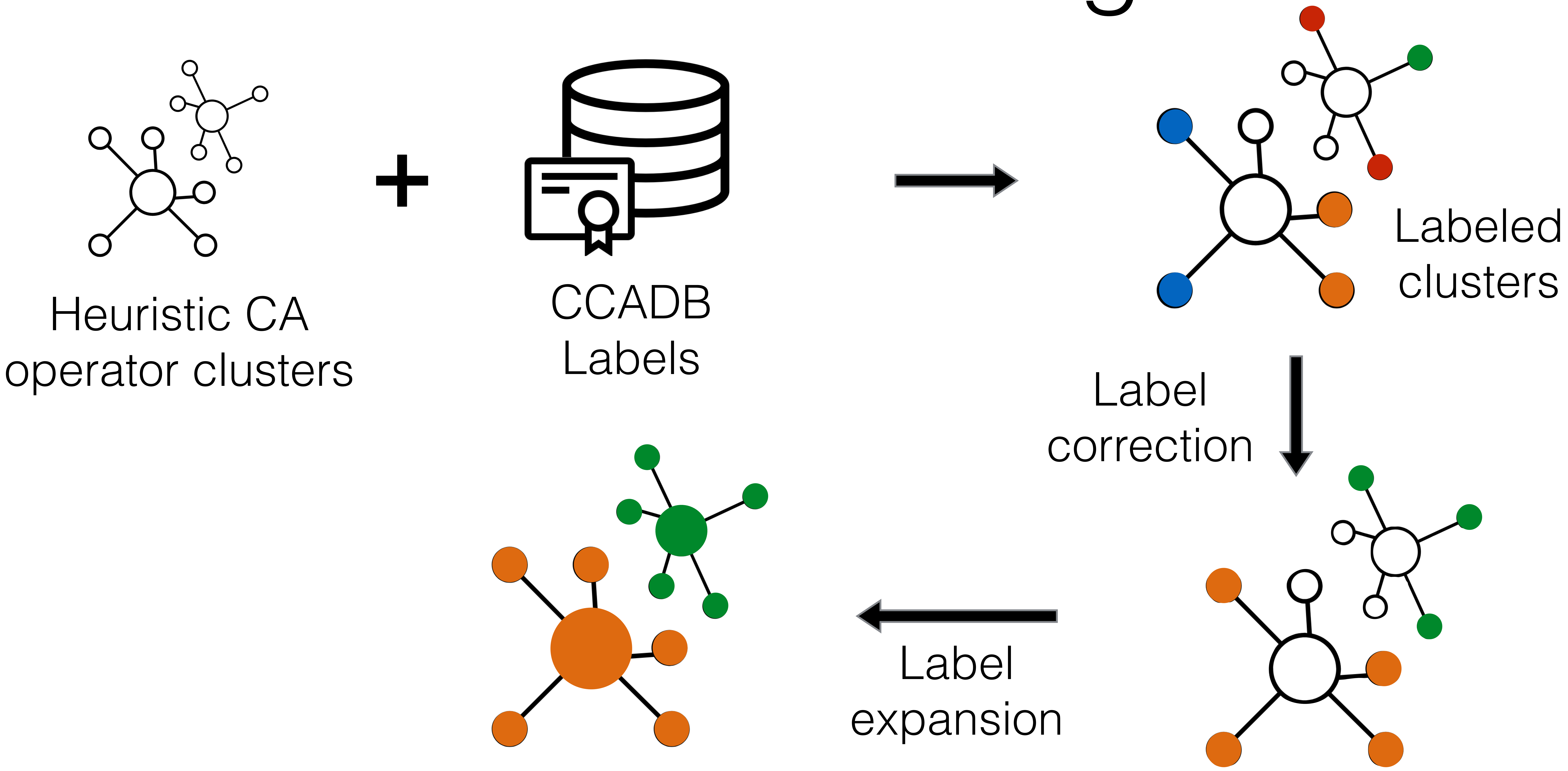
+

CCADB Labels

Label correction and expansion

CA Operator Dataset

Cluster labeling



Heuristic CA operator clusters

+

CCADB Labels

Labeled clusters

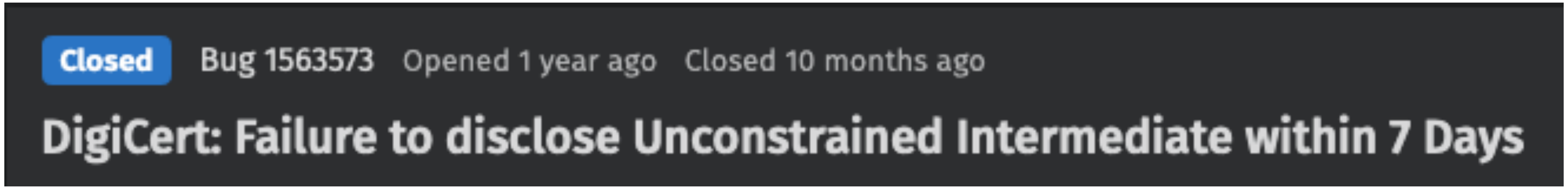
Label correction

Label expansion

Evaluation

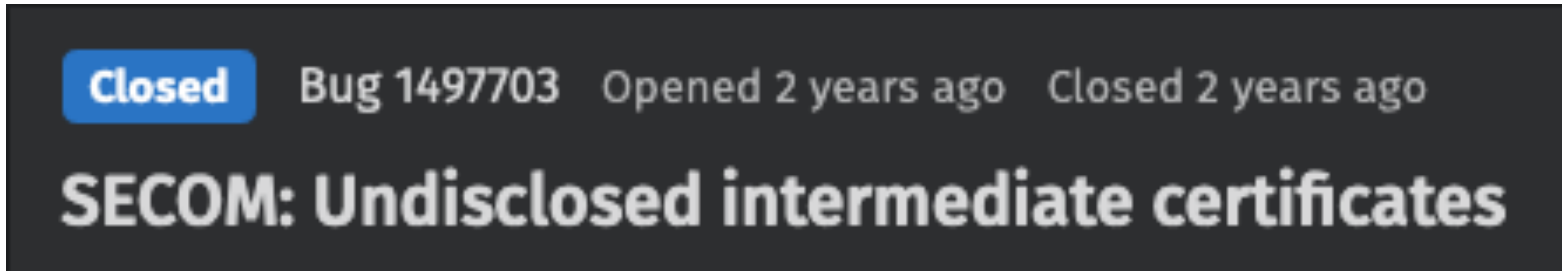
No ground truth data!

Best approximation: manually resolved disclosure issues



Closed Bug 1563573 Opened 1 year ago Closed 10 months ago

DigiCert: Failure to disclose Unconstrained Intermediate within 7 Days



Closed Bug 1497703 Opened 2 years ago Closed 2 years ago

SECOM: Undisclosed intermediate certificates

Evaluation

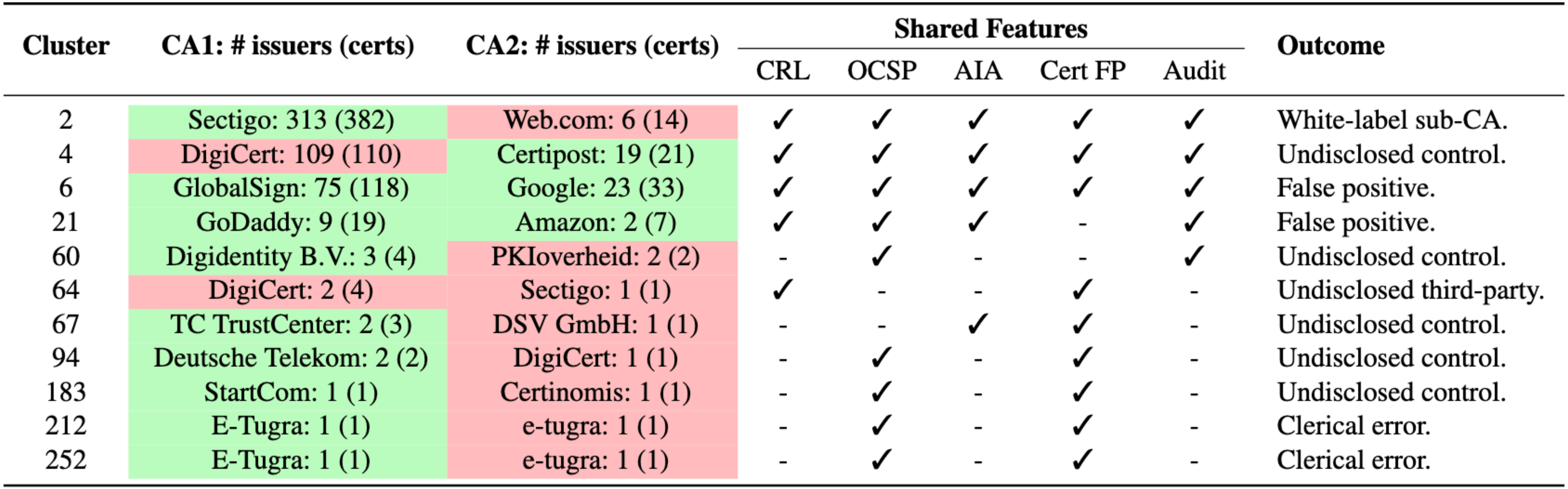
Found all issues from May 2014 - July 2019

	Issuers	Issuers Resolved By Dataset	Issues	Issues Resolved By Dataset
Operational Issuers	103	48 (46.6%)	22	7 (31.8%)

100% specificity

46.6% recall

Results



Cluster	CA1: # issuers (certs)	CA2: # issuers (certs)	Shared Features					Outcome
			CRL	OCSP	AIA	Cert FP	Audit	
2	Sectigo: 313 (382)	Web.com: 6 (14)	✓	✓	✓	✓	✓	White-label sub-CA.
4	DigiCert: 109 (110)	Certipost: 19 (21)	✓	✓	✓	✓	✓	Undisclosed control.
6	GlobalSign: 75 (118)	Google: 23 (33)	✓	✓	✓	✓	✓	False positive.
21	GoDaddy: 9 (19)	Amazon: 2 (7)	✓	✓	✓	-	✓	False positive.
60	Digidentity B.V.: 3 (4)	PKIoverheid: 2 (2)	-	✓	-	-	✓	Undisclosed control.
64	DigiCert: 2 (4)	Sectigo: 1 (1)	✓	-	-	✓	-	Undisclosed third-party.
67	TC TrustCenter: 2 (3)	DSV GmbH: 1 (1)	-	-	✓	✓	-	Undisclosed control.
94	Deutsche Telekom: 2 (2)	DigiCert: 1 (1)	-	✓	-	✓	-	Undisclosed control.
183	StartCom: 1 (1)	Certinomis: 1 (1)	-	✓	-	✓	-	Undisclosed control.
212	E-Tugra: 1 (1)	e-tugra: 1 (1)	-	✓	-	✓	-	Clerical error.
252	E-Tugra: 1 (1)	e-tugra: 1 (1)	-	✓	-	✓	-	Clerical error.

Results

Discovery	Outcome
Improperly disclosed Camerfirma subordinate CA (MULTICERT)[1]	Camerfirma removed from Mozilla root store, distrusted by Google products
Refined CA operator labels for 241 CA certs Added new labels for 651 unlabeled CA certs	CCADB exploring automated sub-CA consistency checking [2] and ownership annotation [3]

CA operational transparency means:

1) More informed root store decision making
2) More accurate research / issue attribution

[1] https://bugzilla.mozilla.org/show_bug.cgi?id=1672029
[2] https://bugzilla.mozilla.org/show_bug.cgi?id=1727204
[3] https://bugzilla.mozilla.org/show_bug.cgi?id=1727205

Looking Forward

Direct disclosure of the legal entity that operates CA certificates

- Mozilla/Microsoft require ownership change disclosure
- CCADB considering addition of new field

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Trust, but verify: additional observation of CA behavior

- Certificate issuance infrastructure, improved fingerprints

Expand to more nuanced view of CA certificate operations

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https://github.com/zzma/ca-transparency

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