DANISH

IETF 110
March 12th 2021

Defining The Problem Space

IoT Ecosystem Challenges

Private PKI everywhere

Establishing trust across private PKI domains is challenging

No technical controls prevent naming collisions across PKI

Discovery API for CA and EE certs oftentimes proprietary

PKI over-consolidation to prevent naming collisions and ease trust challenges

Implied trust in decoupled applications because cert discovery is too difficult

IoT Ecosystem Challenges

Private PKI needs a broadly useful discovery mechanism

Specifically, we need a discovery mechanism which:

...works across private PKI (enabling mTLS authentication)

...works for async applications (object signing/encryption)

...prevents naming collisions

...makes credential rotation easier

...works well for constrained platforms

Create safe bridges between islands of trust

Islands Of Trust

CA bundle makes web PKI work well

- Imagine the web without the browser CA bundle...

IoT typically uses private PKI for client identity

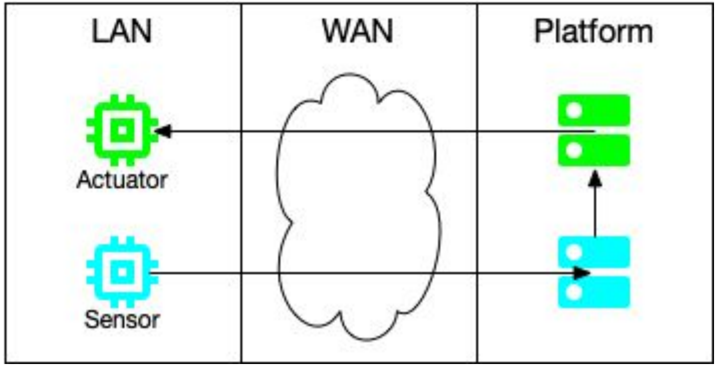
- Web PKI for this use case brings unnecessary cost and complexity

Agreement on IoT roots of trust -> CA cert distribution or consolidation

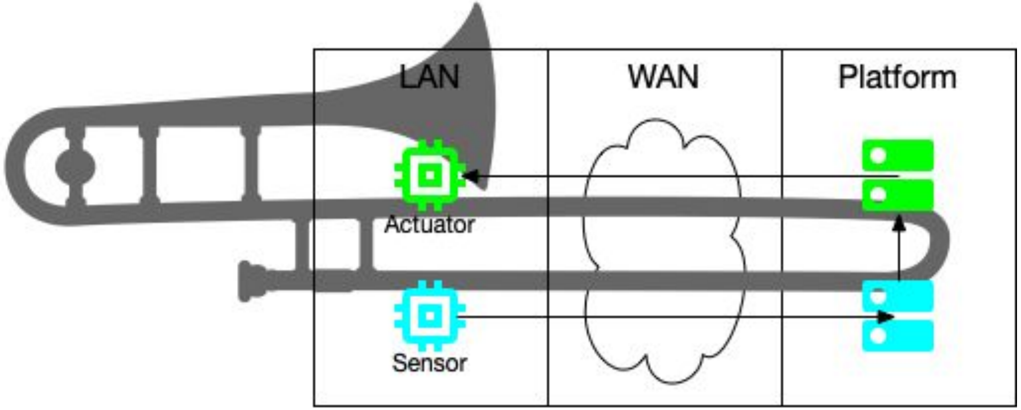
Multiple CA certs invites naming collision, so consolidation is favored

Entire org on the same trust island, cross-org M2M is difficult

Suboptimal Information Flows

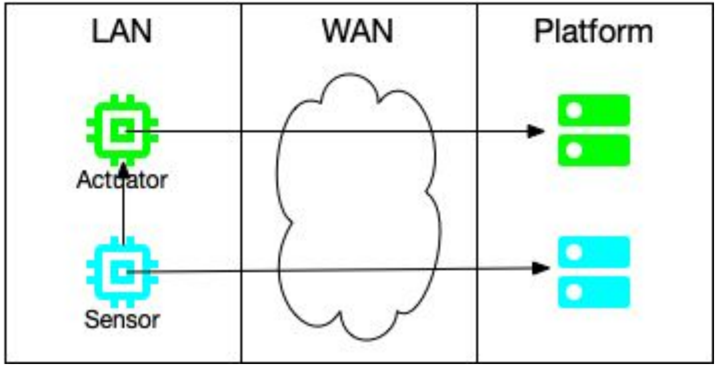


Suboptimal Information Flows (tromboning)

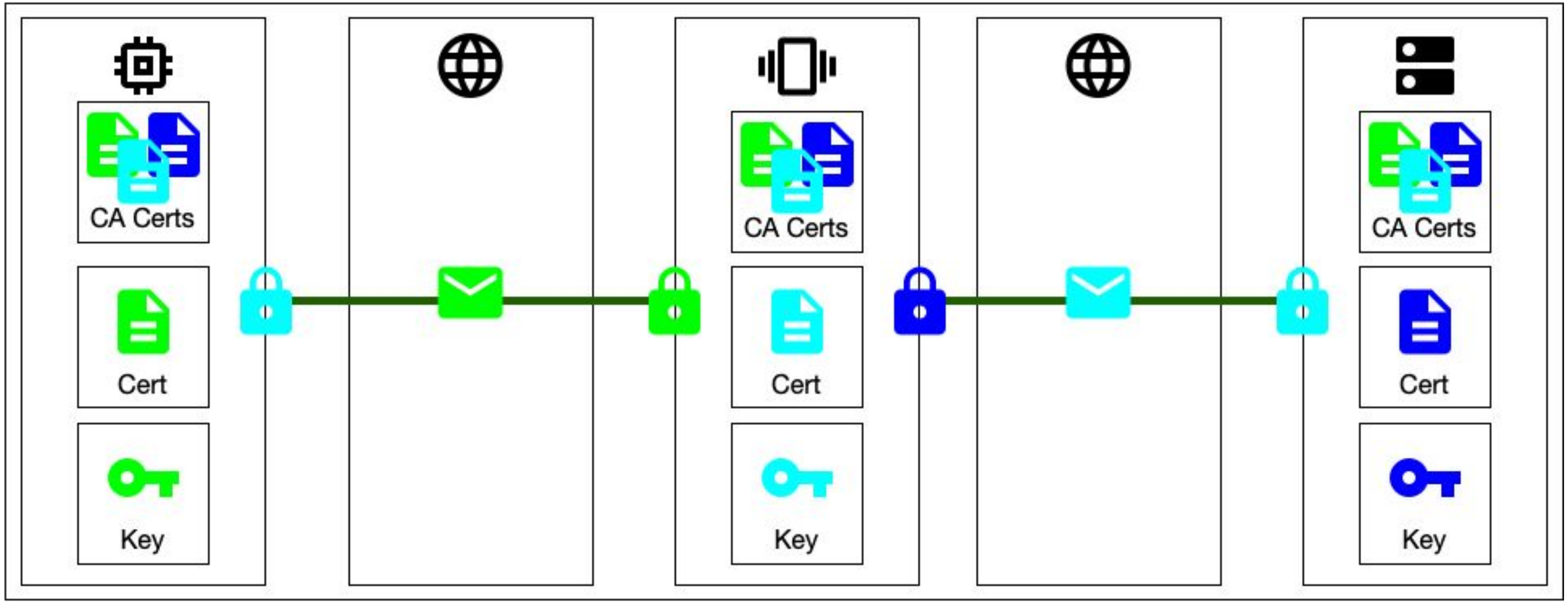


Suboptimal Information Flows

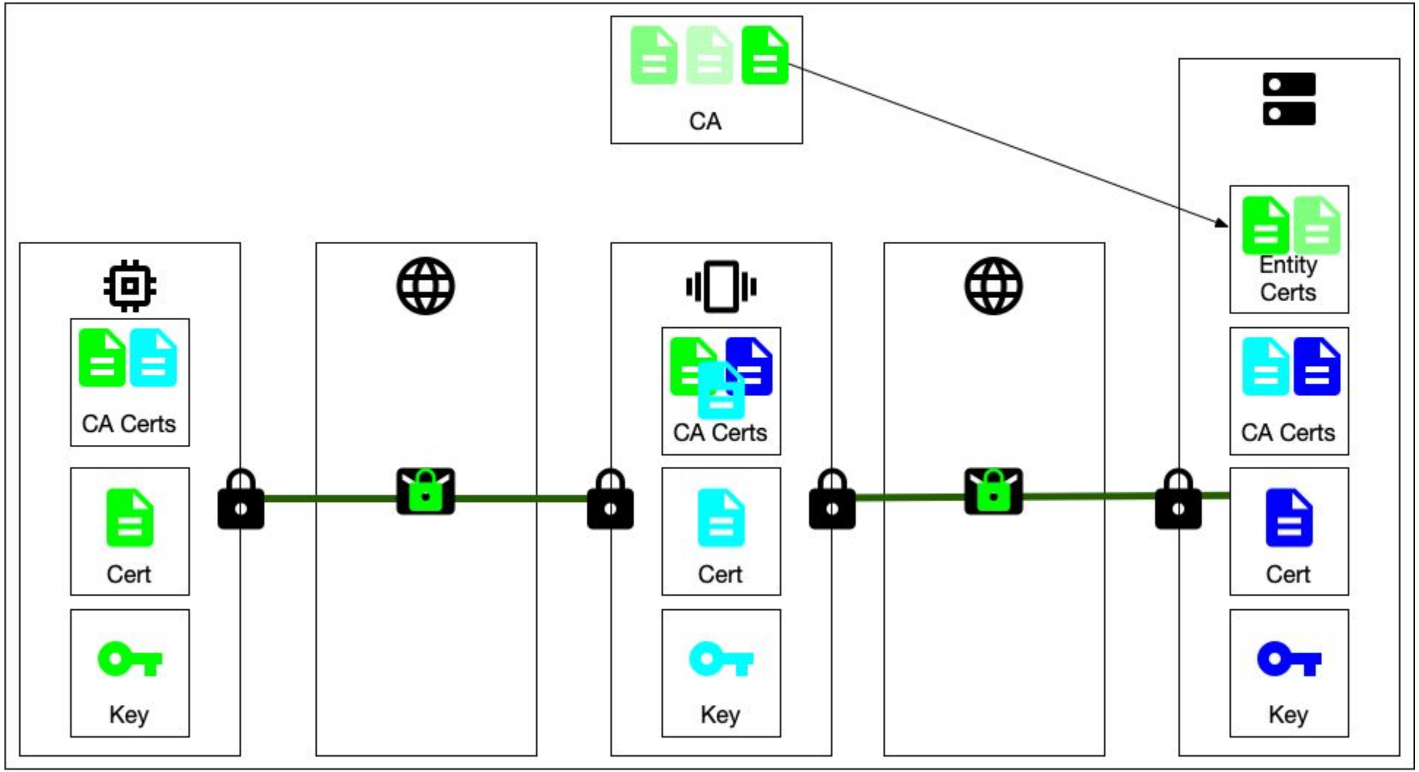
This is what we want:



Assumed Trust In Middleware



Proprietary certificate discovery protocols



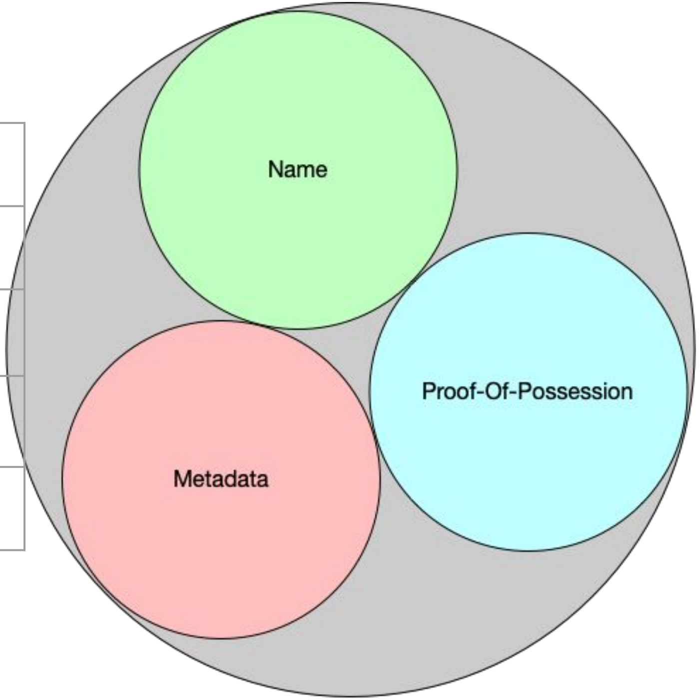
Evaluating existing open identity systems

Looking at existing technologies:

- Open standards
- Ease of integration
- Enable existing PKI authn methods to work better
- Give transition to a better state a gradual adoption curve

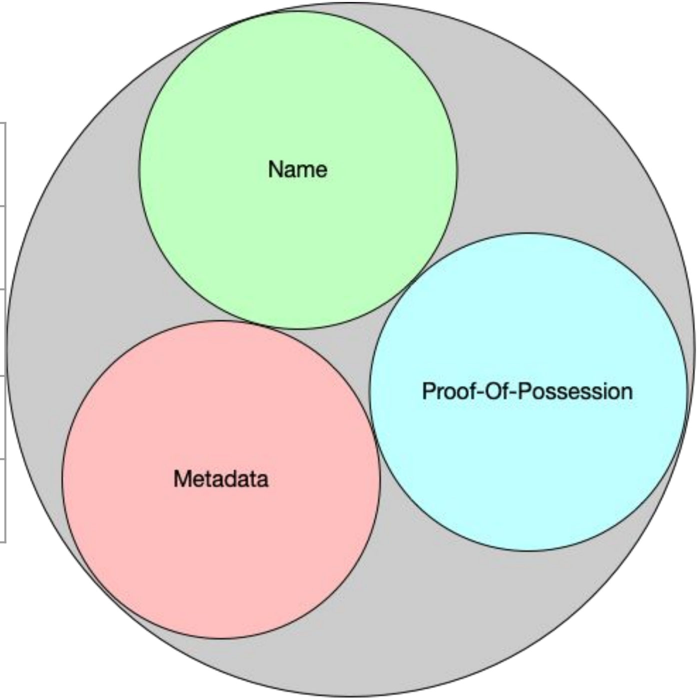
Lens For Examining Identity Systems

How Accessible?	Entire system	integration
How widely-recognized?	Name	federation
How resistant to name collisions?	Name	ambiguity
How resistant to credential theft?	Proof-of-Possession	resilience
Level of effort for credential rotation?	Proof-of-Possession	hygiene



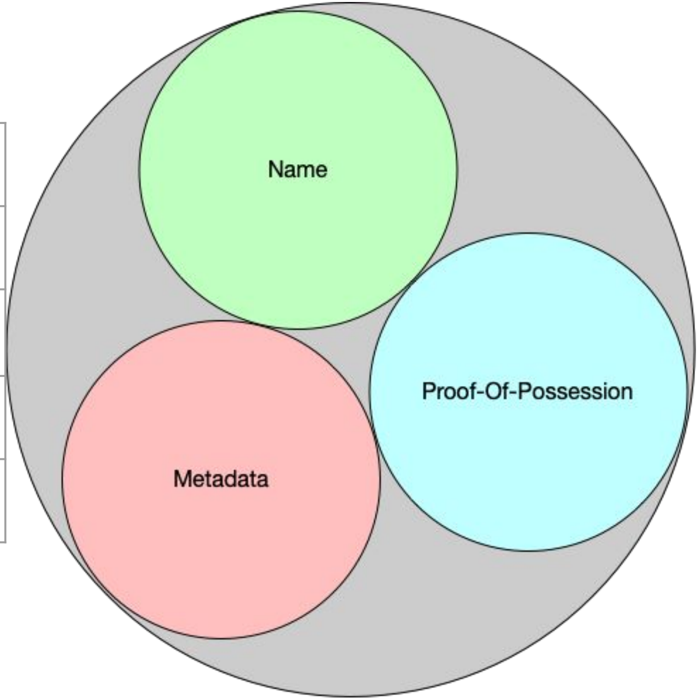
Traditional PKI

How Accessible? (API)	Proprietary
How widely-recognized?	Which PKI?
How resistant to name collisions?	Only within CA
How resistant to credential theft?	Hardware-supported
Level of effort for credential rotation?	High



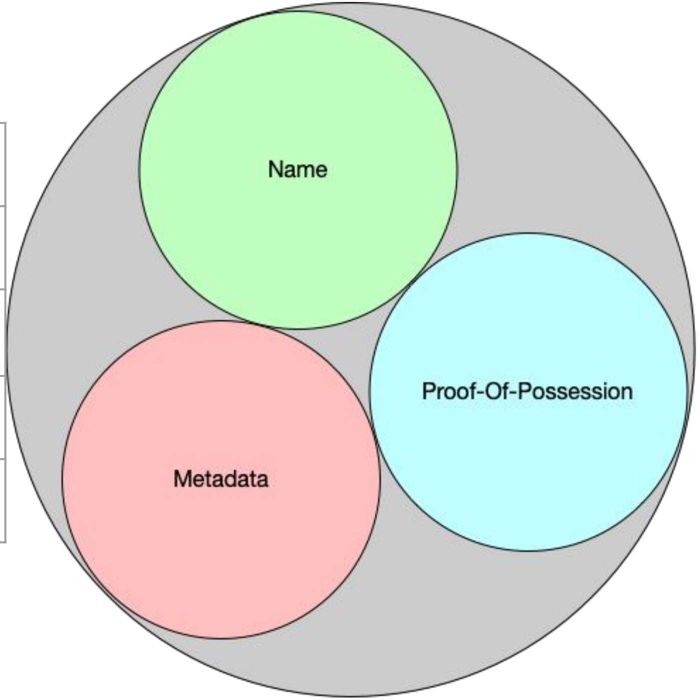
Blockchain and Public Key

How Accessible? (API)	Standards emerging (DID)
How widely-recognized?	Which blockchain?
How resistant to name collisions?	Within same system
How resistant to credential theft?	Hardware-supported
Level of effort for credential rotation?	High



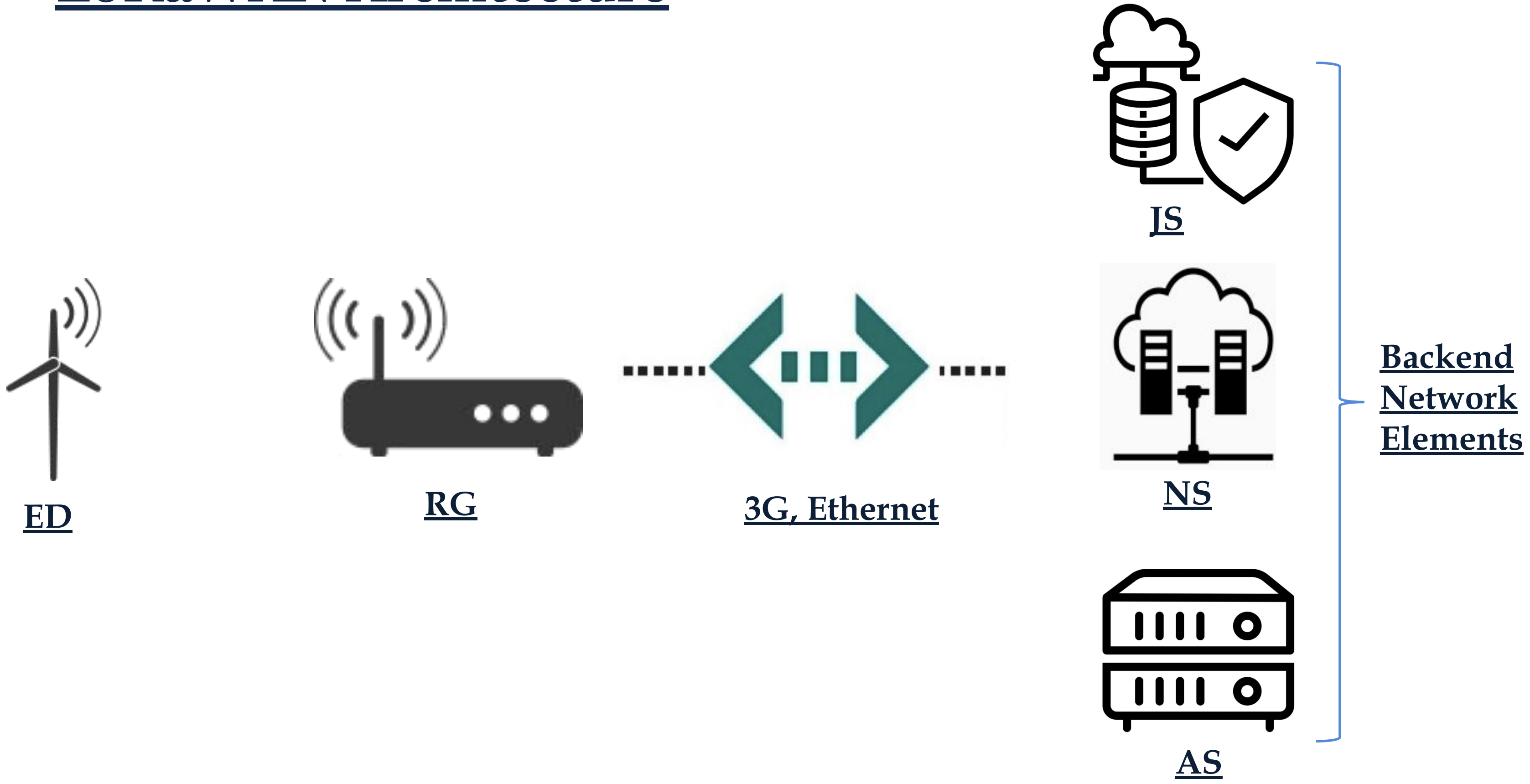
DNS+PKI

How Accessible? (API)	Already in the OS
How widely-recognized?	Only one DNS
How resistant to name collisions?	Only one DNS
How resistant to credential theft?	Hardware-supported
Level of effort for credential rotation?	Low



DANE and LoRaWAN

LoRaWAN Architecture

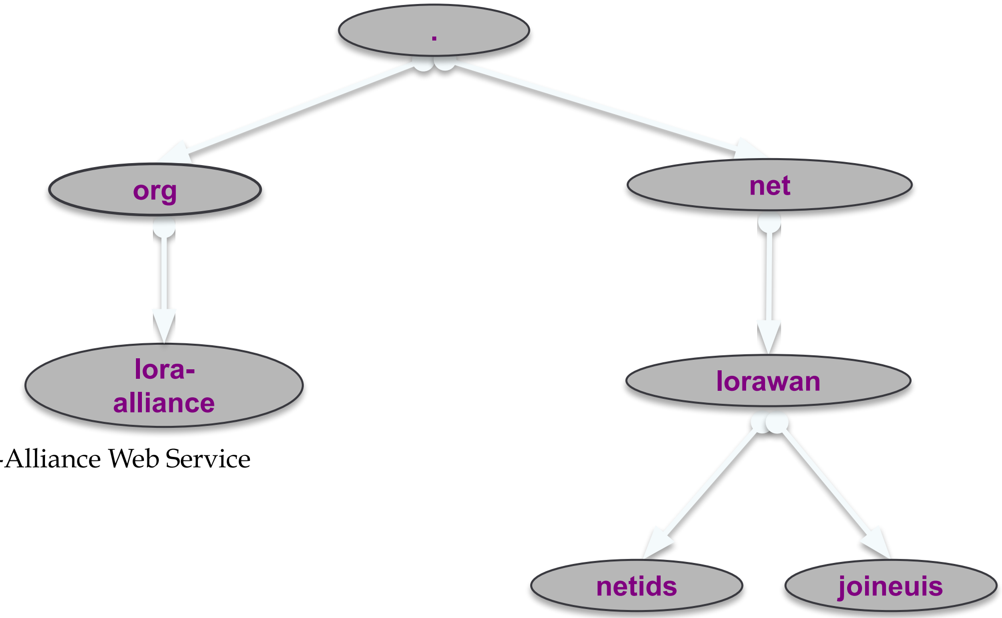


DNS infrastructure usage in LoRaWAN

- For Over the Air Activation (OTAA)
  - Purpose – ED Onboarding
  - The NS uses the DNS infrastructure to find the JS based on the JS identifier (JoinEUI) in the incoming Join-Request (JR) from the ED

- For Roaming
  - When the ED is roaming in a Visited Network (VN), the Visited NS uses the NetID to identify the home network of the ED

LoRaWAN DNS hierarchy



“lora-alliance.org” -> Lora-Alliance Web Service

“netids.lorawan.net” -> Lora-Alliance Roaming Service

“joineuis.lorawan.net” -> Lora-Alliance OTAA Service

Provisioning JoinEUI and NetID in LoRaWAN

JoinEUI

NetId

0x00005E100000002F

0x60050A

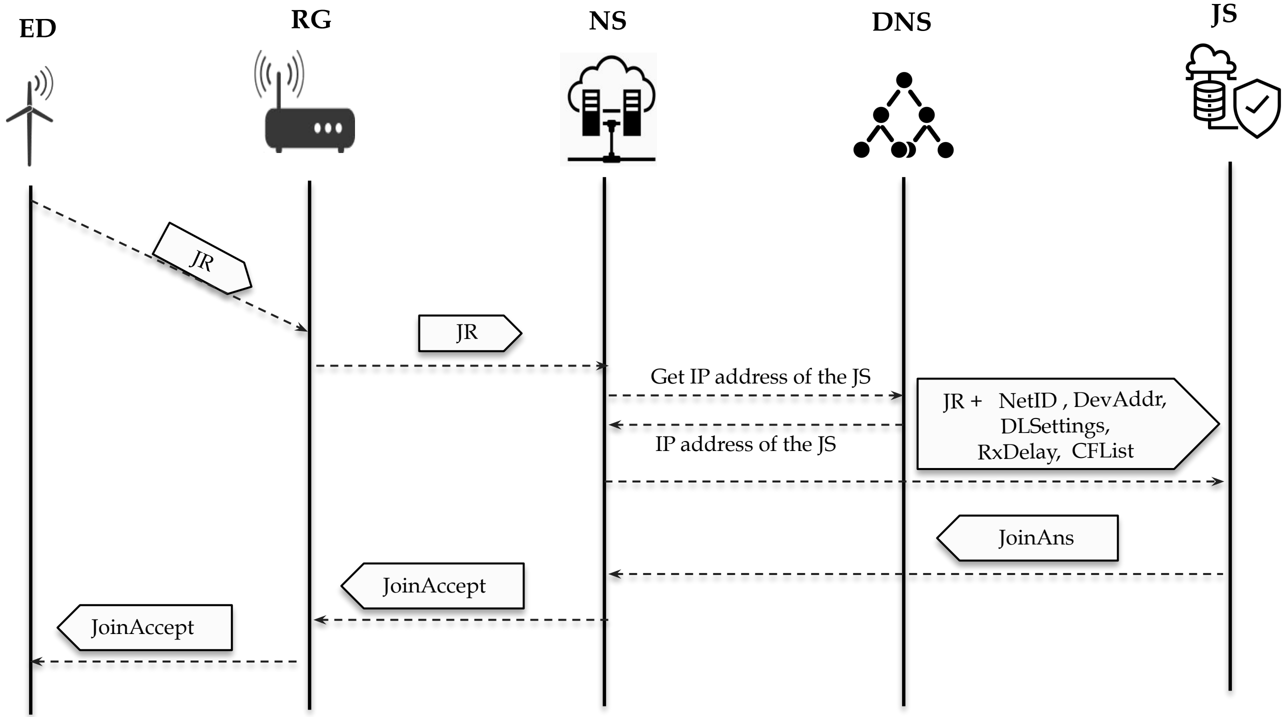
f.2.0.0.0.0.0.0.0.1.e.5.0.0.0.0.joineuis.lorawan.net

60050a.netids.lorawan.net

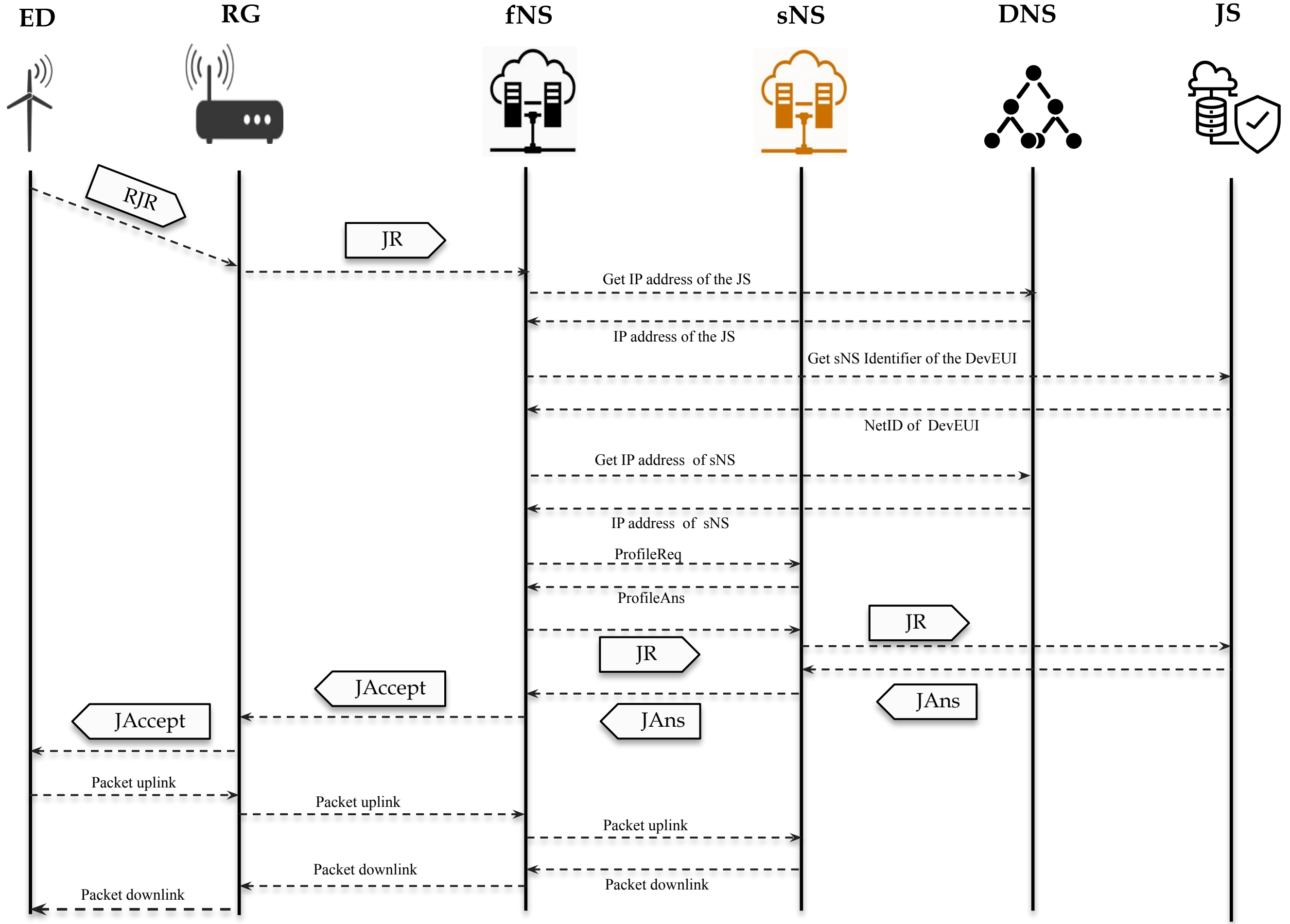
f.2.0.0.0.0.0.0.0.1.e.5.0.0.0.0. joineuis.lorawan.net. IN NS example.net

60050a.NETIDS.lorawan.net IN   A 192.0.2.0.1

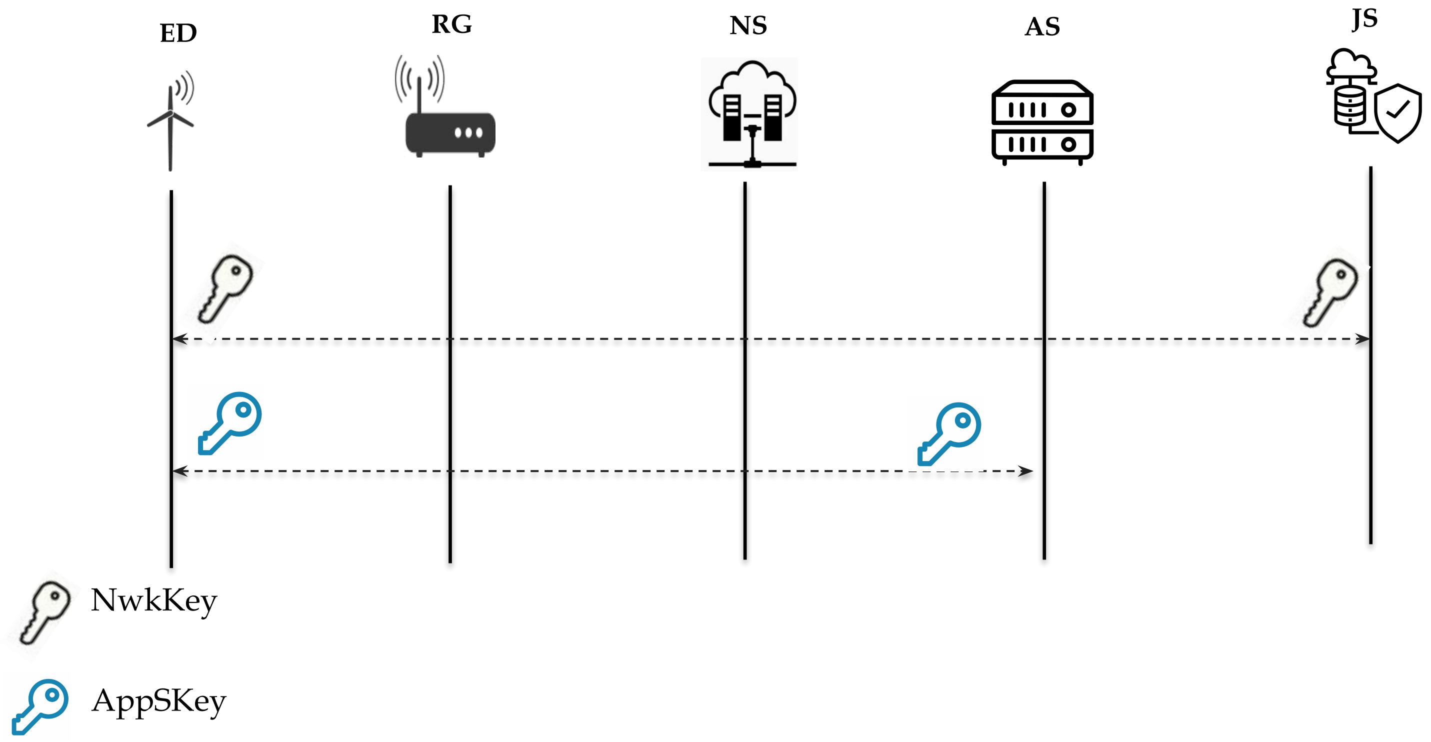
OTAA flow


ED
RG
NS
DNS
JS
JR
JR
Get IP address of the JS
IP address of the JS
JR + NetID , DevAddr,
DLSettings,
RxDelay, CFList
JoinAns
JoinAccept
JoinAccept

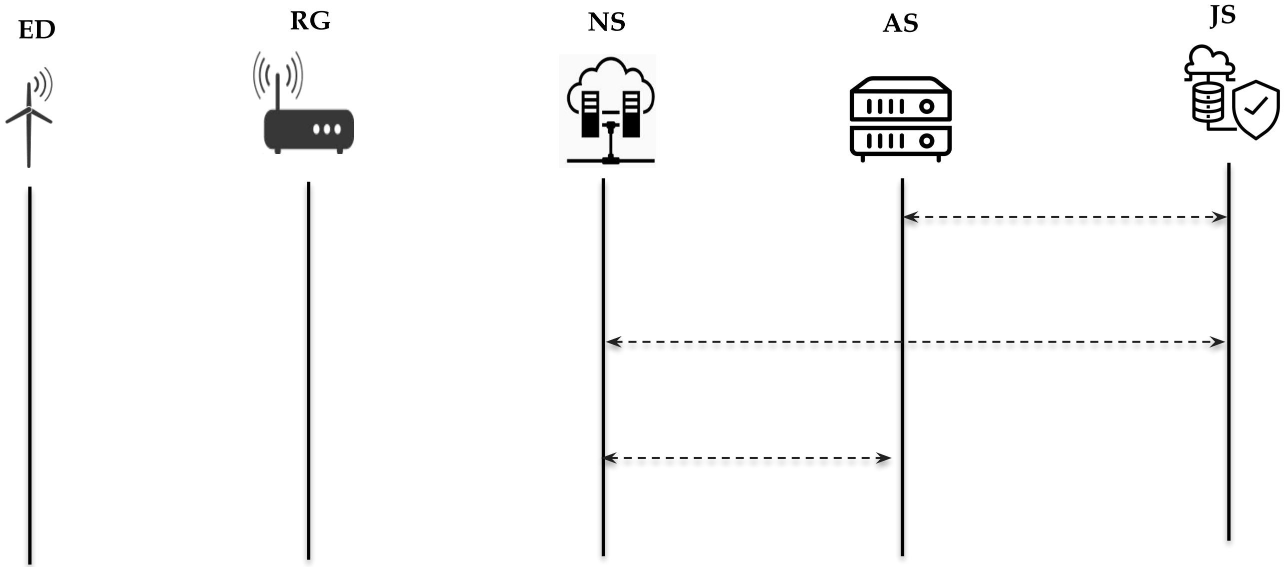
Passive roaming flow



Issues with the current setup (1/2)



Issues with the current setup (2/2)



Naming conventions, SDOs and Naming Services in IoT

Naming Conventions	SDO	Naming Service
URI (e.g. Domain names)	IETF	DNS
EPC	GS1	ONS
OID	ITU and ISO/IEC	ORS
DOI	ISO	Handle

Goal from DANISH

- Use DNS infrastructure and its security extensions (DNSSEC/DANE) to
  - Provide mutual authentication between the Backend Network elements
  - Evaluate End-to-End secured communication between the ED and the backend network elements using asymmetric keys and DNS infrastructure as PKI

Initial Work Areas

Background: TLS Server Authentication With DANE

DANE Primer:

- “DNS-based Authentication of Named Entities”: RFC 6698, 7671
- Uses DNSSEC to authenticate X.509 certificates and/or public keys

Today, DANE is defined primarily for authenticating the TLS server (in certain applications)

- See also 7672 (DANE for SMTP Transport Security, and 7673 (DANE with DNS SRV records)

```
_25._tcp.mail.protonmail.ch.7200 IN TLSA 3 1 1 (
            76BB66711DA416433CA890A5B2E5A0533C6006478F7D
            10A4469A947ACC8399E1 )

_25._tcp.mail.protonmail.ch. 7200 IN RRSIG TLSA 8 5 1200 (
            20210302081502 20210131081502 6753 protonmail.ch.
            UVJuhvyEj................ )
```

port, protocol, domain name

```
_25._tcp.mail.example.com. IN TLSA (
              3 1 1  d2abde240d7cd3ee6b4b28c54df034b9
                     7983a1d16e8a410e4561cb106618e971 )
```

data (hex encoded) associated with the certificate or public key

```
_25._tcp.mail.example.com. IN TLSA (
          3 1 1 d2abde240d7cd3ee6b4b28c54df034b9
                7983a1d16e8a410e4561cb106618e971 )
```

```
_25._tcp.mail.example.com. IN TLSA (
            3 1 1  d2abde240d7cd3ee6b4b28c54df034b9
                   7983a1d16e8a410e4561cb106618e971 )
```

Parameters: Usage, Selector, Matching-Type

Usage 0: PKIX-CA: CA Constraint
Usage 1: PKIX-EE: Service Cert Constraint
Usage 2: DANE-TA: Trust Anchor Assertion
Usage 3: DANE-EE: Domain Issued Certificate

Selector 0: Full Certificate
Selector 1: Public Key (could be raw)

Matching-Type 0: Full Content
Matching-Type 1: SHA-256 Hash
Matching-Type 2: SHA-512 Hash

data (hex encoded) associated with the certificate or public key

port, protocol, domain name

```
_25._tcp.mail.example.com. IN TLSA (
                    3 1 1  d2abde240d7cd3ee6b4b28c54df034b9
                           7983a1d16e8a410e4561cb106618e971 )
```

Parameters: Usage, Selector, Matching-Type

Selector 0: Full Certificate
Selector 1: Public Key (could be raw)

Usage 0: PKIX-CA: CA Constraint
Usage 1: PKIX-EE: Service Cert Constraint
Usage 2: DANE-TA: Trust Anchor Assertion
Usage 3: DANE-EE: Domain Issued Certificate

Matching-Type 0: Full Content
Matching-Type 1: SHA-256 Hash
Matching-Type 2: SHA-512 Hash

DANE record specifies the SHA256 hash of the subject public key of the certificate that should match the End-Entity certificate. Authenticated entirely in the DNS (no PKIX involved).

TLS Client Authentication with DANE

- Original drafts developed in mid 2015; refreshed late last year
  - TLS Client Authentication via DANE TLSA Records:
    - https://tools.ietf.org/html/draft-huque-dane-client-cert
  - TLS Extension to convey DANE Client Identity:
    - https://tools.ietf.org/html/draft-huque-tls-dane-clientid
- Target use cases: IOT & SMTP Transport Security

Protocol Summary

- Client has:
  - DNS domain name identity
  - A public/private key pair & a certificate binding the public key to the domain name
  - Corresponding DANE TLSA record published in DNS
-
- (D)TLS server
  - Sends Certificate Request message in handshake; extracts client identity from presented certificate, constructs TLSA record; queries, and validates DANE TLSA response

Protocol Summary

- New TLS extension for conveying client's identity
  - For signaling support for DANE TLS client authentication (empty extension if signal only)
  - For conveying client DNS identity when used with TLS raw public key auth (RFC 7250)
  - In TLS 1.3, this extension is carried in the (encrypted) Client Certificate message (in TLS 1.2 it is carried in the first flight Client extension and has no provision for privacy protection)

Client DNS Naming Convention

Draft is not proscriptive, but proposes 2 naming formats that may be generally suitable for many applications.

Format 1: Service specific client identity

    _service.[client-domain-name]

e.g. _smtp-client.relay1.example.com

1st label identifies the application service name. The remaining labels are composed of the client domain name. Allows the same client to have distinct authentication credentials for distinct application services.

Client DNS Naming Convention

Format 2: IOT Device Identity

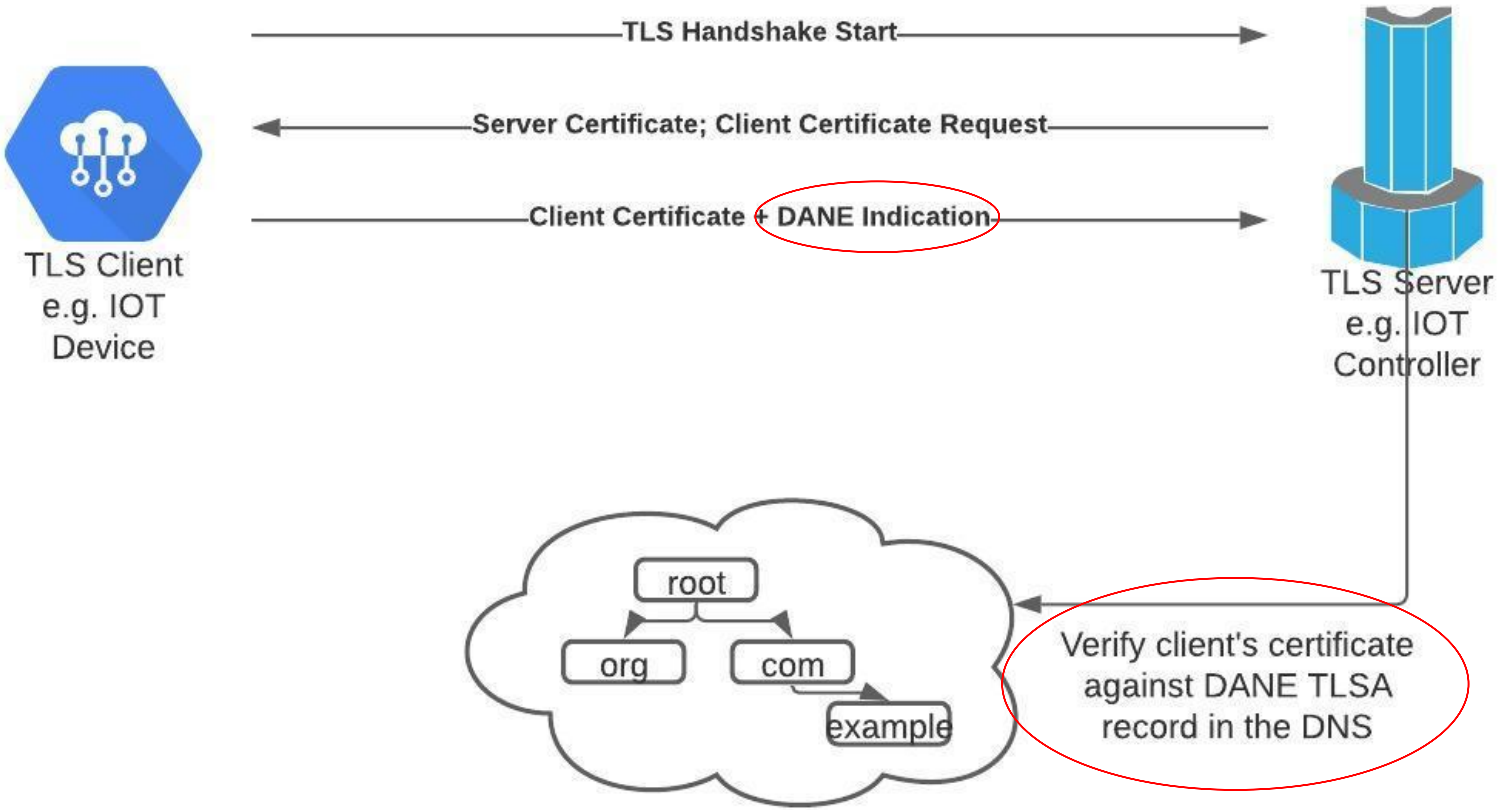
[deviceid]._device.[org-domain-name]

e.g.

a1b2c3._device.subdomain.example.net.

- a1b2c3: device identifier (could be multiple leftmost labels)
- _device: identity grouping label
- subdomain: organizational label (optional)
- example.net: organizational domain

```
sensor7._device.example.com. IN TLSA (
          3 1 2
          0f8b48ff5fd94117f21b6550aaee89c8
          d8adbc3f433c8e587a85a14e54667b25
          f4dcd8c4ae6162121ea9166984831b57
          b408534451fd1b9702f8de0532ecd03c )
```


TLS Handshake Start
Server Certificate; Client Certificate Request
Client Certificate + DANE Indication
TLS Client
e.g. IOT
Device
TLS Server
e.g. IOT
Controller
root
org
com
example
Verify client's certificate
against DANE TLSA
record in the DNS

```
     TLS CLIENT                                             TLS SERVER
Key  ^ ClientHello
Exch | + key_share*
     | + psk_key_exchange_modes*
     v + pre_shared_key*               -------->
                                                       ServerHello  ^ Key
                                                      + key_share*  | Exch
                                                 + pre_shared_key*  v
                                             {EncryptedExtensions}  ^  Server
                                             {CertificateRequest    v  Params
                                               *+DANE Client ID ext}
                                                    {Certificate*}  ^
                                              {CertificateVerify*}  | Auth
                                                        {Finished}  v
                                       <--------   [Application Data*]
     ^ {Certificate
       +DANE Client ID ext]}
Auth | {CertificateVerify*}
     v {Finished}                      -------->

                                                [Verify Client w/ DANE]
                                                [TLS alert on failure ]

      [Application Data]               <------->    [Application Data]
```

Bridging the Gap

DANE requires DNSSEC, and that’s the endgame, but ..

DNSSEC is not universally deployed (yet). And we’d like to be able to use the DANE, even if DNSSEC has not been deployed in the relevant pieces of the DNS infrastructure.

And interim proposal to (securely) achieve that goal involves the specification of an additional TLSA usage mode that allows the certificate data to be authenticated solely with traditional PKIX.

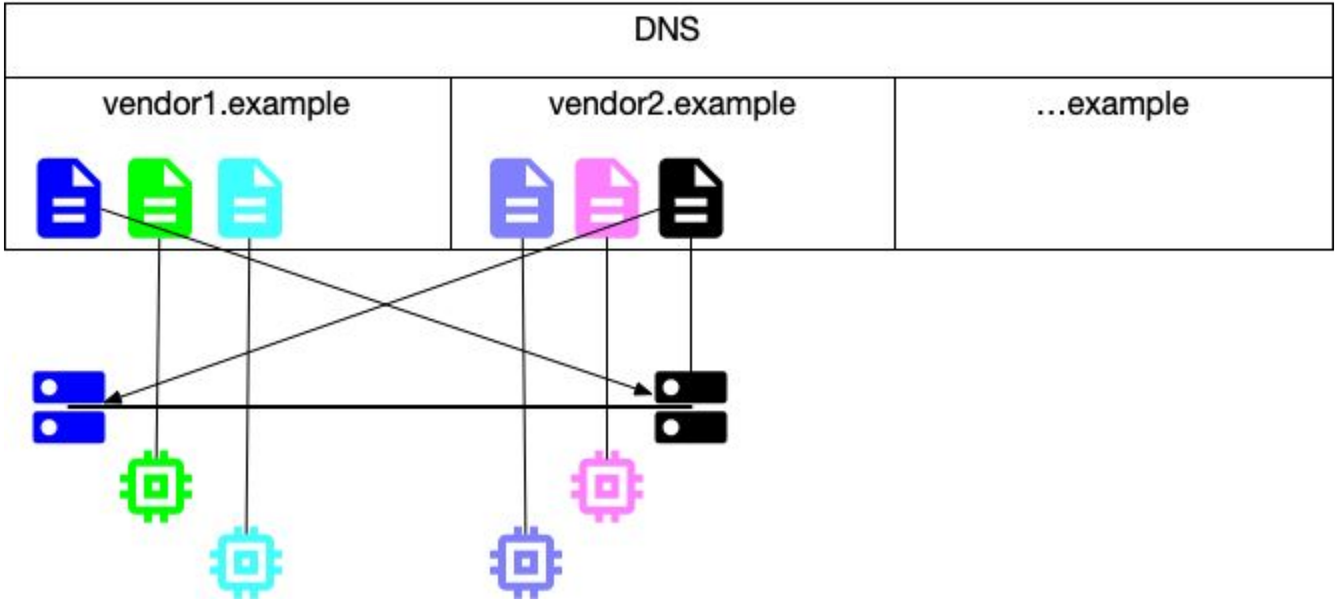
TLS Mutual Authentication With DANE

Simplify PKI management tasks:

- Certificate rotation happens via your own DNS.
- Certificate rotation happens as frequently as desired, TTL is only delay.

Attribution for authenticating peer is straightforward (DNS hierarchy)

TLS Mutual Authentication With DANE



DANE for Certificate Discovery: PKIX-CD

Provide a transitional DANE mode en route to DNSSEC DANE

Two closely-related use cases:

- Entity certificate discovery (object security)
- Trust anchor certificate discovery (TLS client CA certificates)

DANE for Certificate Discovery: PKIX-CD

New certificate usage mode 4: PKIX-CD

Entity certificate is authenticated by a discoverable CA certificate

CA certificate discovery is authenticated by Web PKI

This is for domains which cannot yet adopt DNSSEC

DANE for Certificate Discovery: PKIX-CD

DANE TLSA record containing an x.509 certificate

abc._device.vendor.example IN TLSA 4 0 0 …………….

Breaking down the identity name:

abc: Device identifier
_device: Identity grouping label
vendor.example: Organizational domain

DANE for Certificate Discovery: PKIX-CD

Identity name components:

abc:	Device identifier
_device:	Identity grouping label
device:	Identity type (remove underscore)
vendor.example:	Organizational domain
authorityKeyID:	Extracted from entity certificate

CA certificate URI pattern:
https://**${ID_TYPE}**.**${ORG_DOMAIN}**/.well-known/ca/**${AKI}**.pem

https://device.vendor.example/.well-known/ca/AA-BB-CC….pem

DANE for Certificate Discovery: PKIX-CD

Entity certificate >> abc._device.vendor.example

CA certificate >> https://device.vendor.example/.well-known/ca/AA-BB-CC….pem

Discovery protected by Web PKI, in the absence of DNSSEC

PKIX-CD: Caveats

Must ensure name alignment between DNS query and x.509 contents

Mitigation for same-domain impersonation

Must limit discovered CA certificates to their associated domains

Mitigation for cross-domain impersonation

Must ensure the uniqueness of distinguishedName in cached CA certificates

Mitigate TLS 1.3 confusion with trust chains (RFC 8446, sec 4.2.4)

PKIX-CD: Implementation remaining questions

Is the dNSName the best field to use in the certificate for name alignment?

Will underscores in this field cause friction with CAs issuing private PKI?

We could use otherName, but dNSName seems like a better fit.

Should x.509 nameConstraints (RFC5280) be required for CA certificates?

PKIX-CD: Object Security Use Case

Sender’s certificate discoverable in DNS

Message contains the sender’s DNS name

Message is signed by sender’s private key

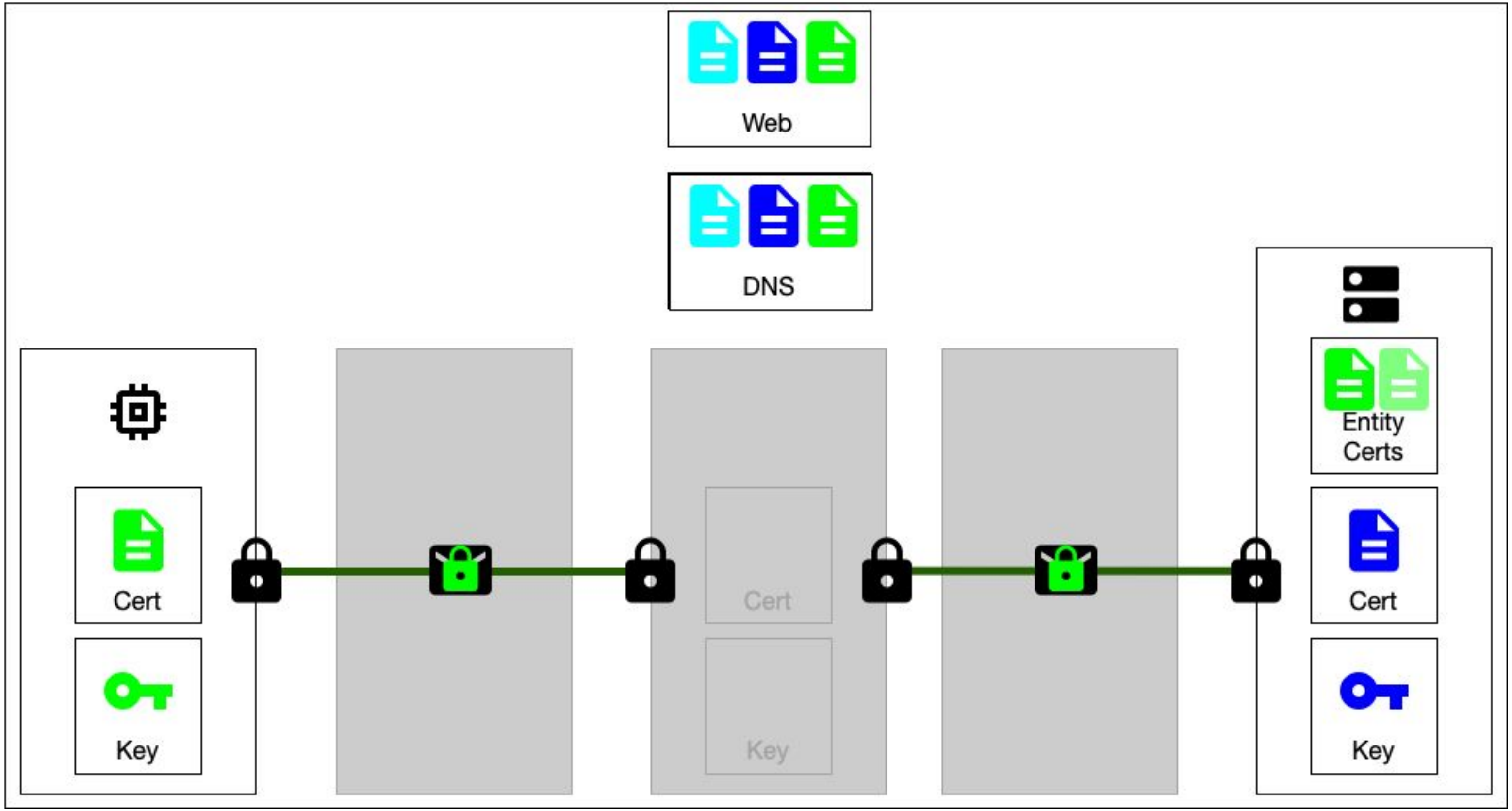
\---

Recipient uses sender’s DNS name to retrieve certificate from DNS

Sender’s signing CA cert discoverable at a URI relative to sender’s DNS name

Discovery of CA certificate protected by traditional Web PKI and TLS

PKIX-CD: Object Security Use Case



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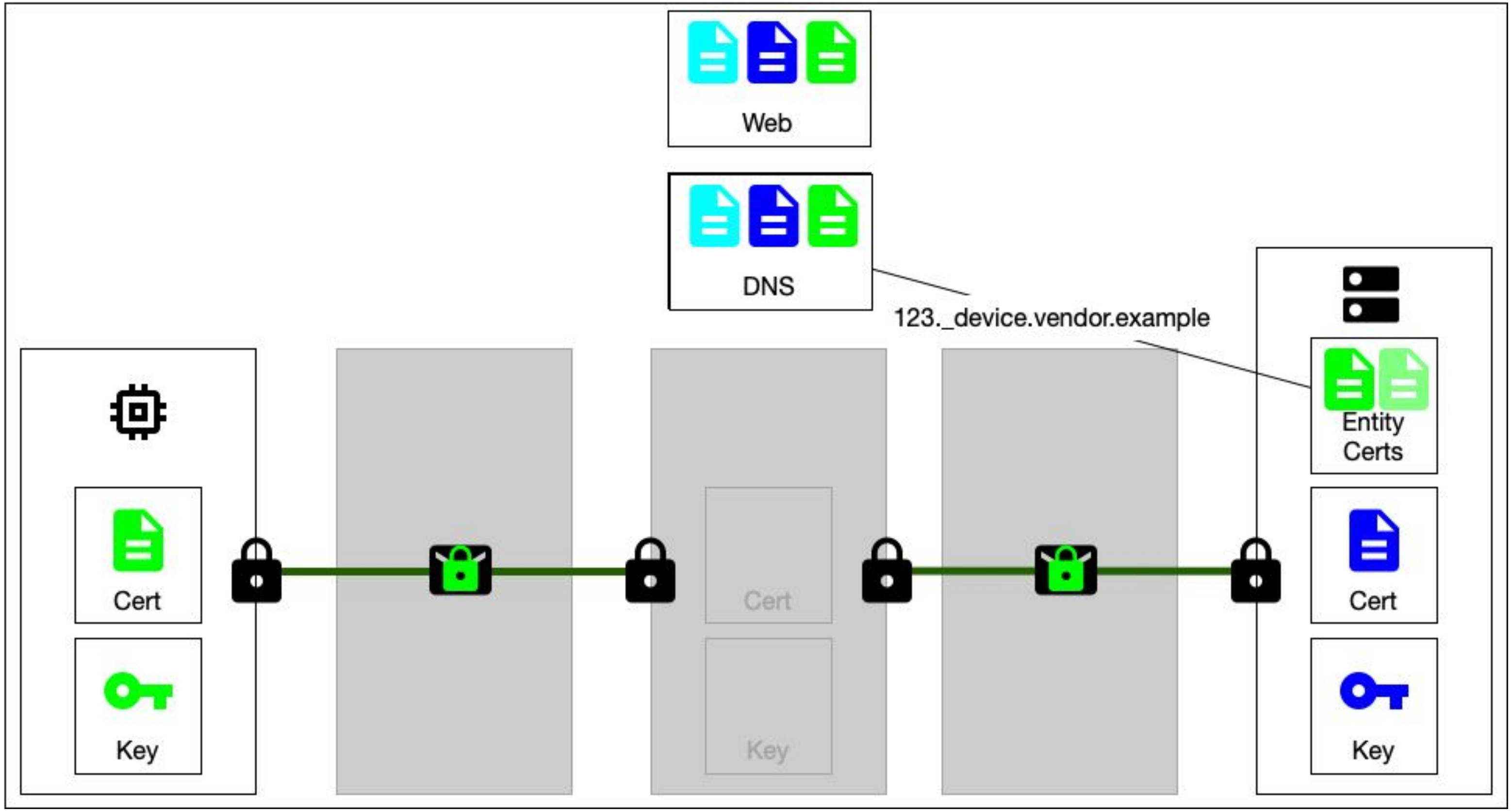

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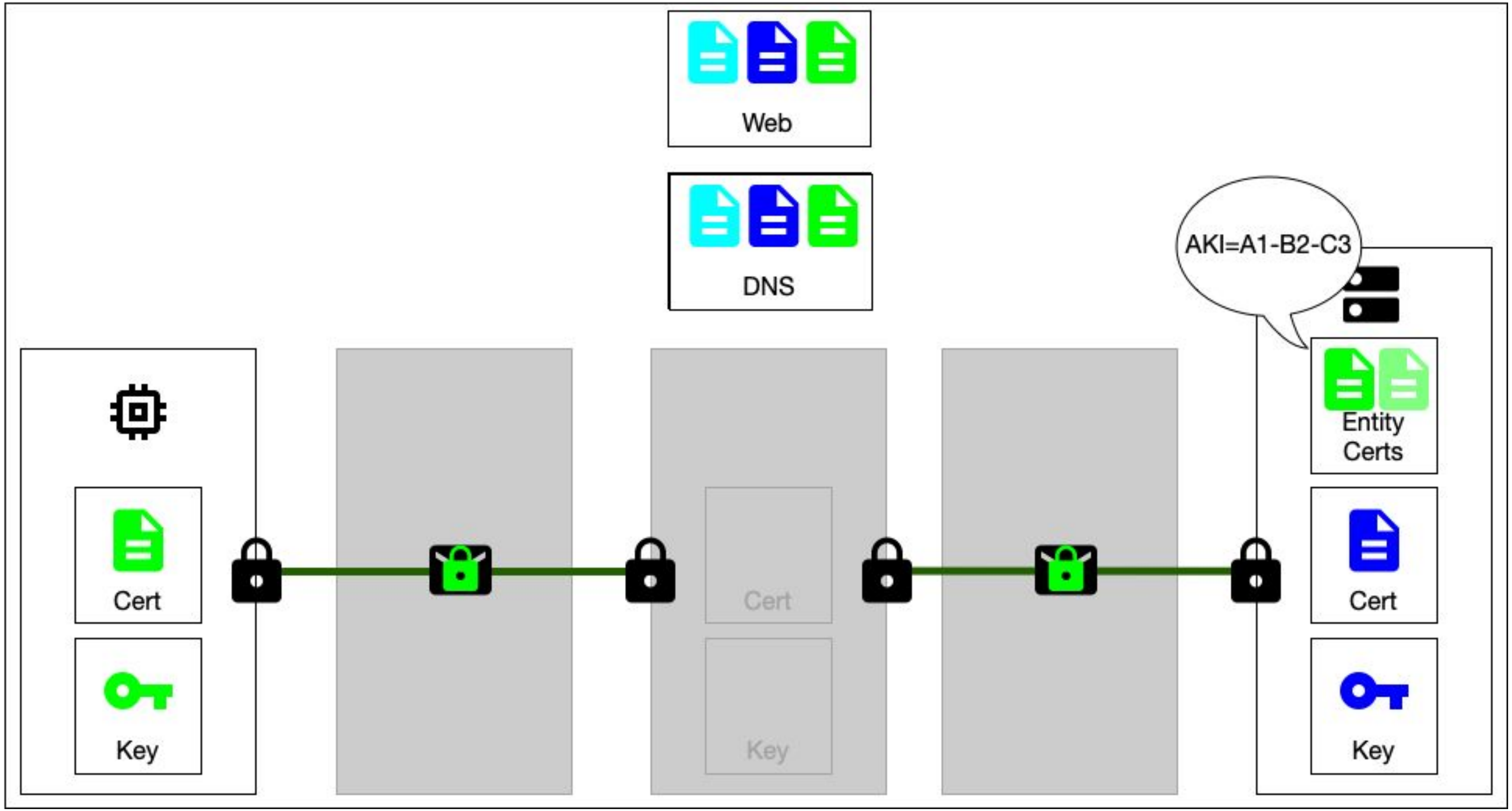

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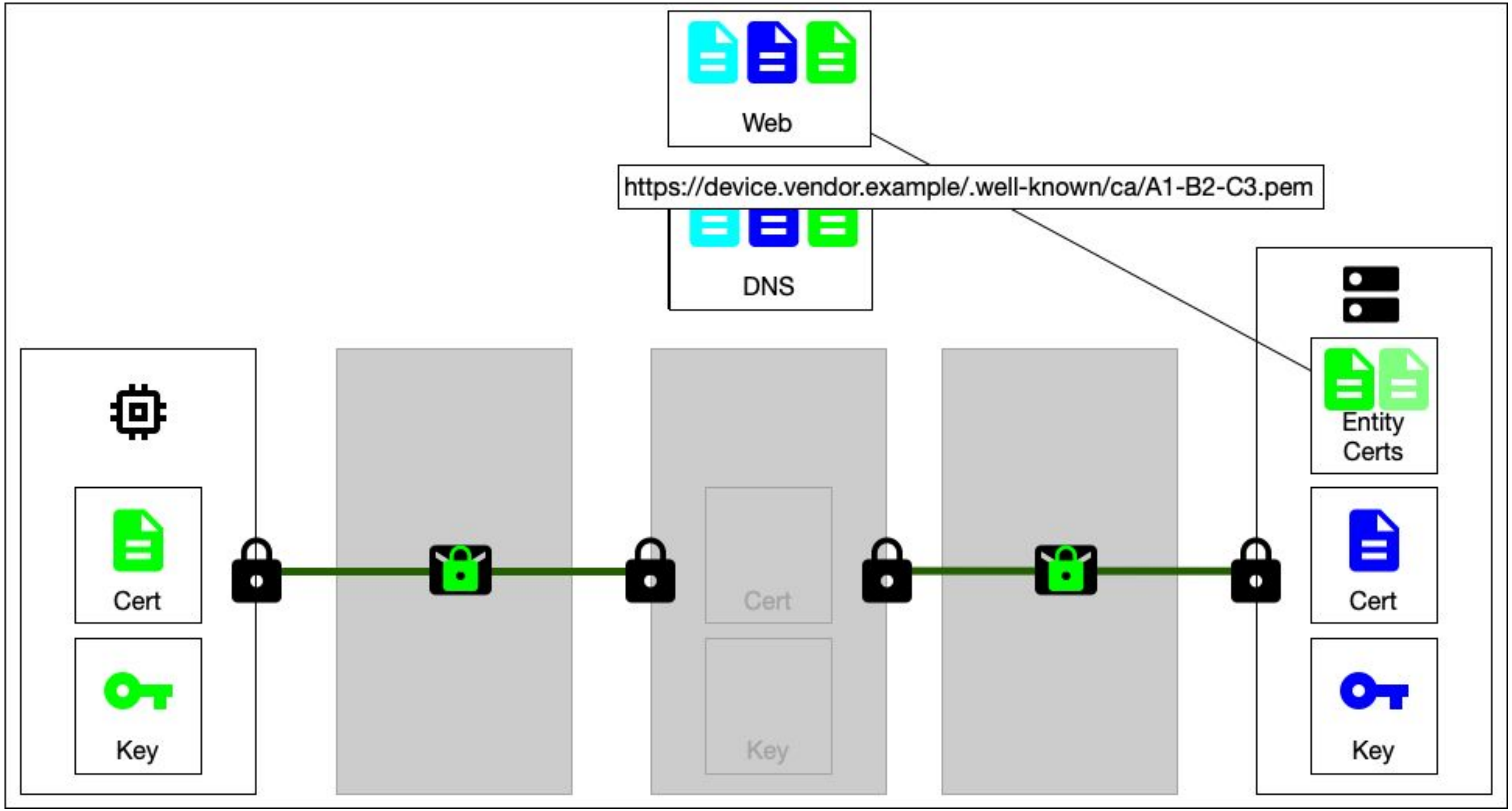


PKIX-CD: Trust Anchor Discovery (for mTLS/PKI)

PKIX-CD process requires the discovery of entity and CA certs

Trust chain:

EE-Cert >> **Private-CA-Cert** >> TLS/WebPKI

Object security (message sign/encrypt) -> Retain **EE-Cert**

Trust anchor discovery (mTLS/PKI) -> Retain **Private-CA-Cert**

Note: Trust anchor discovery happens out-of-band, not a part of the TLS handshake.

Network Access Use Cases

PKIX-CD and EAP-TLS use case (CA cert discovery)

Desired behavior:

Use supplier-provisioned DANE identity for EAP-TLS
Avoid supplier lock-in

Challenges:

Onboarding all mfr CA certs is a manual process
Authz is complicated by different PKI naming conventions
Prevent cross-CA impersonation

With PKIX-CD and EAP-TLS:

RADIUS performs authz based on DNS name to ca cert mapping

PKIX-CD and EAP-TLS use case (CA cert discovery)

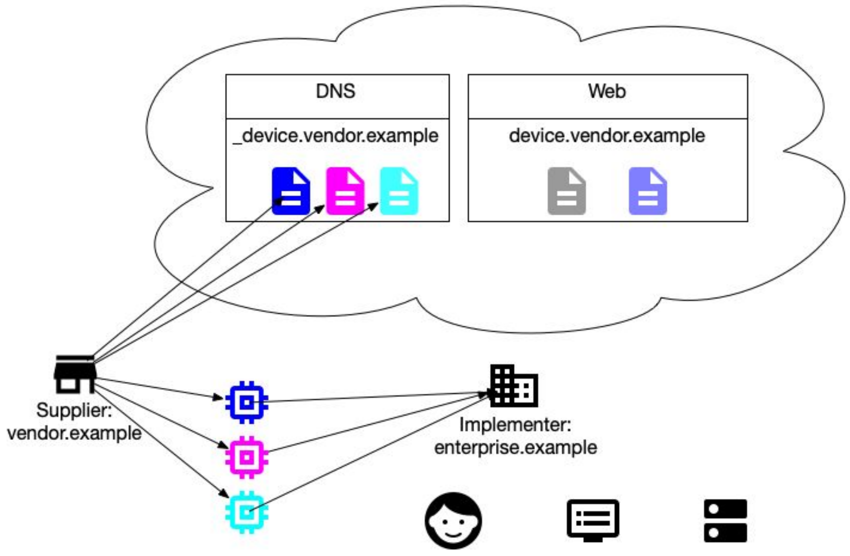
Supplier responsibility:
- Publish TLSA records for devices, which contain authorityKeyID (AKI).
- Publish authority server (https://device.vendor.example/.well-known/ca/${AKI}.pem)

Implementer responsibility:
- Manage names of authorized identities in RADIUS
- EAP-TLS server CA certificate installation on device

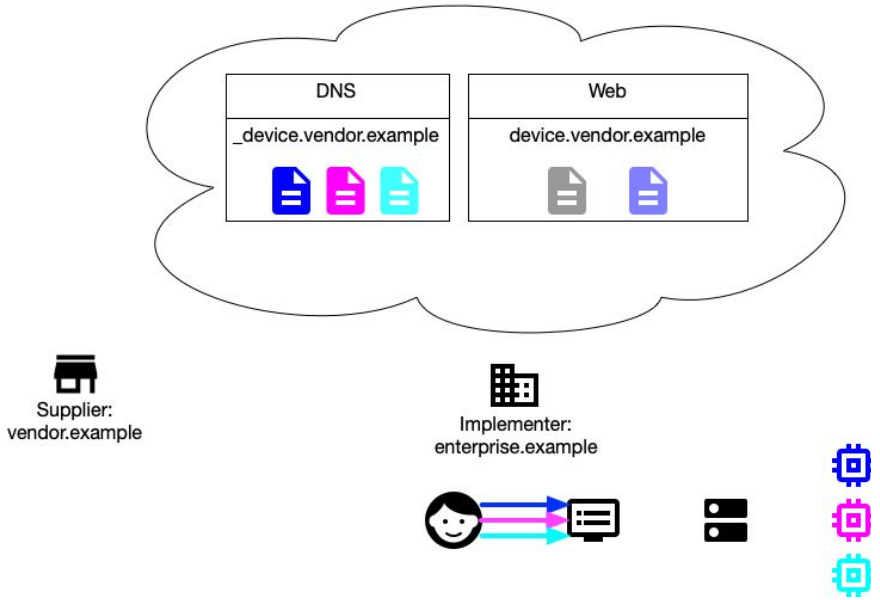
RADIUS automation:
- Periodically update **DANE_ID : AKI** mappings
- Periodic out-of-band CA cert sync

RADIUS AA:
- Perform authn using traditional PKI
- Perform authz based on **DANE_ID : AKI** mapping

PKIX-CD and EAP-TLS (CA cert discovery)



PKIX-CD and EAP-TLS (CA cert discovery)



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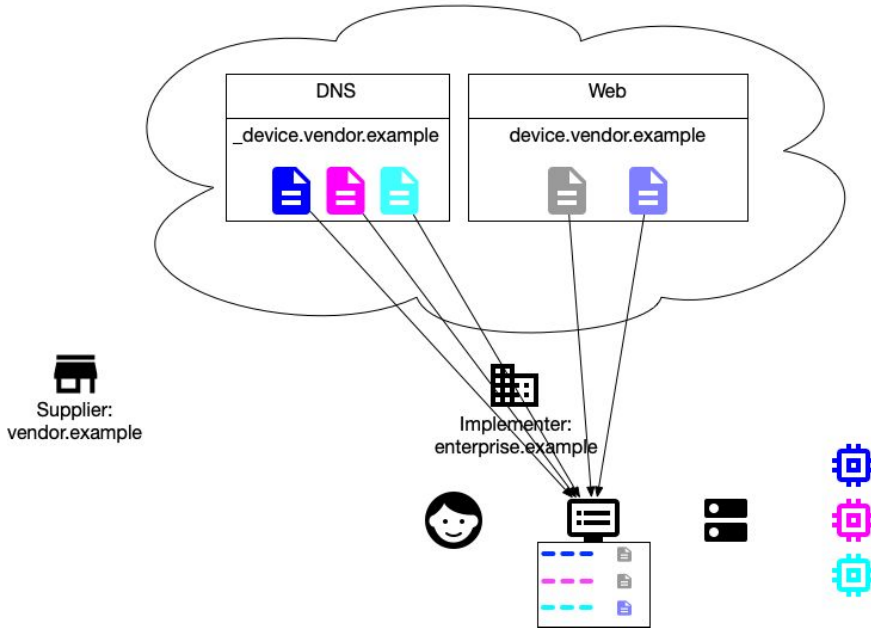

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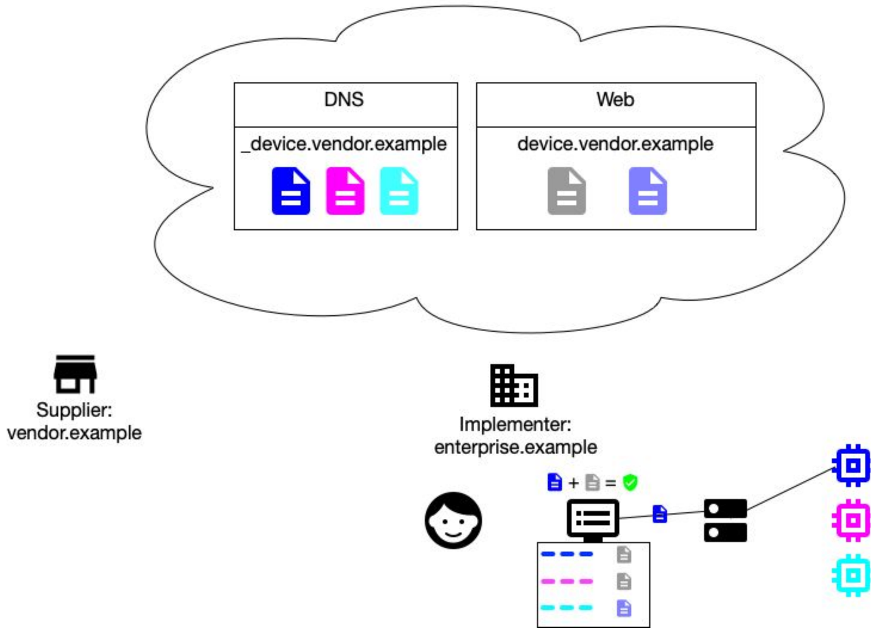


DANE Client ID and EAP-TLS use case

Desired behavior:

- Use supplier-provisioned DANE identity for EAP-TLS
- Avoid supplier lock-in

Challenges:

- Onboarding all mfr CA certs is a manual process
- Authz is complicated by different PKI naming conventions
- Prevent cross-CA impersonation

With DANE Client ID and EAP-TLS:

- RADIUS performs authn/authz based on a list of allowed DNS names

DANE Client ID and EAP-TLS use case

Supplier responsibility:

Publish TLSA records for devices~~, which contain authorityKeyID (AKI).~~

~~Publish authority server (https://device.example.com/.well-known/ca/${AKI}.pem)~~

Implementer responsibility:

Manage names of authorized identities in RADIUS

RADIUS Server authentication via:

RADIUS server CA certificate installation on device

-or- tls-dnssec-chain-extension for DANE auth before network access is granted

RADIUS automation:

~~Periodically update **DANE_ID : AKI** mappings~~

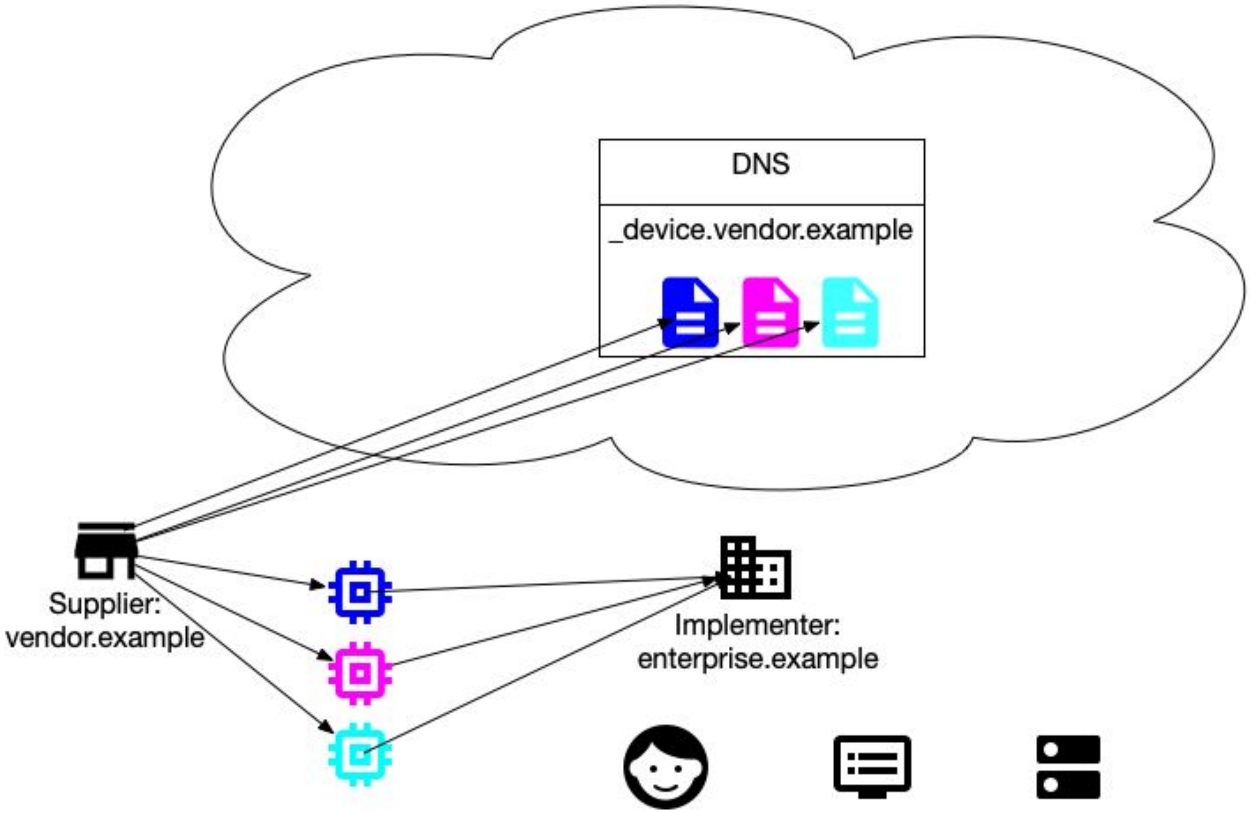
~~Periodically sync discovered CA certs~~

RADIUS AA:

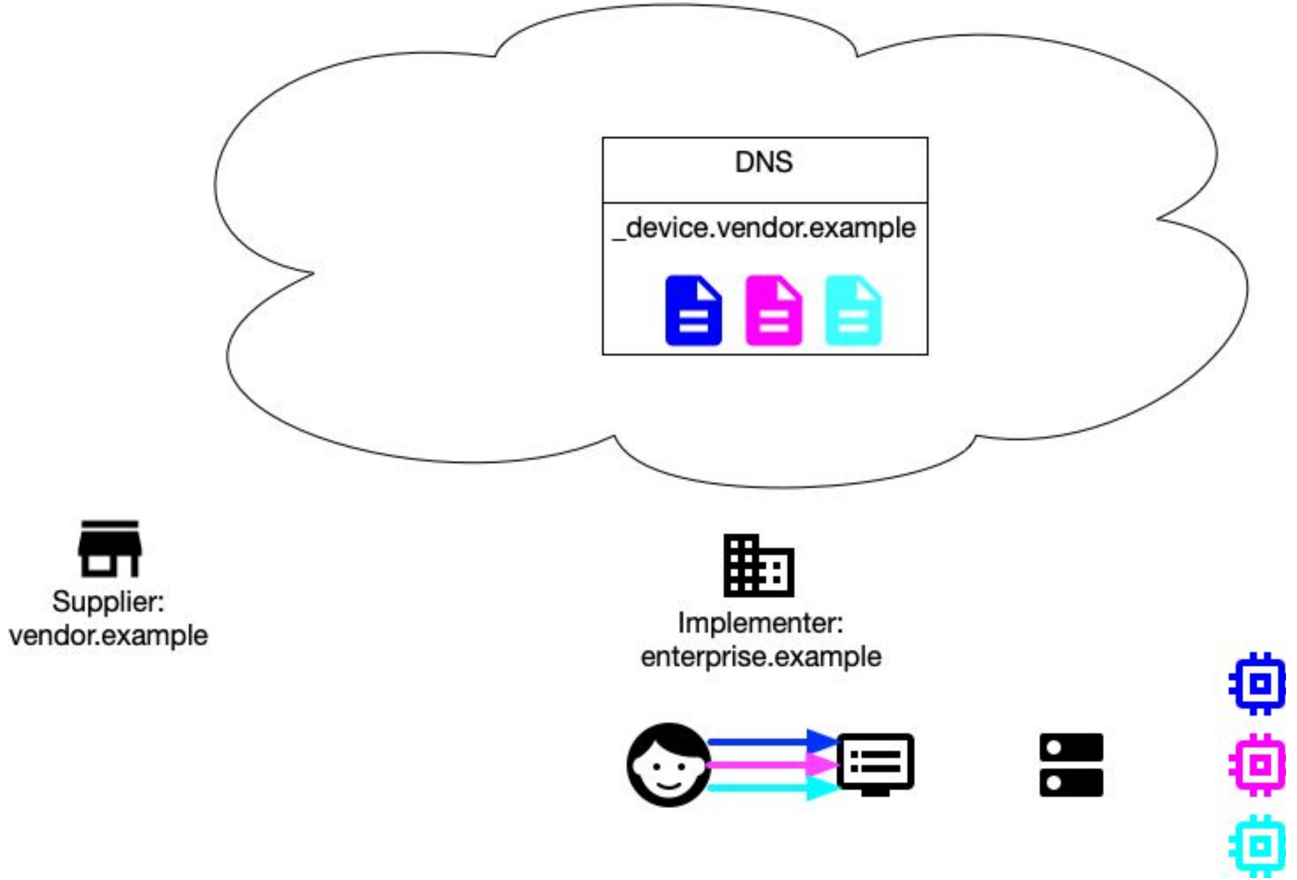
Perform authn/z using DANE ~~traditional PKI~~

~~Perform authz based on **DANE_ID : AKI** mapping~~

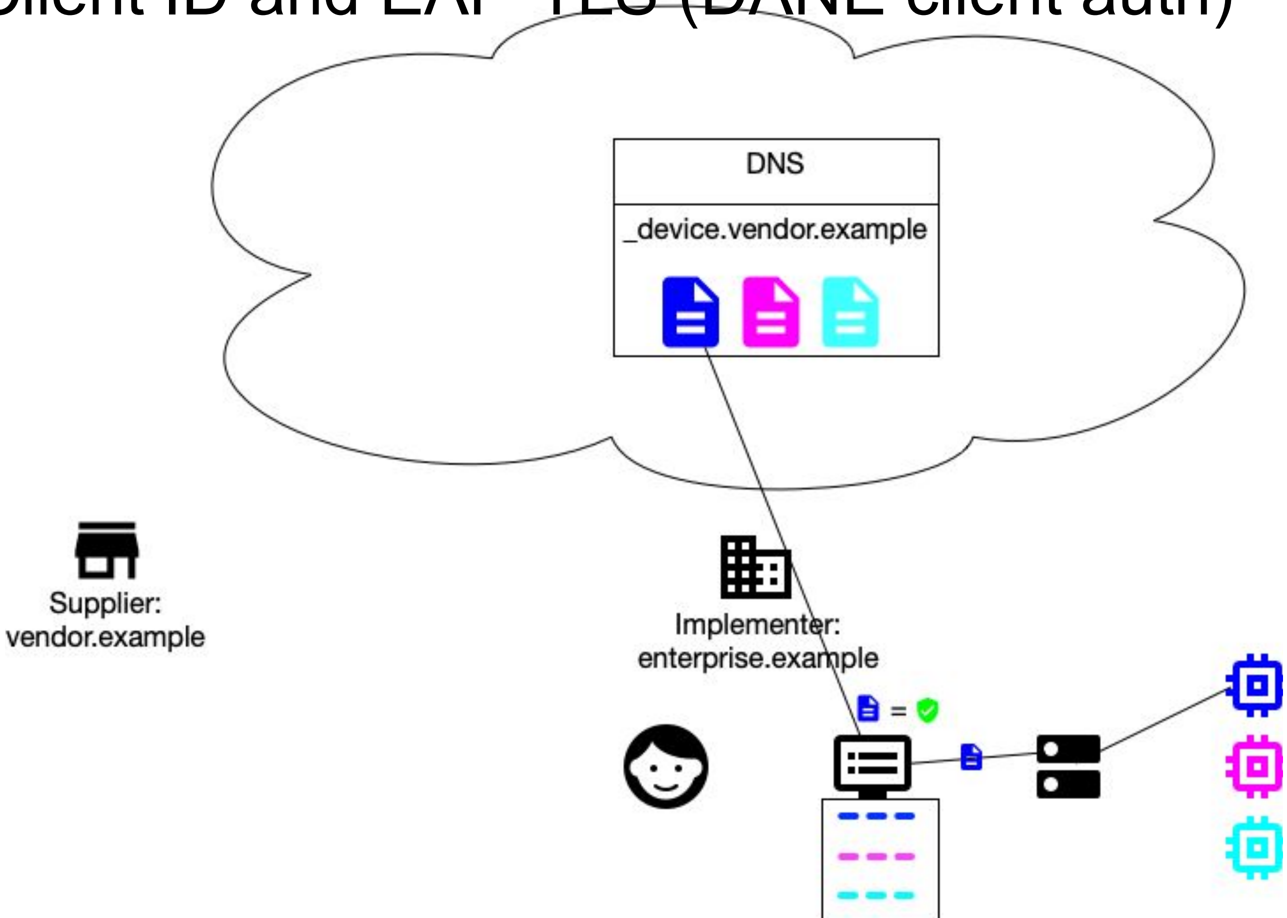
DANE Client ID and EAP-TLS (DANE client auth)



DANE Client ID and EAP-TLS (DANE client auth)



DANE Client ID and EAP-TLS (DANE client auth)



DANE for EAP-TLS Summary

Safely enable mfr-supplied PKI identity for network access

Use with or without DNSSEC

PKIX-CD is a first step into DANE, using WebPKI for trust

DANE for client auth is simpler than PKIX-CD (DNSSEC makes things simpler!)

Ecosystem Interaction: mDNS and DANE

mDNS and DANE Use Case: Dash Cam Retention

Taxi service must retain #days of dash cam footage for insurance compliance

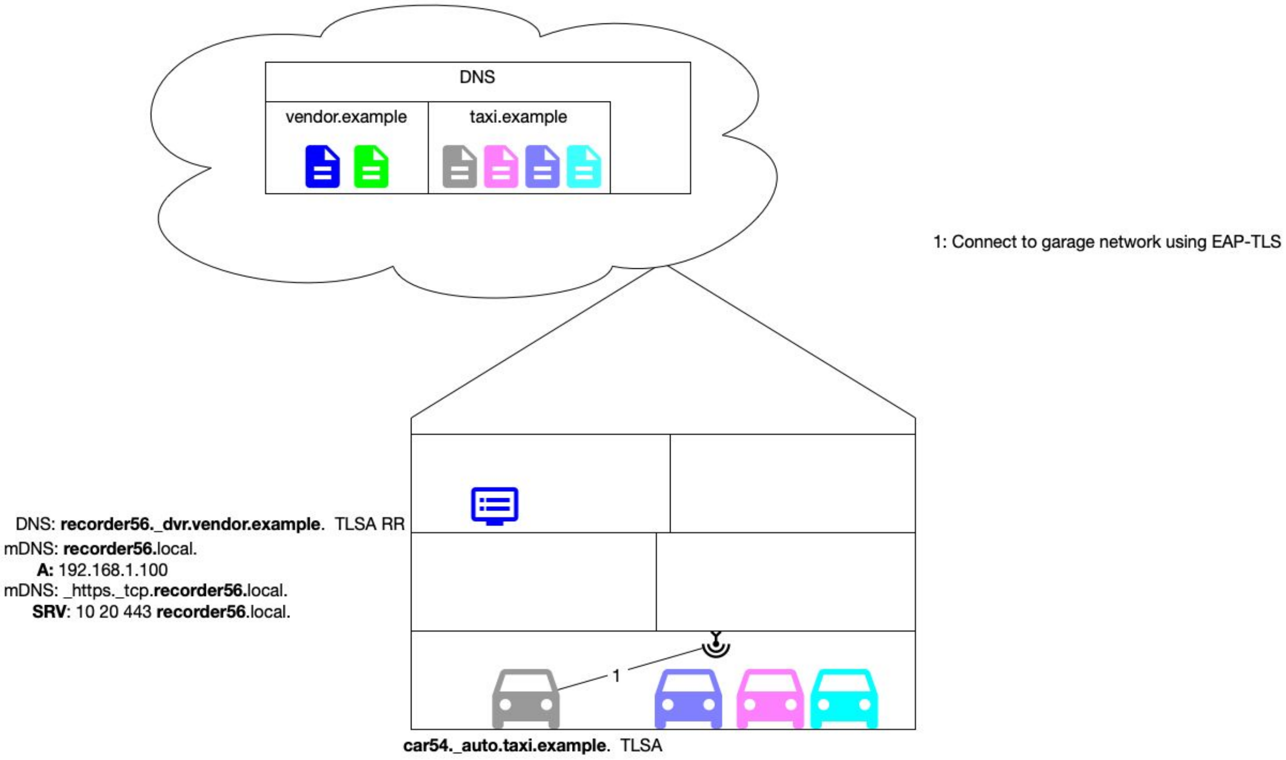
Constraints:

- Cost of onboard storage for all cameras for #days too high
- Cost of cellular bandwidth for video transmission too high
- Local storage at taxi garage/offices preferred

Solution:

- Flush video archives from car’s dash cam to office DVR:
  - Every day at end of shift
  - Using office WiFi
  - Video files are signed by dash cam’s private key

mDNS and DANE Use Case: Dash Cam Retention



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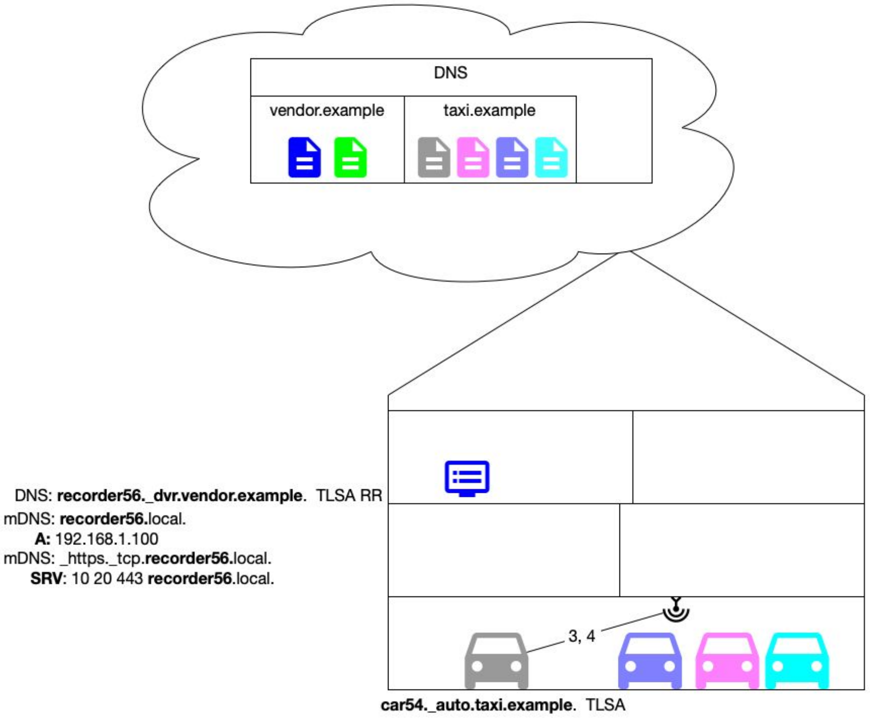

1: Connect to garage network using EAP-TLS

2: Compose mDNS SRV query from DNS name of DVR:
DNS_NAME=**recorder56._dvr.vendor.example.**
MDNS_INSTANCE=recorder56
SRV_QUERY=recorder56._https._tcp.local.

3: MDNS: get SRV for ${SRV_QUERY}
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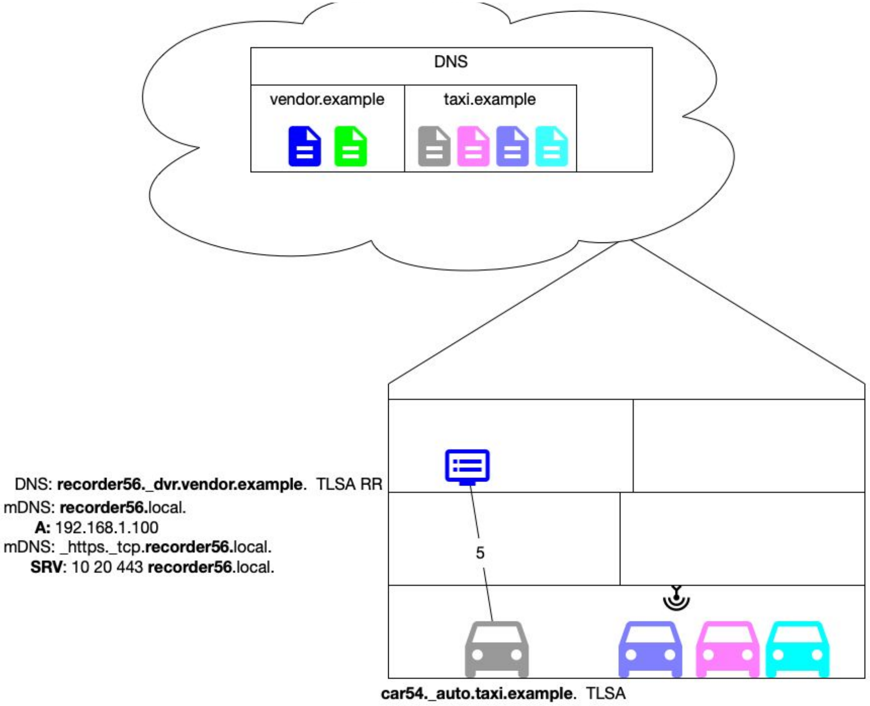

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SNI=${DNS_NAME}
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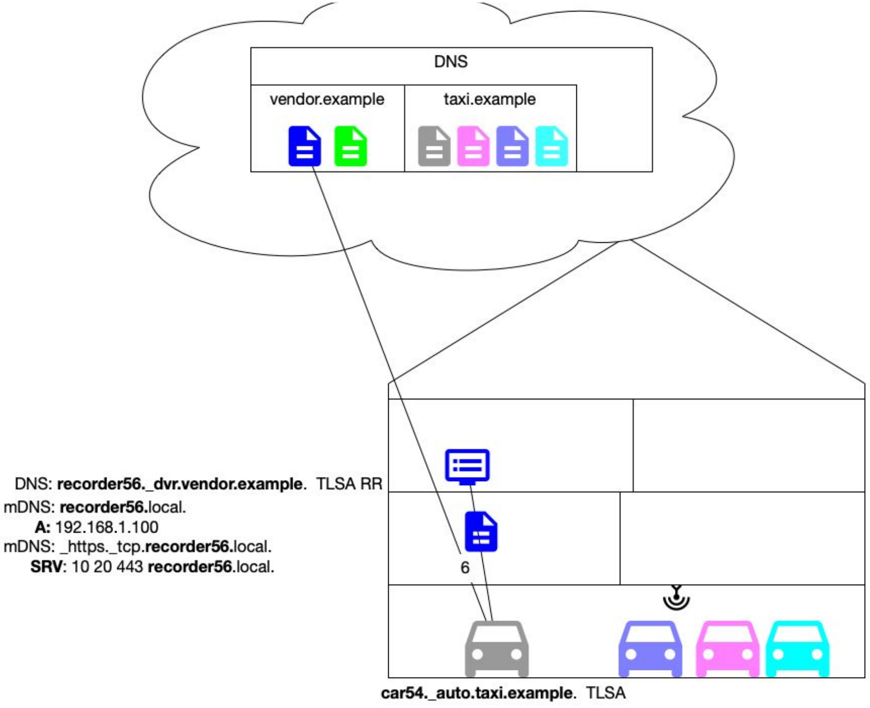

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6: Perform DANE match against server certificate
Pattern:_${PORT}._${PROTO}.${SNI}
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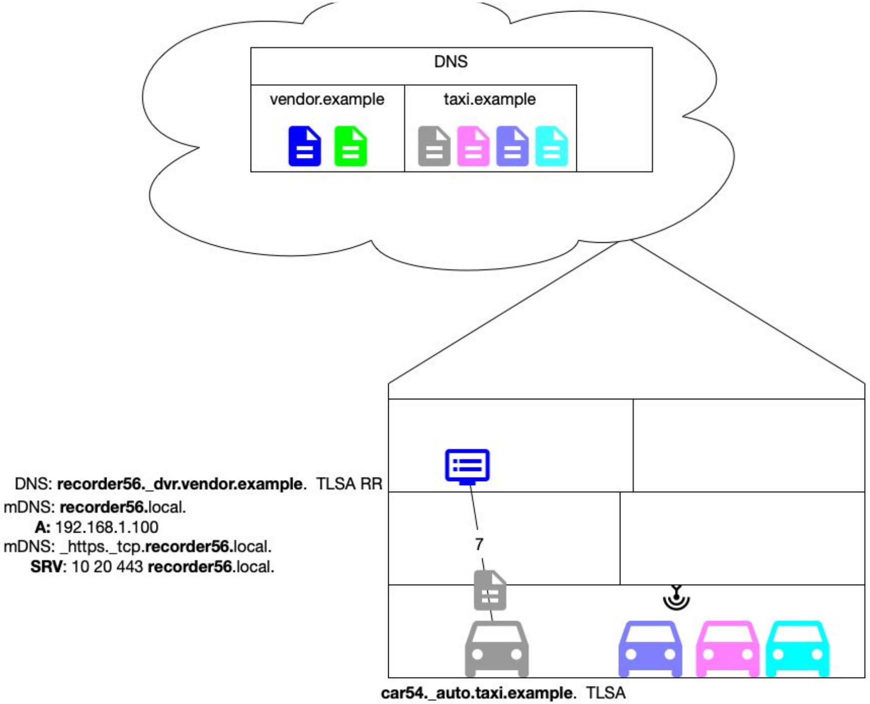
mDNS and DANE Use Case: Dash Cam Retention



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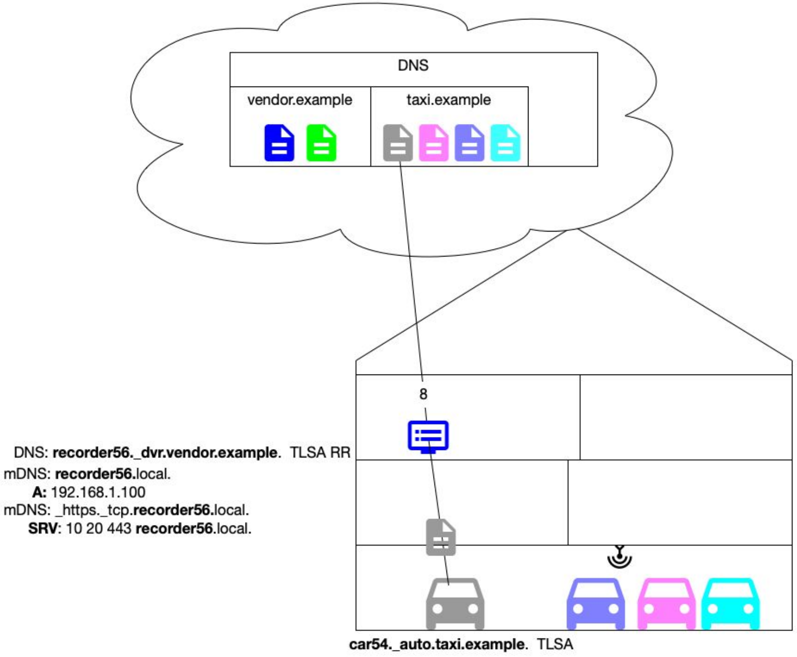
7: Present client certificate

mDNS and DANE Use Case: Dash Cam Retention



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7: Present client certificate

8: Compare client certificate against TLSA at **car54._auto.taxi.example**

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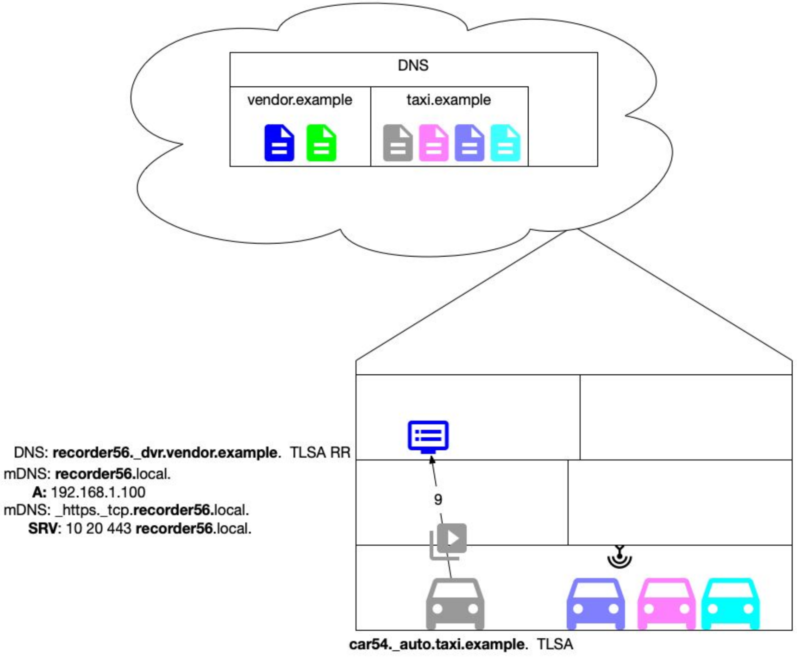

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9: Upload signed dash cam archives to DVR system

Scope of Work

DANISH Core Objectives

DANE for Client Identity:

https://tools.ietf.org/html/draft-huque-tls-dane-clientid-04

https://tools.ietf.org/html/draft-huque-dane-client-cert-05

DANE for Certificate Discovery:

https://tools.ietf.org/html/draft-wilson-dane-pkix-cd-00.html

DANISH Peripheral Objectives

HTTP, MQTT, etc:
    HTTP and PROXY protocol header standardization

Email ecosystem:
    STARTTLS, IANA email auth parameters for DANE client ID

Object security:
    JOSE/COSE updates for ‘x5u’ field usage

HTTP and PROXY protocol headers

HTTP proxy headers:

- Need to convey the DANE client name
- Suggest: **X-Forwarded-DANE-Client-Id**

TCP TLVs for PROXY protocol:

- **PP2_TYPE_SSL**: contains **PP2_SUBTYPE_SSL_CN** for cert CN.
- Suggest adding **PP2_SUBTYPE_SSL_DANE** for DANE DNS name

JOSE

JWS and JWE define x5u field for locating an x509 cert:

- https://tools.ietf.org/html/rfc7515#section-4.1.5
- https://tools.ietf.org/html/rfc7516#section-4.1.7

Currently:

- Only PEM-formatted certificates
- Only over HTTPS

Update:

- Support DNS URI and DER encoding:
  - dns:abc._device.example.com?type=TLSA
- OR dns://1.1.1.1/abc._device.example.com?type=TLSA

COSE

COSE defines x5u and x5u-sender fields for OOB discovery of x509 certs

Currently:

Only **application/pkix-cert** and **application/pkcs7-mime** media types

Update:

Support for **application/dns** media type

Eligible for Inclusion

SMIMEA Update

SMIMEA (RFC8162):

DANE for SMIME certificate discovery

Naming convention:

${LOCAL_PART_SHA}._smimecert.${DOMAIN}

Requires DNSSEC (https://tools.ietf.org/html/rfc8162#section-6)

Update:

Allow PKIX-CD for discovery of cert and chain.

Use PKIX-CD pattern:

https://smimecert.${DOMAIN}/.well-known/ca/${AKI}.pem

Uses of the TLS DNSSEC Chain Extension

https://tools.ietf.org/html/draft-dukhovni-tls-dnssec-chain-02

“The DANE Authentication Chain Extension for TLS”

Currently planned to be published through the Independent Submissions Editor (ISE) channel.

But has potential applicability in the IOT space, e.g. for DANE TLS server authentication in Network Access Authentication scenarios where the EAP-TLS client has no initial access to the network to perform DNS queries, ...

DANE for SIP Authentication

Some mention on mailing list, worth exploring further?

Possible outcomes:

- Supplier-issued endpoint identity used for network auth
- Supplier-issued endpoint identity used for SIP client authentication
- Could PKIX-CD make RFC 5922 (domain certs for SIP) easier to implement?

Oauth2 mTLS Update

Oauth2 supports mutual TLS for authentication (https://tools.ietf.org/html/rfc8705)

The client_id is derived from information in the x509 certificate

The jwks_uri points to a JWKS doc (https://tools.ietf.org/html/rfc8705#section-2.2)

JWKS doc contains client certs

Update:

Add dane_uri for indicating TLSA records to be used for mTLS authentication

MLS Protocol

https://tools.ietf.org/html/draft-ietf-mls-protocol-11

Makes use of a Directory for public key distribution and discovery

Would DNS be a good fit as a directory for MLS?

Appendix

DANE operational guidance:
https://tools.ietf.org/html/rfc7671

DANE for Client Identity:
https://tools.ietf.org/html/draft-huque-tls-dane-clientid-04
https://tools.ietf.org/html/draft-huque-dane-client-cert-05

DANE for certificate discovery:
https://github.com/ashdwilson/dane-pkix-cd

Well-Known URIs:
https://tools.ietf.org/html/rfc8615

TLS 1.3:
https://tools.ietf.org/html/rfc8446

JOSE:
https://datatracker.ietf.org/wg/jose/documents/

COSE:
https://datatracker.ietf.org/wg/cose/documents/

IANA Email Auth Parameters:
https://www.iana.org/assignments/email-auth/email-auth.xhtml

Internet X.509 PKI Certificate and CRL Profiles:
https://tools.ietf.org/html/rfc5280

DNSSEC Chain Extension:
https://tools.ietf.org/html/draft-dukhovni-tls-dnssec-chain-02

Multicast DNS:
https://tools.ietf.org/html/rfc6762

EAP-TLS:
https://tools.ietf.org/html/rfc5216

Proxy Headers:
https://tools.ietf.org/html/rfc7239
https://tools.ietf.org/html/draft-bdc-something-something-certificate-04
https://www.haproxy.com/blog/haproxy/proxy-protocol/

DANE for S/MIME:
https://tools.ietf.org/html/rfc8162

SIP Certificate-Based Authentication:
https://tools.ietf.org/html/rfc5922

Oauth2:
https://tools.ietf.org/html/rfc8705