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ACME for Subdomains
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Abstract

This document outlines how ACME can be used by a client to obtain a certificate for a subdomain identifier from a certification authority. The client has fulfilled a challenge against a parent domain but does not need to fulfill a challenge against the explicit subdomain as certificate policy allows issuance of the subdomain certificate without explicit subdomain ownership proof.

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Table of Contents

1. Introduction	2
2. Terminology	2
3. ACME Workflow and Identifier Requirements	4
4. ACME Issuance of Subdomain Certificates	5
4.1. ACME Challenge Type	6
4.2. Authorization Object	6
4.3. Pre-Authorization	7
4.4. New Orders	8
4.5. Directory Object Metadata	10
5. Illustrative Call Flow	10
6. IANA Considerations	16
6.1. Authorization Object Fields Registry	16
6.2. Directory Object Metadata Fields Registry	16
7. Security Considerations	17
7.1. ACME Server Policy Considerations	18
8. Informative References	18
Appendix A. CA Browser Forum Baseline Requirements Extracts . .	19
Authors' Addresses	20

1. Introduction

ACME [RFC8555] defines a protocol that a certification authority (CA) and an applicant can use to automate the process of domain name ownership validation and X.509v3 (PKIX) [RFC5280] certificate issuance. This document outlines how ACME can be used to issue subdomain certificates, without requiring the ACME client to explicitly fulfill an ownership challenge against the subdomain identifiers - the ACME client need only fulfill an ownership challenge against a parent domain identifier.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

The following terms are defined in DNS Terminology [RFC8499] and are reproduced here:

- o Label: An ordered list of zero or more octets that makes up a portion of a domain name. Using graph theory, a label identifies one node in a portion of the graph of all possible domain names.
- o Domain Name: An ordered list of one or more labels.
- o Subdomain: "A domain is a subdomain of another domain if it is contained within that domain. This relationship can be tested by seeing if the subdomain's name ends with the containing domain's name." (Quoted from [RFC1034], Section 3.1) For example, in the host name "nnn.mmm.example.com", both "mmm.example.com" and "nnn.mmm.example.com" are subdomains of "example.com". Note that the comparisons here are done on whole labels; that is, "ooo.example.com" is not a subdomain of "oo.example.com".
- o Fully-Qualified Domain Name (FQDN): This is often just a clear way of saying the same thing as "domain name of a node", as outlined above. However, the term is ambiguous. Strictly speaking, a fully-qualified domain name would include every label, including the zero-length label of the root: such a name would be written "www.example.net." (note the terminating dot). But, because every name eventually shares the common root, names are often written relative to the root (such as "www.example.net") and are still called "fully qualified". This term first appeared in [RFC0819]. In this document, names are often written relative to the root.

The following terms are defined in the CA/Browser Forum Baseline Requirements [CAB] version 1.7.1 and are reproduced here:

- o Authorization Domain Name (ADN): The Domain Name used to obtain authorization for certificate issuance for a given FQDN. The CA may use the FQDN returned from a DNS CNAME lookup as the FQDN for the purposes of domain validation. If the FQDN contains a wildcard character, then the CA MUST remove all wildcard labels from the left most portion of requested FQDN. The CA may prune zero or more labels from left to right until encountering a Base Domain Name and may use any one of the intermediate values for the purpose of domain validation
- o Base Domain Name: The portion of an applied-for FQDN that is the first domain name node left of a registry-controlled or public suffix plus the registry-controlled or public suffix (e.g. "example.co.uk" or "example.com"). For FQDNs where the right-most domain name node is a gTLD having ICANN Specification 13 in its registry agreement, the gTLD itself may be used as the Base Domain Name.

- o **Certification Authority (CA):** An organization that is responsible for the creation, issuance, revocation, and management of Certificates. The term applies equally to both Roots CAs and Subordinate CAs
- o **Domain Namespace:** The set of all possible Domain Names that are subordinate to a single node in the Domain Name System

The following additional terms are used in this document:

- o **Certification Authority (CA):** An organization that is responsible for the creation, issuance, revocation, and management of Certificates. The term applies equally to both Roots CAs and Subordinate CAs
- o **CSR:** Certificate Signing Request
- o **Parent Domain:** a domain is a parent domain of a subdomain if it contains that subdomain, as per the [RFC8499] definition of subdomain. For example, for the host name "nnn.mmm.example.com", both "mmm.example.com" and "example.com" are parent domains of "nnn.mmm.example.com".

3. ACME Workflow and Identifier Requirements

A typical ACME workflow for issuance of certificates is as follows:

1. client POSTs a newOrder request that contains a set of "identifiers"
2. server replies with a set of "authorizations" and a "finalize" URI
3. client sends POST-as-GET requests to retrieve the "authorizations", with the downloaded "authorization" object(s) containing the "identifier" that the client must prove that they control, and a set of associated "challenges", one of which the the client must fulfil
4. client proves control over the "identifier" in the "authorization" object by completing one of the specified challenges, for example, by publishing a DNS TXT record
5. client POSTs a CSR to the "finalize" API
6. server replies with an updated order object that includes a "certificate" URI

7. client sends POST-as-GET request to the "certificate" URI to download the certificate

ACME places the following restrictions on "identifiers":

- o [RFC8555] section 7.1.3: The authorizations required are dictated by server policy; there may not be a 1:1 relationship between the order identifiers and the authorizations required.
- o [RFC8555] section 7.1.4: the only type of "identifier" defined by the ACME specification is an FQDN: "The only type of identifier defined by this specification is a fully qualified domain name (type: "dns"). The domain name MUST be encoded in the form in which it would appear in a certificate."
- o [RFC8555] section 7.4: the "identifier" in the CSR request must match the "identifier" in the newOrder request: "The CSR MUST indicate the exact same set of requested identifiers as the initial newOrder request."
- o [RFC8555] section 8.3: the "identifier", or FQDN, in the "authorization" object must be used when fulfilling challenges via HTTP: "Construct a URL by populating the URL template ... where the domain field is set to the domain name being verified"
- o [RFC8555] section 8.4: the "identifier", or FQDN, in the "authorization" object must be used when fulfilling challenges via DNS: "The client constructs the validation domain name by prepending the label "_acme-challenge" to the domain name being validated."

ACME does not mandate that the "identifier" in a newOrder request matches the "identifier" in "authorization" objects.

4. ACME Issuance of Subdomain Certificates

As noted in the previous section, ACME does not mandate that the "identifier" in a newOrder request matches the "identifier" in "authorization" objects. This means that the ACME specification does not preclude an ACME server processing newOrder requests and issuing certificates for a subdomain without requiring a challenge to be fulfilled against that explicit subdomain.

ACME server policy could allow issuance of certificates for a subdomain to a client where the client only has to fulfill an authorization challenge for a parent domain of that subdomain. This allows a flow where a client proves ownership of, for example,

"example.org" and then successfully obtains a certificate for "sub.example.org".

ACME server policy is out of scope of this document, however some commentary is provided in Section 7.1.

Clients need a mechanism to instruct the ACME server that they are requesting authorization for a Domain Namespace subordinate to a given ADN, as opposed to just requesting authorization for an explicit ADN identifier. Clients need a mechanism to do this in both newAuthz and newOrder requests. ACME servers need a mechanism to indicate to clients that authorization objects are valid for an entire Domain Namespace. These are described in this section.

4.1. ACME Challenge Type

ACME for subdomains is restricted for use with "dns-01" challenges. If a server policy allows a client to fulfill a challenge against a parent ADN of a requested certificate FQDN identifier, then the server MUST issue a "dns-01" challenge against that parent ADN.

4.2. Authorization Object

ACME [RFC8555] section 7.1.4 defines the authorization object. When ACME server policy allows authorization for Domain Namespaces subordinate to an ADN, the server indicates this by including the "domainNamespace" flag in the authorization object for that ADN identifier:

domainNamespace (optional, boolean): This field MUST be present and true for authorizations where ACME server policy allows certificates to be issued for any Domain Name in the Domain Namespace subordinate to the ADN specified in the 'identifier' field of the authorization object.

The following example shows an authorization object for the ADN "example.org" where the authorization covers the Domain Namespace subordinate to "example.org".

```
{
  "status": "valid",
  "expires": "2015-03-01T14:09:07.99Z",

  "identifier": {
    "type": "dns",
    "value": "example.org"
  },

  "challenges": [
    {
      "url": "https://example.com/acme/chall/prV_B7yEyA4",
      "type": "http-01",
      "status": "valid",
      "token": "DGyRejmCefe7v4NfDGDkFA",
      "validated": "2014-12-01T12:05:58.16Z"
    }
  ],

  "domainNamespace": true
}
```

If the "domainNamespace" field is not included, then the assumed default value is false.

4.3. Pre-Authorization

The standard ACME workflow has authorization objects created reactively in response to a certificate order. ACME also allows for pre-authorization, where clients obtain authorization for an identifier proactively, outside of the context of a specific issuance. With the ACME pre-authorization flow, a client can pre-authorize for a parent ADN once, and then issue multiple newOrder requests for certificates with identifiers in the Domain Namespace subordinate to that ADN.

ACME [RFC8555] section 7.4.1 defines the "identifier" object for newAuthz requests. One additional field for the "identifier" object is defined:

domainNamespace (optional, boolean): An ACME client sets this flag to indicate to the server that it is requesting an authorization for the Domain Namespace subordinate to the specified ADN identifier value

Clients include the flag in the "identifier" object of newAuthz requests to indicate that they are requesting a Domain Namespace authorization. In the following example newAuthz payload, the client

is requesting pre-authorization for the Domain Namespace subordinate to "example.org".

```
"payload": base64url({
  "identifier": {
    "type": "dns",
    "value": "example.org",
    "domainNamespace": true
  }
})
```

If the server is willing to allow a single authorization for the Domain Namespace, and there is not an existing authorization object for the identifier, then it will create an authorization object and include the "domainNamespace" flag with value of true. If the server policy does not allow creation of Domain Namespace authorizations subordinate to that ADN, the server can create an authorization object for the indicated identifier, and include the "domainNamespace" flag with value of false. In both scenarios, handling of the pre-authorization follows the process documented in ACME section 7.4.1.

4.4. New Orders

Clients need a mechanism to optionally indicate to servers whether or not they are authorized to fulfill challenges against parent ADNs for a given identifier FQDN. For example, if a client places an order for an identifier "foo.bar.example.org", and is authorized to update DNS TXT records against the parent ADNs "bar.example.org" or "example.org", then the client needs a mechanism to indicate control over the parent ADNs to the ACME server.

This can be achieved by adding an optional field "domainNamespace" to the "identifiers" field in the order object:

domainNamespace (optional, string): This is the parent ADN of a Domain Namespace that the requested identifier belongs to. The client MUST have DNS control over the parent ADN.

This field specifies the ADN of the Domain Namespace that the client has DNS control over, and is capable of fulfilling challenges against. Based on server policy, the server can choose to issue a challenge against any parent domain of the identifier in the Domain Namespace up to and including the specified "domainNamespace", and create a corresponding authorization object against the chosen identifier.

In the following example `newOrder` payload, the client requests a certificate for identifier `"foo.bar.example.org"` and indicates that it can fulfill a challenge against the parent ADN and the Domain Namespace subordinate to `"bar.example.org"`. The server can then choose to issue a challenge against either `"foo.bar.example.org"` or `"bar.example.org"` identifiers.

```
"payload": base64url({
  "identifiers": [
    { "type": "dns",
      "value": "foo.bar.example.org",
      "domainNamespace": "bar.example.org"  }
  ],
  "notBefore": "2016-01-01T00:04:00+04:00",
  "notAfter": "2016-01-08T00:04:00+04:00"
})
```

In the following example `newOrder` payload, the client requests a certificate for identifier `"foo.bar.example.org"` and indicates that it can fulfill a challenge against the parent ADN and the Domain Namespace subordinate to `"example.org"`. The server can then choose to issue a challenge against any one of `"foo.bar.example.org"`, `"bar.example.org"` or `"example.org"` identifiers.

```
"payload": base64url({
  "identifiers": [
    { "type": "dns",
      "value": "foo.bar.example.org",
      "domainNamespace": "example.org"  }
  ],
  "notBefore": "2016-01-01T00:04:00+04:00",
  "notAfter": "2016-01-08T00:04:00+04:00"
})
```

If the client is unable to fulfill authorizations against parent ADNs, the client should not include the `"domainNamespace"` field.

Server `newOrder` handling generally follows the process documented ACME section 7.4. If the server is willing to allow Domain Namespace authorizations for the ADN specified in `"domainNamespace"`, then it creates an authorization object against that ADN and includes the `"domainNamespace"` flag with a value of `true`. If the server policy does not allow creation of Domain Namespace authorizations against that ADN, then it can create an authorization object for the indicated identifier value, and include the `"domainNamespace"` flag with value of `false`.

4.5. Directory Object Metadata

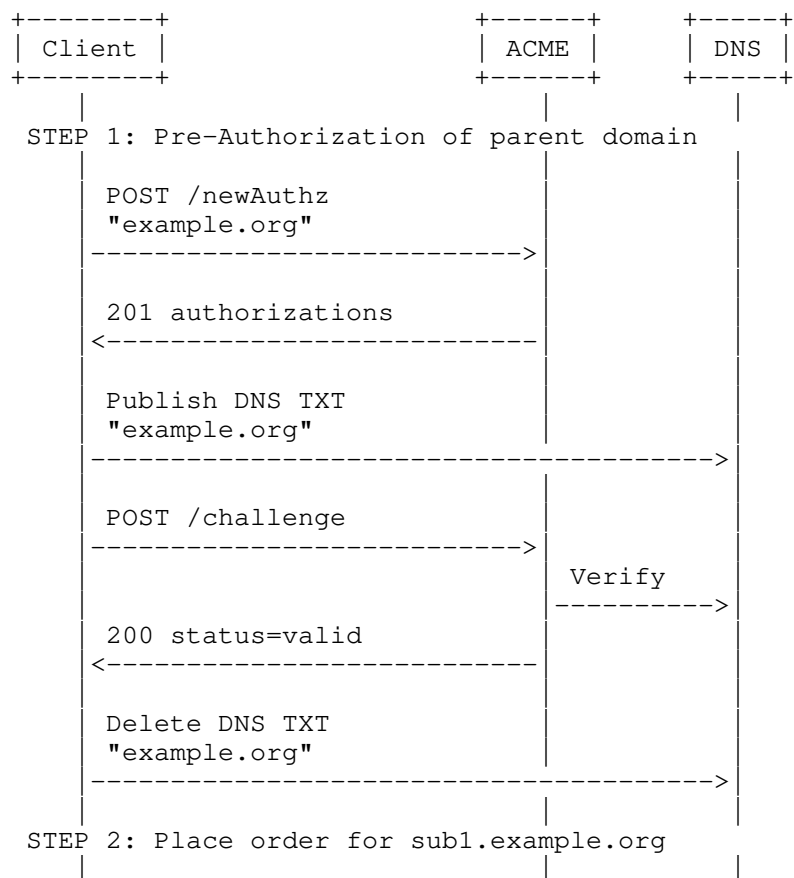
An ACME server can advertise support for authorization of Domain Namespaces by including the following boolean flag in its "ACME Directory Metadata Fields" registry:

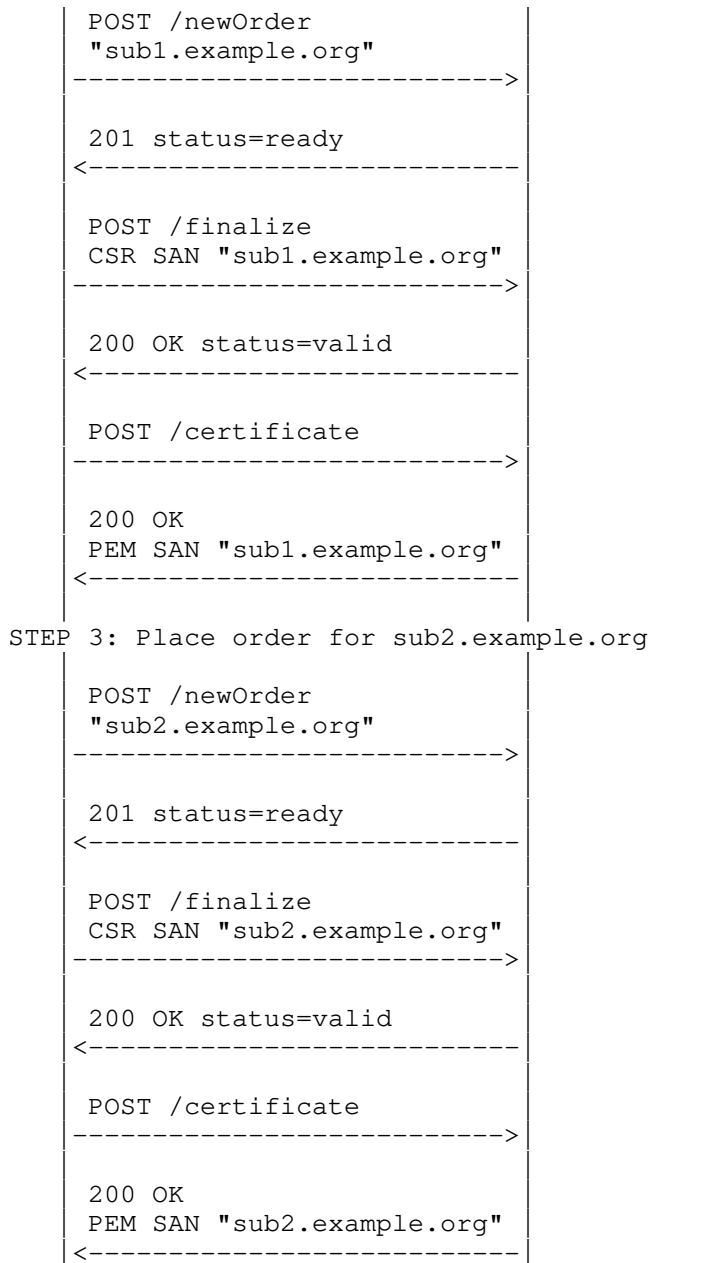
`domainNamespace` (optional, bool): Indicates if an ACME server supports authorization of Domain Namespaces.

If not specified, then no default value is assumed. If an ACME server supports authorization of Domain Namespaces, it can indicate this by including this field with a value of "true".

5. Illustrative Call Flow

The call flow illustrated here uses the ACME pre-authorization flow using DNS-based proof of ownership.





- o STEP 1: Pre-authorization of Domain Namespace

The client sends a newAuthz request for the parent ADN of the Domain Namespace including the "domainNamespace" flag in the identifier object.

```
POST /acme/new-authz HTTP/1.1
Host: example.com
Content-Type: application/jose+json
```

```
{
  "protected": base64url({
    "alg": "ES256",
    "kid": "https://example.com/acme/acct/evOfKhNU60wg",
    "nonce": "uQpSjlRb4vQVCjVYAyyUWg",
    "url": "https://example.com/acme/new-authz"
  }),
  "payload": base64url({
    "identifier": {
      "type": "dns",
      "value": "example.org",
      "domainNamespace": true
    }
  }),
  "signature": "nuSDISbWG8mMgE7H...QyVUL68yzf3Zawps"
}
```

The server creates and returns an authorization object for the identifier including the "domainNamespace" flag. The object is initially in "pending" state. Once the client completes the challenge, the server will transition the authorization object and associated challenge object status to "valid".

```
{
  "status": "pending",
  "expires": "2015-03-01T14:09:07.99Z",

  "identifier": {
    "type": "dns",
    "value": "example.org"
  },

  "challenges": [
    {
      "url": "https://example.com/acme/chall/prV_B7yEyA4",
      "type": "http-01",
      "status": "pending",
      "token": "DGyRejmCefe7v4NfDGDkFA",
      "validated": "2014-12-01T12:05:58.16Z"
    }
  ],

  "domainNamespace": true
}
```

- o STEP 2: The client places a newOrder for "subl.example.org"

The client sends a newOrder request to the server and includes the subdomain identifier. Note that the identifier is in the Domain Namespace that has been pre-authorized in step 1. The client does not need to include the "domainNamespace" field in the "identifier" object as it has already pre-authorized the Domain Namespace.

```
POST /acme/new-order HTTP/1.1
Host: example.com
Content-Type: application/jose+json

{
  "protected": base64url({
    "alg": "ES256",
    "kid": "https://example.com/acme/acct/evOfKhNU60wg",
    "nonce": "5XJ1L3lEkMG7tR6pA00clA",
    "url": "https://example.com/acme/new-order"
  }),
  "payload": base64url({
    "identifiers": [
      { "type": "dns", "value": "sub1.example.org" }
    ],
    "notBefore": "2016-01-01T00:04:00+04:00",
    "notAfter": "2016-01-08T00:04:00+04:00"
  }),
  "signature": "H6ZXtGjTZyUnPeKn...wEA4Tk1Bdh3e454g"
}
```

As an authorization object already exists for the parent ADN of the Domain Namespace, the server replies with an order object with a status of "valid" that includes a link to the existing "valid" authorization object.

```
HTTP/1.1 201 Created
Replay-Nonce: MYAuvOpaoIiywTezizk5vw
Link: <https://example.com/acme/directory>;rel="index"
Location: https://example.com/acme/order/TolocE8rfgo

{
  "status": "valid",
  "expires": "2016-01-05T14:09:07.99Z",

  "notBefore": "2016-01-01T00:00:00Z",
  "notAfter": "2016-01-08T00:00:00Z",

  "identifiers": [
    { "type": "dns", "value": "sub1.example.org" }
  ],

  "authorizations": [
    "https://example.com/acme/authz/PAniVnsZcis"
  ],

  "finalize": "https://example.com/acme/order/Tolocrfgo/finalize"
}
```

The client can proceed to finalize the order and download the certificate for "sub1.example.org".

- o STEP 3: The client places a newOrder for "sub2.example.org"

The client sends a newOrder request to the server and includes the subdomain identifier. Note that the identifier is in the Domain Namespace that has been pre-authorized in step 1. The client does not need to include the "domainNamespace" field in the "identifier" object as it has already pre-authorized the Domain Namespace.

```
POST /acme/new-order HTTP/1.1
Host: example.com
Content-Type: application/jose+json
```

```
{
  "protected": base64url({
    "alg": "ES256",
    "kid": "https://example.com/acme/acct/evOfKhNU60wg",
    "nonce": "5XJ1L3lEkMG7tR6pA00clA",
    "url": "https://example.com/acme/new-order"
  }),
  "payload": base64url({
    "identifiers": [
      { "type": "dns", "value": "sub2.example.org" }
    ],
    "notBefore": "2016-01-01T00:04:00+04:00",
    "notAfter": "2016-01-08T00:04:00+04:00"
  }),
  "signature": "H6ZXtGjTZyUnPeKn...wEA4Tk1Bdh3e454g"
}
```

As an authorization object already exists for the parent ADN of the Domain Namespace, the server replies with an order object with a status of "valid" that includes a link to the existing "valid" authorization object.

```
HTTP/1.1 201 Created
Replay-Nonce: MYAuvOpaoIiywTezizk5vw
Link: <https://example.com/acme/directory>;rel="index"
Location: https://example.com/acme/order/T0locE8rfgo

{
  "status": "valid",
  "expires": "2016-01-05T14:09:07.99Z",

  "notBefore": "2016-01-01T00:00:00Z",
  "notAfter": "2016-01-08T00:00:00Z",

  "identifiers": [
    { "type": "dns", "value": "sub1.example.org" }
  ],

  "authorizations": [
    "https://example.com/acme/authz/PAniVnsZcis"
  ],

  "finalize": "https://example.com/acme/order/R0ni7rdde/finalize"
}
```

The client can proceed to finalize the order and download the certificate for "sub2.example.org".

6. IANA Considerations

6.1. Authorization Object Fields Registry

The following field is added to the "ACME Authorization Object Fields" registry defined in ACME [RFC8555].

Field Name	Field Type	Configurable	Reference
domainNamespace	boolean	false	RFC XXXX

6.2. Directory Object Metadata Fields Registry

The following field is added to the "ACME Directory Metadata Fields" registry defined in ACME [RFC8555].

Field Name	Field Type	Reference
domainNamespace	boolean	RFC XXXX

7. Security Considerations

This document documents enhancements to ACME [RFC8555] that optimize the protocol flows for issuance of certificates for subdomains. The underlying goal of ACME for Subdomains remains the same as that of ACME: managing certificates that attest to identifier/key bindings for these subdomains. Thus, ACME for Subdomains has the same two security goals as ACME:

1. Only an entity that controls an identifier can get an authorization for that identifier
2. Once authorized, an account key's authorizations cannot be improperly used by another account

ACME for Subdomains makes no changes to:

- o account or account key management
- o ACME channel establishment, security mechanisms or threat model
- o Validation channel establishment, security mechanisms or threat model

Therefore, all Security Considerations in ACME in the following areas are equally applicable to ACME for Subdomains:

- o Threat Model
- o Integrity of Authorizations
- o Denial-of-Service Considerations
- o Server-Side Request Forgery
- o CA Policy Considerations

Some additional comments on ACME server policy are given in the following section.

7.1. ACME Server Policy Considerations

The ACME for Subdomains and the ACME specifications do not mandate any specific ACME server or CA policies, or any specific use cases for issuance of certificates. For example, an ACME server could be used:

- o to issue Web PKI certificates where the ACME server must comply with CA/Browser Forum [CAB] Baseline Requirements.
- o as a Private CA for issuance of certificates within an organisation. The organisation could enforce whatever policies they desire on the ACME server.
- o for issuance of IoT device certificates. There are currently no IoT device certificate policies that are generally enforced across the industry. Organizations issuing IoT device certificates can enforce whatever policies they desire on the ACME server.

ACME server policy could specify whether:

- o issuance of subdomain certificates is allowed based on proof of ownership of a parent domain
- o issuance of subdomain certificates is allowed, but only for a specific set of parent domains
- o whether DNS based proof of ownership, or HTTP based proof of ownership, or both, are allowed

ACME server policy specification is explicitly out of scope of this document. For reference, extracts from CA/Browser Forum Baseline Requirements are given in the appendices.

8. Informative References

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Appendix A. CA Browser Forum Baseline Requirements Extracts

The CA/Browser Forum Baseline Requirements [CAB] allow issuance of subdomain certificates where authorization is only required for a parent domain. Baseline Requirements version 1.7.1 states:

- o Section: "1.6.1 Definitions": Authorization Domain Name: The Domain Name used to obtain authorization for certificate issuance for a given FQDN. The CA may use the FQDN returned from a DNS CNAME lookup as the FQDN for the purposes of domain validation. If the FQDN contains a wildcard character, then the CA MUST remove all wildcard labels from the left most portion of requested FQDN. The CA may prune zero or more labels from left to right until encountering a Base Domain Name and may use any one of the intermediate values for the purpose of domain validation.
- o Section: "3.2.2.4.6 Agreed-Upon Change to Website": Once the FQDN has been validated using this method, the CA MAY also issue Certificates for other FQDNs that end with all the labels of the

validated FQDN. This method is suitable for validating Wildcard Domain Names.

- o Section: "3.2.2.4.7 DNS Change": Once the FQDN has been validated using this method, the CA MAY also issue Certificates for other FQDNs that end with all the labels of the validated FQDN. This method is suitable for validating Wildcard Domain Names.

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ACME Integrations
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Abstract

This document outlines multiple advanced use cases and integrations that ACME facilitates without any modifications or enhancements required to the base ACME specification. The use cases include ACME integration with EST, BRSKI and TEAP.

Status of This Memo

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Table of Contents

1. Introduction	2
2. Terminology	3
3. ACME Integration with EST	4
4. ACME Integration with BRSKI	7
5. ACME Integration with BRSKI Default Cloud Registrar	9
6. ACME Integration with TEAP	11
7. ACME Integration Considerations	15
7.1. Service Operators	15
7.2. CSR Attributes	15
7.3. Certificate Chains and Trust Anchors	15
7.3.1. EST /cacerts	16
7.3.2. TEAP PKCS#7 TLV	16
7.4. id-kp-cmcRA	16
7.5. Error Handling	17
8. IANA Considerations	17
9. Security Considerations	17
9.1. Denial of Service against ACME infrastructure	18
10. Informative References	19
Authors' Addresses	21

1. Introduction

ACME [RFC8555] defines a protocol that a certification authority (CA) and an applicant can use to automate the process of domain name ownership validation and X.509 (PKIX) certificate issuance. The protocol is rich and flexible and enables multiple use cases that are not immediately obvious from reading the specification. This document explicitly outlines multiple advanced ACME use cases including:

- o ACME integration with EST [RFC7030]
- o ACME integration with BRSKI [RFC8995]
- o ACME integration with BRSKI Default Cloud Registrar [I-D.ietf-anima-brski-cloud]
- o ACME integration with TEAP [RFC7170] and TEAP Update and Extensions for Bootstrapping [I-D.lear-eap-teap-brski]

The integrations with EST, BRSKI (which is based upon EST), and TEAP enable automated certificate enrollment for devices.

ACME for subdomains [I-D.ietf-acme-subdomains] outlines how ACME can be used by a client to obtain a certificate for a subdomain identifier from an ACME server where the client has fulfilled a challenge against a parent domain, but does not need to fulfil a challenge against the explicit subdomain. This is a useful optimization when ACME is used to issue certificates for large numbers of devices as it reduces the domain ownership proof traffic (DNS or HTTP) and ACME traffic overhead, but is not a necessary requirement.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

The following terms are defined in DNS Terminology [RFC8499] and are reproduced here:

- o Label: An ordered list of zero or more octets that makes up a portion of a domain name. Using graph theory, a label identifies one node in a portion of the graph of all possible domain names.
- o Domain Name: An ordered list of one or more labels.
- o Subdomain: "A domain is a subdomain of another domain if it is contained within that domain. This relationship can be tested by seeing if the subdomain's name ends with the containing domain's name." (Quoted from [RFC1034], Section 3.1) For example, in the host name "nnn.mmm.example.com", both "mmm.example.com" and "nnn.mmm.example.com" are subdomains of "example.com". Note that the comparisons here are done on whole labels; that is, "ooo.example.com" is not a subdomain of "oo.example.com".
- o Fully-Qualified Domain Name (FQDN): This is often just a clear way of saying the same thing as "domain name of a node", as outlined above. However, the term is ambiguous. Strictly speaking, a fully-qualified domain name would include every label, including the zero-length label of the root: such a name would be written "www.example.net." (note the terminating dot). But, because every name eventually shares the common root, names are often written relative to the root (such as "www.example.net") and are still called "fully qualified". This term first appeared in [RFC0819]. In this document, names are often written relative to the root.

The following terms are used in this document:

- o BRSKI: Bootstrapping Remote Secure Key Infrastructures [RFC8995]
- o Certification Authority (CA): An organization that is responsible for the creation, issuance, revocation, and management of Certificates. The term applies equally to both Roots CAs and Subordinate CAs
- o CMS: Cryptographic Message Syntax [RFC5652]
- o CMC: Certificate Management over CMS [RFC5272]
- o CSR: Certificate Signing Request
- o EST: Enrollment over Secure Transport [RFC7030]
- o MASA: Manufacturer Authorized Signing Authority as defined in [RFC8995]
- o RA: PKI Registration Authority
- o TEAP: Tunneled Extensible Authentication Protocol [RFC7170]
- o TLV: Type-Length-Value format defined in TEAP

3. ACME Integration with EST

EST [RFC7030] defines a mechanism for clients to enroll with a PKI Registration Authority by sending CMC messages over HTTP. EST section 1 states:

"Architecturally, the EST service is located between a Certification Authority (CA) and a client. It performs several functions traditionally allocated to the Registration Authority (RA) role in a PKI."

EST section 1.1 states that:

"For certificate issuing services, the EST CA is reached through the EST server; the CA could be logically "behind" the EST server or embedded within it."

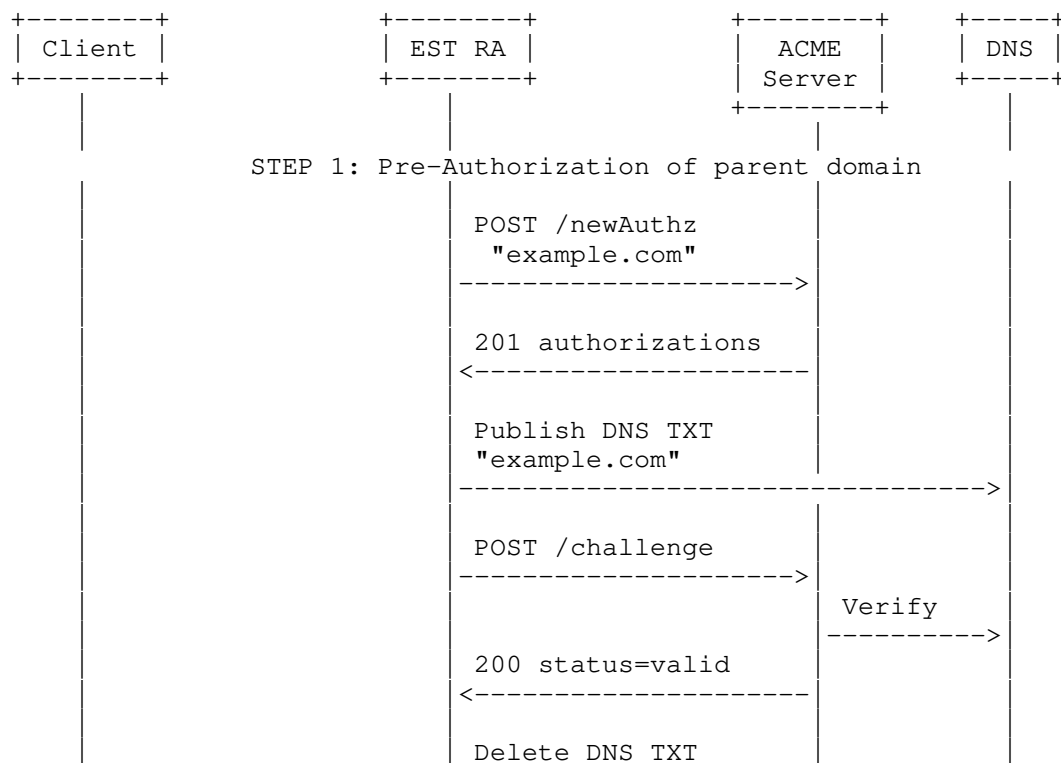
When the CA is logically "behind" the EST RA, EST does not specify how the RA communicates with the CA. EST section 1 states:

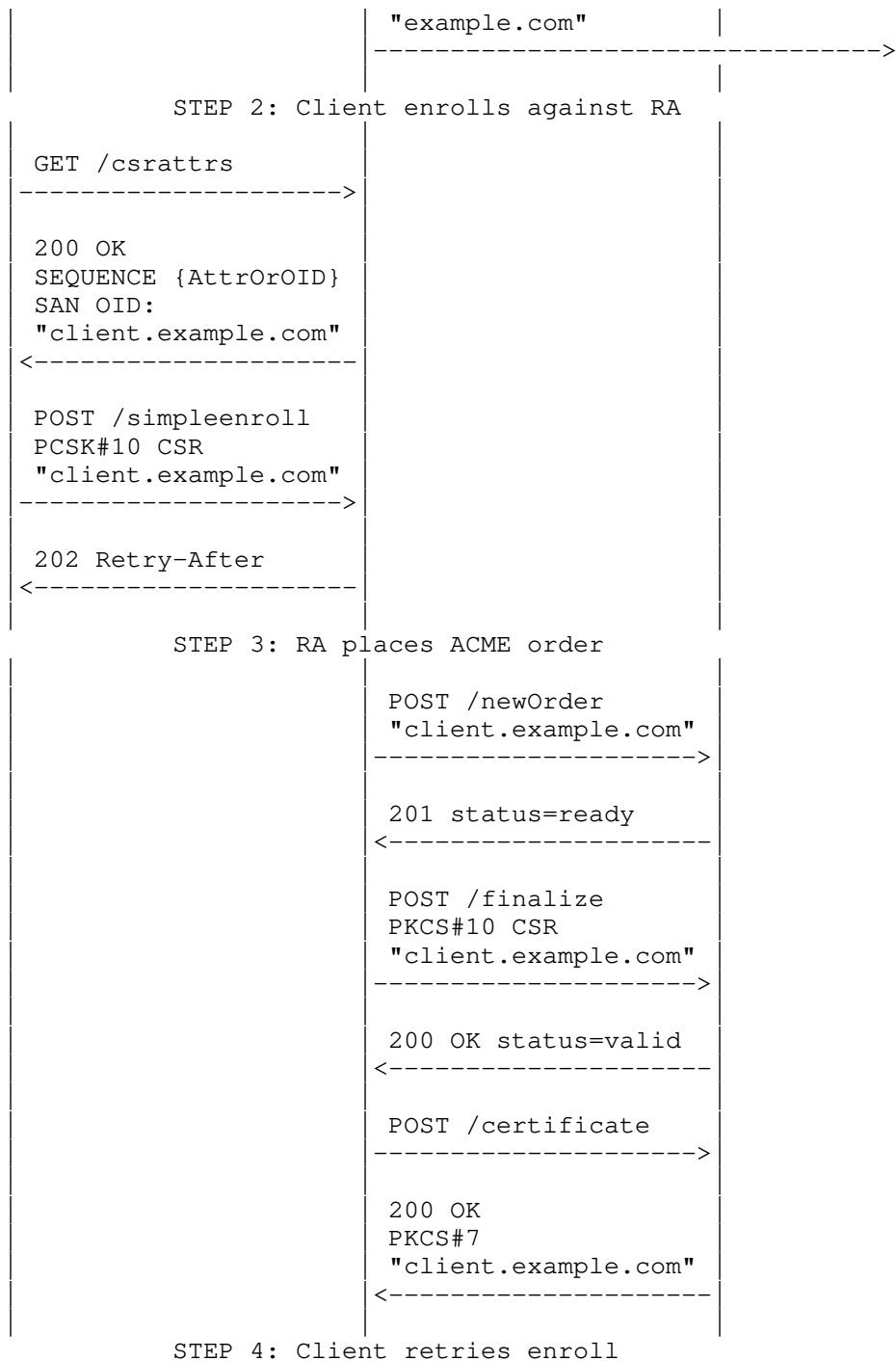
"The nature of communication between an EST server and a CA is not described in this document."

This section outlines how ACME could be used for communication between the EST RA and the CA. The example call flow leverages [I-D.ietf-acme-subdomains] and shows the RA proving ownership of a parent domain, with individual client certificates being subdomains under that parent domain. This is an optimization that reduces DNS and ACME traffic overhead. The RA could of course prove ownership of every explicit client certificate identifier. The example also illustrates using the ACME DNS challenge type, but this integration is not limited to DNS challenges.

The call flow illustrates the client calling the EST /csrattrs API before calling the EST /simpleenroll API. This enables the server to indicate what fields the client should include in the CSR that the client sends in the /simpleenroll API. CSR Attributes handling are discussed in Section 7.2.

The call flow illustrates the EST RA returning a 202 Retry-After response to the client's simpleenroll request. This is an optional step and may be necessary if the interactions between the RA and the ACME server take some time to complete. The exact details of when the RA returns a 202 Retry-After are implementation specific.





<pre> POST /simpleenroll PCSK#10 CSR "client.example.com" -----> 200 OK PKCS#7 "client.example.com" <----- </pre>			
---	--	--	--

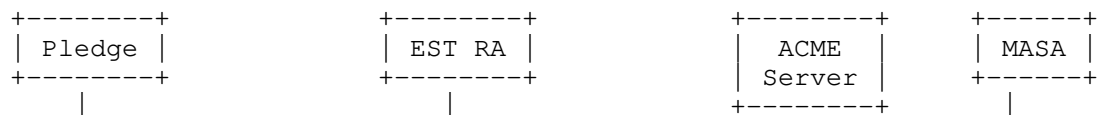
4. ACME Integration with BRSKI

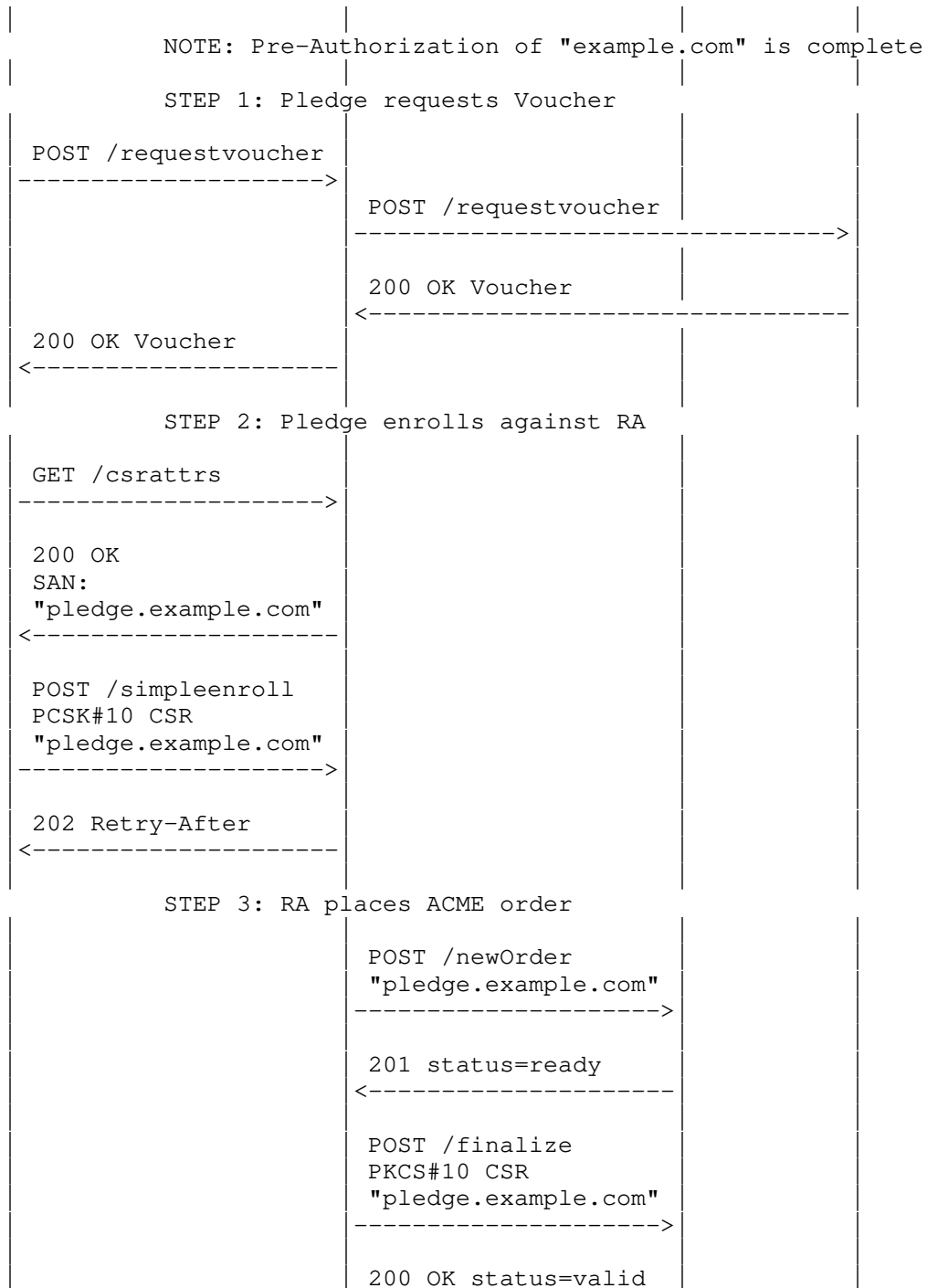
BRSKI [RFC8995] is based upon EST [RFC7030] and defines how to autonomically bootstrap PKI trust anchors into devices via means of signed vouchers. EST certificate enrollment may then optionally take place after trust has been established. BRSKI voucher exchange and trust establishment are based on EST extensions and the certificate enrollment part of BRSKI is fully based on EST. Similar to EST, BRSKI does not define how the EST RA communicates with the CA. Therefore, the mechanisms outlined in the previous section for using ACME as the communications protocol between the EST RA and the CA are equally applicable to BRSKI.

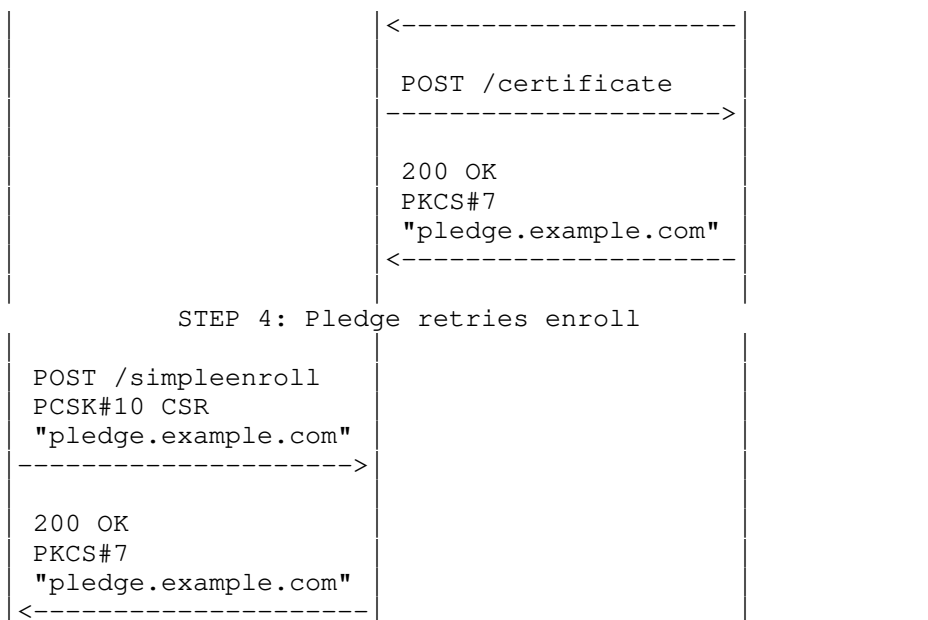
The following call flow shows how ACME may be integrated into a full BRSKI voucher plus EST enrollment workflow. For brevity, it assumes that the EST RA has previously proven ownership of a parent domain and that pledge certificate identifiers are a subdomain of that parent domain. The domain ownership exchanges between the RA, ACME and DNS are not shown. Similarly, not all BRSKI interactions are shown and only the key protocol flows involving voucher exchange and EST enrollment are shown.

Similar to the EST section above, the client calls EST /csrattrs API before calling the EST /simpleenroll API. This enables the server to indicate what fields the pledge should include in the CSR that the client sends in the /simpleenroll API. Refer to section {csr-attributes} for more details.

The call flow illustrates the RA returning a 202 Retry-After response to the initial EST /simpleenroll API. This may be appropriate if processing of the /simpleenroll request and ACME interactions takes some time to complete.





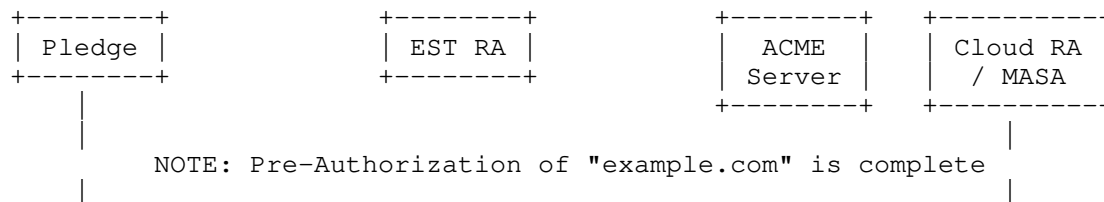


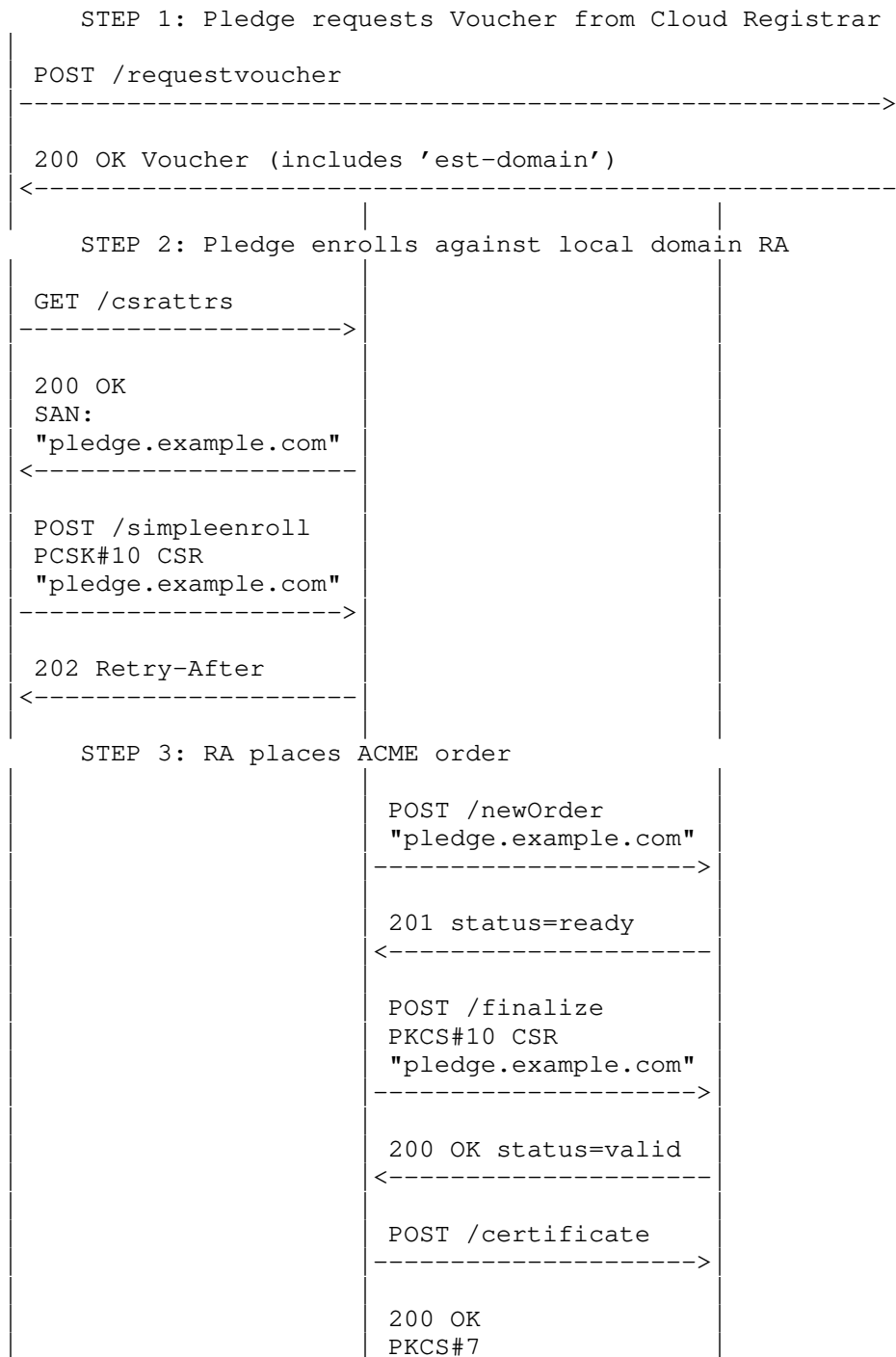
5. ACME Integration with BRSKI Default Cloud Registrar

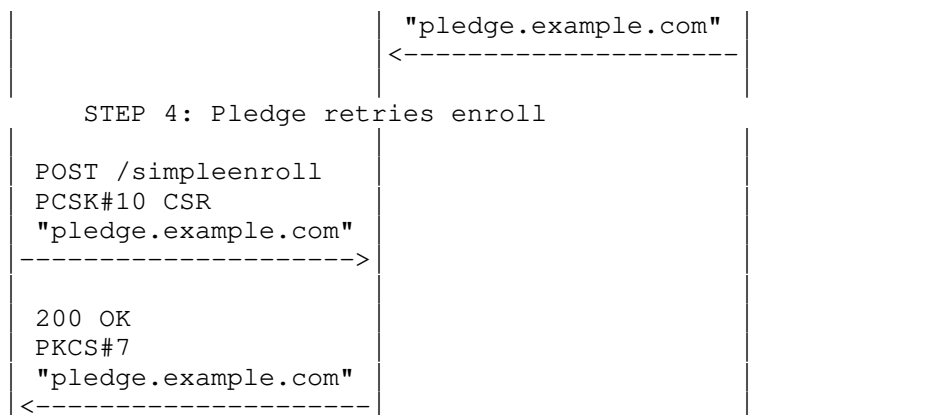
BRSKI Cloud Registrar [I-D.ietf-anima-brski-cloud] specifies the behaviour of a BRSKI Cloud Registrar, and how a pledge can interact with a BRSKI Cloud Registrar when bootstrapping. Similar to the local domain registrar BRSKI flow, ACME can be easily integrated with a cloud registrar bootstrap flow.

BRSKI cloud registrar is flexible and allows for multiple different local domain discovery and redirect scenarios. In the example illustrated here, the extension to [RFC8366] Vouchers which is defined in [I-D.ietf-anima-brski-cloud], and allows the specification of a bootstrap EST domain, is leveraged. This extension allows the cloud registrar to specify the local domain RA that the pledge should connect to for the purposes of EST enrollment.

Similar to the sections above, the client calls EST /csrattrs API before calling the EST /simpleenroll API.







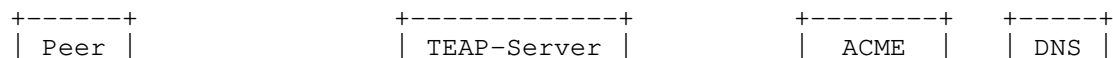
6. ACME Integration with TEAP

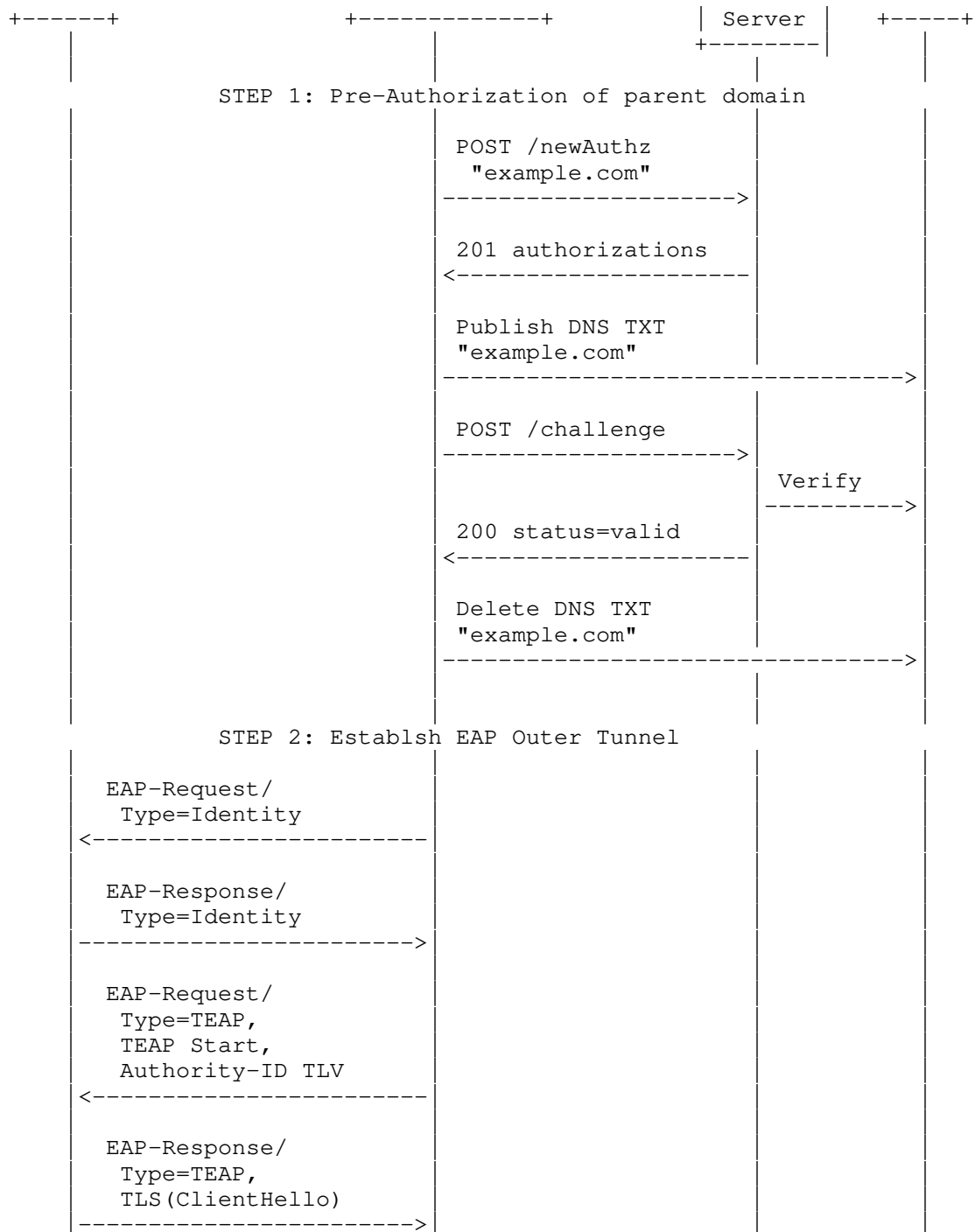
TEAP [RFC7170] defines a tunnel-based EAP method that enables secure communication between a peer and a server by using TLS to establish a mutually authenticated tunnel. TEAP enables certificate provisioning within the tunnel. TEAP Update and Extensions for Bootstrapping [I-D.lear-eap-teap-brski] defines extensions to TEAP that includes additional Type-Length-Value (TLV) elements for certificate enrollment and BRSKI handling inside the TEAP tunnel. Neither TEAP [RFC7170] or TEAP Update and Extensions for Bootstrapping [I-D.lear-eap-teap-brski] define how the TEAP server communicates with the CA.

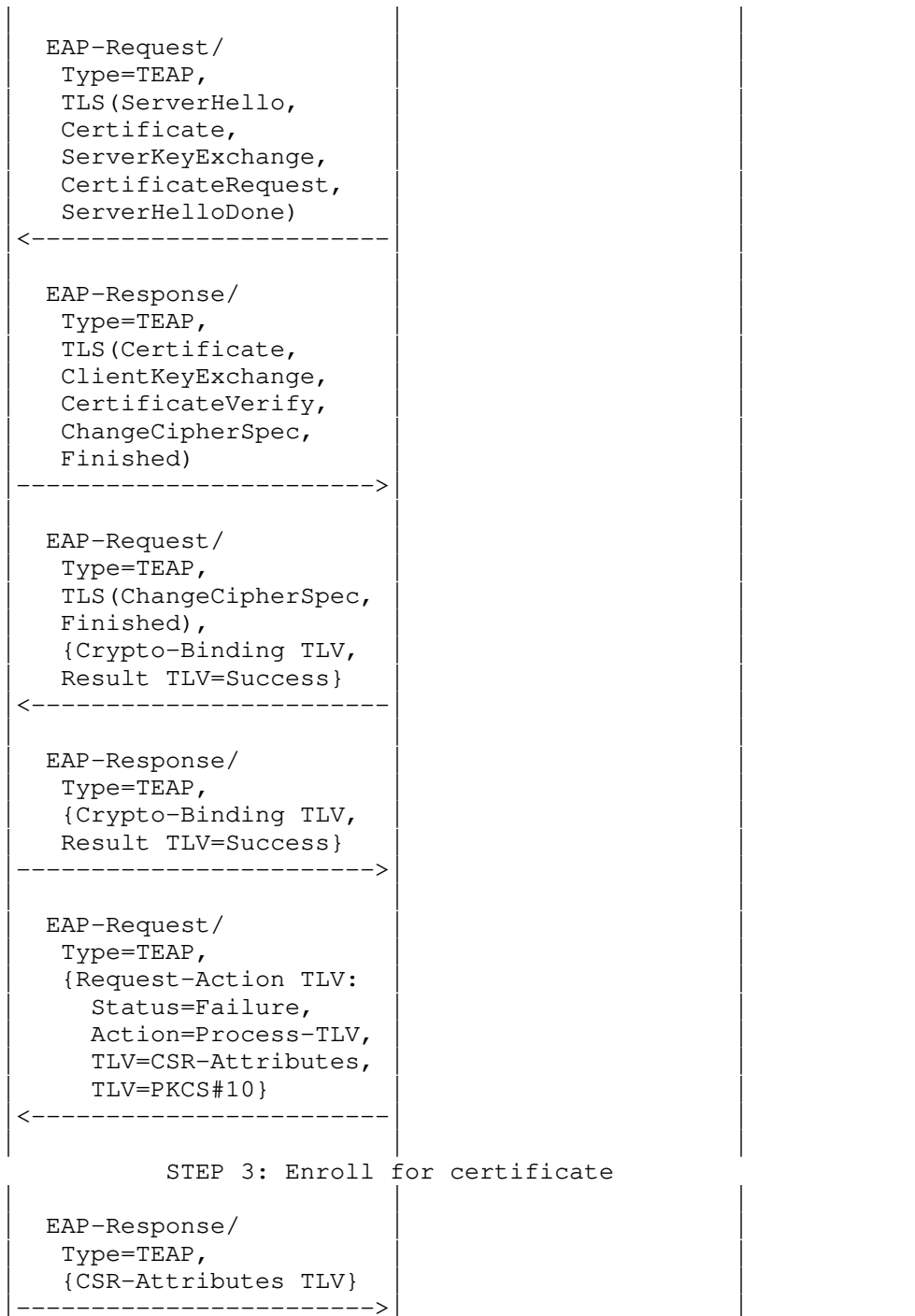
This section outlines how ACME could be used for communication between the TEAP server and the CA. The example call flow leverages [I-D.ietf-acme-subdomains] and shows the TEAP server proving ownership of a parent domain, with individual client certificates being subdomains under that parent domain.

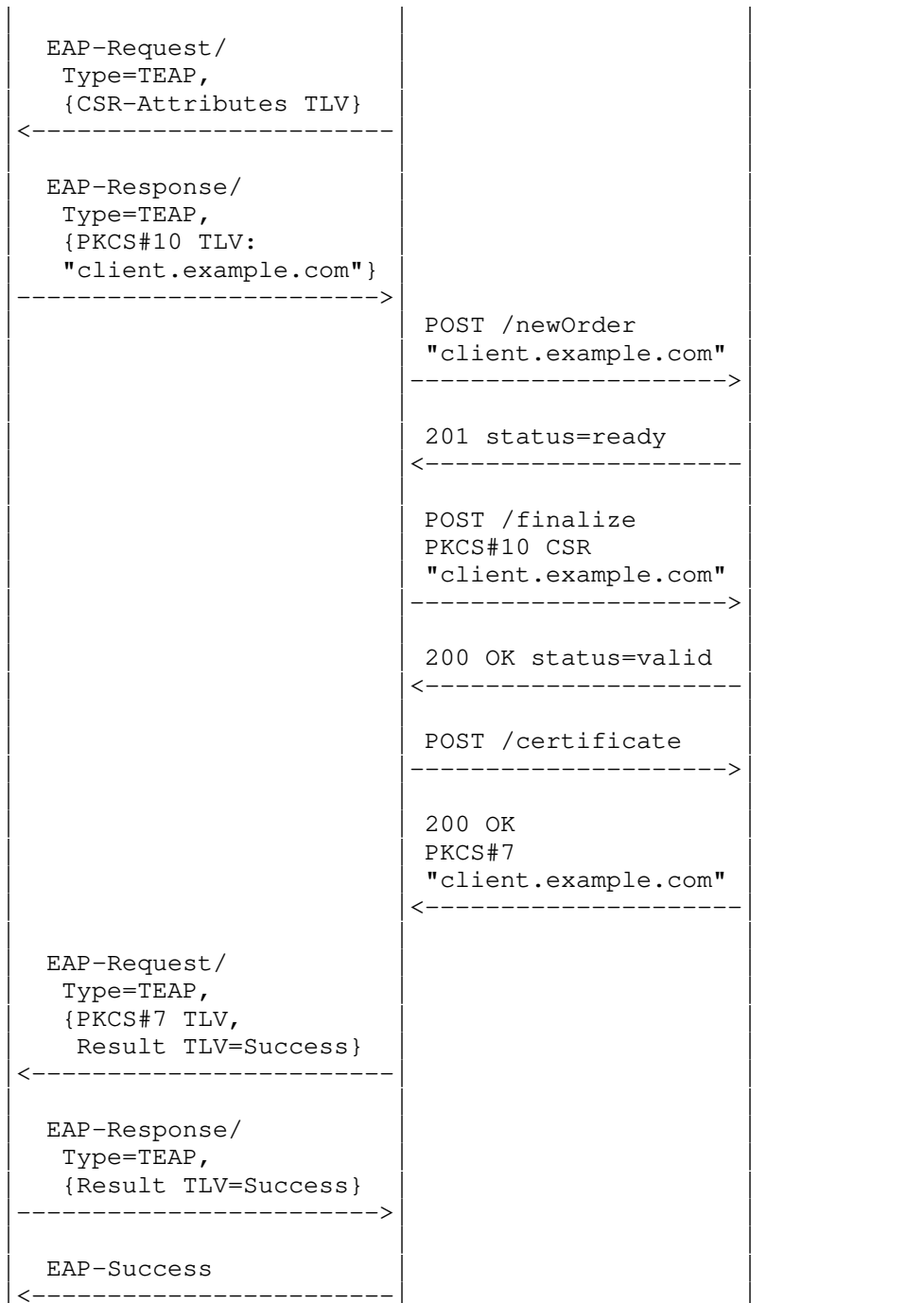
The example illustrates the TEAP server sending a Request-Action TLV including a CSR-Attributes TLV instructing the peer to send a CSR-Attributes TLV to the server. This enables the server to indicate what fields the peer should include in the CSR that the peer sends in the PKCS#10 TLV.

Although not explicitly illustrated in this call flow, the Peer and TEAP Server could exchange BRSKI TLVs, and a BRSKI integration and voucher exchange with a MASA server could take place over TEAP. Whether a BRSKI TLV exchange takes place or not does not impact the ACME specific message exchanges.









7. ACME Integration Considerations

7.1. Service Operators

The goal of these integrations is enabling issuance of certificates with identifiers in a given domain by an ACME server to a client. It is expected that the EST RA or TEAP servers that the client sends certificate enrollment requests to are operated by the organization that controls the domains. The ACME server is not necessarily operated by the organization that controls the domain.

7.2. CSR Attributes

In all integrations, the client **MUST** send a CSR Attributes request to the EST or TEAP server prior to sending a certificate enrollment request. This enables the server to indicate to the client what attributes, and what attribute values, it expects the client to include in the subsequent CSR request. For example, the server could instruct the peer what Subject Alternative Name entries to include in its CSR.

EST [RFC7030] is not clear on how the CSR Attributes response should be structured, and in particular is not clear on how a server can instruct a client to include specific attribute values in its CSR. [I-D.richardson-lamps-rfc7030-csrattrs] clarifies how a server can use CSR Attributes response to specify specific values for attributes that the client should include in its CSR.

Servers **MUST** use this mechanism to tell the client what identifiers to include in CSR request. ACME [RFC8555] allows the identifier to be included in either CSR Subject or Subject Alternative Name fields, however [I-D.ietf-uta-use-san] states that Subject Alternative Name field **MUST** be used. This document aligns with [I-D.ietf-uta-use-san] and Subject Alternate Name field **MUST** be used. The identifier must be a subdomain of a domain that the server has control over and can fulfill ACME challenges against. The leftmost part of the identifier **MAY** be a field that the client presented to the server in an IEEE 802.1AR [IDevID].

Servers **MAY** use this field to instruct the client to include other attributes such as specific policy OIDs. Refer to EST [RFC7030] section 2.6 for further details.

7.3. Certificate Chains and Trust Anchors

ACME [RFC8555] section 9.1 states that ACME servers may return a certificate chain to an ACME client where an end entity certificate is followed by certificates that certify it. The trust anchor

certificate MAY be omitted from the chain as it is assumed that the trust anchor is already known by the ACME client i.e. the EST or TEAP server.

7.3.1. EST /cacerts

EST [RFC7030] section 4.2.3 states that the /simpleenroll response contains "only the certificate that was issued". EST [RFC7030] section 4.1.3 states that the /cacerts response "MUST include any additional certificates the client would need to build a chain from an EST CA-issued certificate to the current EST CA TA".

Therefore, the EST server MUST return only the ACME end entity certificate in the /simpleenroll response. The EST server MUST return the remainder of the chain returned by the ACME server to the EST server in the /cacerts response to the client, appending the trust anchor root CA if necessary.

7.3.2. TEAP PKCS#7 TLV

TEAP [RFC7170] section 4.2.16 allows for download of a PKCS#7 certificate chain in response to a TEAP PKCS#10 TLV request. TEAP also allows for download of multiple PKCS#7 certificates in response to a TEAP Trusted-Server-Root TLV request.

The TEAP server MUST return the full ACME client certificate chain in the PKCS#7 response to the PKCS#10 TLV request. The TEAP server MUST return the ACME server trust anchor in a PKCS#7 response to a Trusted-Server-Root TLV request. As outlined in Section 7.4, the TEAP server SHOULD also return the trust anchor that was used for issuing its own identity certificate, if different from the ACME server trust anchor.

7.4. id-kp-cmcRA

BRSKI [RFC8995] mandates that the id-kp-cmcRA extended key usage bit is set in the Registrar (or EST RA) end entity certificate that the Registrar uses when signing voucher request messages sent to the MASA. Public ACME servers may not be willing to issue end entity certificates that have the id-kp-cmcRA extended key usage bit set. In these scenarios, the EST RA may be used by the pledge to get issued certificates by a public ACME server, but the EST RA itself will need an end entity certificate that has been issued by a different CA (e.g. an operator deployed private CA) and that has the id-kp-cmcRA bit set.

7.5. Error Handling

ACME [RFC8555] section 6.7 defines multiple errors that may be returned by an ACME server to an ACME client. TEAP [RFC7170] section 4.2.6 defines multiple errors that may be returned by a TEAP server to a client in an Error TLV. EST [RFC7030] section 4.2.3 defines how an EST server may return an error encoded in a CMC response, or may return a human readable error in the response body.

The following mapping from ACME errors to CMC [RFC5272] section 6.1.4 CMCFailInfo and TEAP [RFC7170] section 4.2.6 error codes is RECOMMENDED.

ACME	CMCFailInfo	TEAP Error Code
badCSR	badRequest	1025 Bad CSR
caa	badRequest	1025 Bad CSR
rejectedIdentifier	badIdentity	1024 Bad Identity In CSR
all other errors	internalCAError	1026 Internal CA Error

8. IANA Considerations

This document does not make any requests to IANA.

9. Security Considerations

This draft is informational and makes no changes to the referenced specifications. All security considerations from these referenced documents are applicable here:

- o EST [RFC7030]
- o BRSKI [RFC8995]
- o BRSKI Default Cloud Registrar [I-D.ietf-anima-brski-cloud]
- o TEAP [RFC7170] and TEAP Update and Extensions for Bootstrapping [I-D.lear-eap-teap-brski]

Additionally, all Security Considerations in ACME in the following areas are equally applicable to ACME Integrations.

It is expected that the integration mechanisms proposed here will primarily use the DNS-01 challenge documented in [RFC8555] section 8.4. The security considerations in RFC8555 says:

The DNS is a common point of vulnerability for all of these challenges. An entity that can provision false DNS records for a domain can attack the DNS challenge directly and can provision false A/AAAA records to direct the ACME server to send its HTTP validation query to a remote server of the attacker's choosing.

It is expected that the TEAP-EAP server/EST Registrar will perform DNS dynamic updates to a DNS primary server using [RFC3007] Dynamic updates, secured with either SIG(0), or TSIG keys.

A major source of vulnerability is the disclosure of these DNS key records. An attacker that has access to them, can provision their own certificates into the the name space of the entity.

For many uses, this may allow the attacker to get access to some enterprise resource. When used to provision, for instance, a (SIP) phone system this would permit an attacker to impersonate a legitimate phone. Not only does this allow for redirection of phone calls, but possibly also toll fraud.

Operators should consider restricting the integration server such that it can only update the DNS records for a specific zone or zones where ACME is required for client certificate enrollment automation. For example, if all IoT devices in an organisation enroll using EST against an EST RA, and all IoT devices will be issued certificates in a subdomain under `iot.example.com`, then the integration server could be issued a credential that only allows updating of DNS records in a zone that includes domains in the `iot.example.com` namespace, but does not allow updating of DNS records under any other `example.com` DNS namespace.

When performing challenge fulfilment via writing files to HTTP web servers, write access should only be granted to a specific set of servers, and only to a specific set of directories for storage of challenge files.

9.1. Denial of Service against ACME infrastructure

The intermediate node (the TEAP-EAP server, or the EST Registrar) should cache the resulting certificates such that if the communication with the pledge is lost, subsequent attempts to enroll will result in the cache certificate being returned.

As many ACME servers have per-day, per-IP and per-subjectAltName limits, it is prudent not to request identical certificates too often. This could be due to operator or installer error, with multiple configuration resets occurring within a short period of time.

The cache should be indexed by the complete contents of the Certificate Signing Request, and should not persist beyond the notAfter date in the certificate.

This means that if the private/public keypair changes on the pledge, then a new certificate will be issued. If the requested SubjectAltName changes, then a new certificate will be requested.

In a case where a device is simply factory reset, and enrolls again, then the same certificate can be returned.

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