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RFC 9646
Conveying a Certificate Signing Request (CSR) in a Secure Zero-Touch Provisioning (SZTP) Bootstrapping Request

Abstract

This document extends the input to the "get-bootstrapping-data" RPC defined in RFC 8572 to include an optional certificate signing request (CSR), enabling a bootstrapping device to additionally obtain an identity certificate (e.g., a Local Device Identifier (LDevID) from IEEE 802.1AR) as part of the "onboarding information" response provided in the RPC-reply.

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1. Introduction

1.1. Overview

This document extends the input to the "get-bootstrapping-data" RPC defined in [RFC8572] to include an optional certificate signing request (CSR) [RFC2986], enabling a bootstrapping device to additionally obtain an identity certificate (e.g., an LDevID from [Std-802.1AR-2018]) as part of the "onboarding information" response provided in the RPC-reply.

The ability to provision an identity certificate that is purpose-built for a production environment during the bootstrapping process removes reliance on the manufacturer Certification Authority (CA), and it also enables the bootstrapped device to join the production environment with an appropriate identity and other attributes in its identity certificate (e.g., an LDevID).

Two YANG [RFC7950] modules are defined. The "ietf-ztp-types" module defines three YANG groupings for the various messages defined in this document. The "ietf-sztp-csr" module augments two groupings into the "get-bootstrapping-data" RPC and defines a YANG data structure [RFC8791] around the third grouping.

1.2. Terminology

This document uses the following terms from [RFC8572]:

- Bootstrap Server
- Bootstrapping Data
- Conveyed Information
- Device
- Manufacturer
- Onboarding Information

- Signed Data

This document defines the following new terms:

SZTP-client: The term "SZTP-client" refers to a "device" that is using a "bootstrap server" as a source of "bootstrapping data".

SZTP-server: The term "SZTP-server" is an alternative term for "bootstrap server" that is symmetric with the "SZTP-client" term.

1.3. Requirements Language

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.

1.4. Conventions

Various examples in this document use "BASE64VALUE=" as a placeholder value for binary data that has been base64 encoded (per Section 9.8 of [RFC7950]). This placeholder value is used because real base64-encoded structures are often many lines long and hence distracting to the example being presented.

Various examples in this document contain long lines that may be folded, as described in [RFC8792].

2. The "ietf-sztp-csr" Module

The "ietf-sztp-csr" module is a YANG 1.1 [RFC7950] module that augments the "ietf-sztp-bootstrap-server" module defined in [RFC8572] and defines a YANG "structure" that is to be conveyed in the "error-info" node defined in Section 7.1 of [RFC8040].

2.1. Data Model Overview

The following tree diagram [RFC8340] illustrates the "ietf-sztp-csr" module.

```
module: ietf-sztp-csr

  augment /sztp-svr:get-bootstrapping-data/sztp-svr:input:
    +---w (msg-type)?
       +--:(csr-support)
       |  +---w csr-support
       |     +---w key-generation!
       |     |  +---w supported-algorithms
       |     |     +---w algorithm-identifier*   binary
       |     +---w csr-generation
       |        +---w supported-formats
       |           +---w format-identifier*   identityref
       +--:(csr)
          +---w (csr-type)
             +--:(p10-csr)
             |  +---w p10-csr?   ct:csr
             +--:(cmc-csr)
             |  +---w cmc-csr?   binary
             +--:(cmp-csr)
                +---w cmp-csr?   binary

  structure csr-request:
    +-- key-generation!
    |  +-- selected-algorithm
    |     +-- algorithm-identifier    binary
    +-- csr-generation
    |  +-- selected-format
    |     +-- format-identifier    identityref
    +-- cert-req-info?    ct:csr-info
```

The augmentation defines two kinds of parameters that an SZTP-client can send to an SZTP-server. The YANG structure defines one collection of parameters that an SZTP-server can send to an SZTP-client.

In the order of their intended use:

1. The SZTP-client sends a "csr-support" node, encoded in a first "get-bootstrapping-data" request to the SZTP-server, to indicate that it supports the ability to generate CSRs. This input parameter conveys if the SZTP-client is able to generate a new asymmetric key and, if so, which key algorithms it supports, as well as what kinds of CSR structures the SZTP-client is able to generate.
2. The SZTP-server responds with an error, containing the "csr-request" structure, to request the SZTP-client to generate a CSR. This structure is used to select the key algorithm the SZTP-client should use to generate a new asymmetric key (if supported), the kind of CSR structure the SZTP-client should generate, and optionally the content for the CSR itself.
3. The SZTP-client sends one of the "*-csr" nodes, encoded in a second "get-bootstrapping-data" request to the SZTP-server. This node encodes the server-requested CSR.
4. The SZTP-server responds with onboarding information to communicate the signed certificate to the SZTP-client. How to do this is discussed in Section 2.2.

To further illustrate how the augmentation and structure defined by the "ietf-sztp-csr" module are used, below are two additional tree diagrams showing these nodes placed where they are used.

The following tree diagram [RFC8340] illustrates SZTP's "get-bootstrapping-data" RPC with the augmentation in place.

```
=============== NOTE: '\' line wrapping per RFC 8792 ================

module: ietf-sztp-bootstrap-server

  rpcs:
    +---x get-bootstrapping-data
       +---w input
       |  +---w signed-data-preferred?          empty
       |  +---w hw-model?                       string
       |  +---w os-name?                        string
       |  +---w os-version?                     string
       |  +---w nonce?                          binary
       |  +---w (sztp-csr:msg-type)?
       |     +--:(sztp-csr:csr-support)
       |     |  +---w sztp-csr:csr-support
       |     |     +---w sztp-csr:key-generation!
       |     |     |  +---w sztp-csr:supported-algorithms
       |     |     |     +---w sztp-csr:algorithm-identifier*   bina\
ry
       |     |     +---w sztp-csr:csr-generation
       |     |        +---w sztp-csr:supported-formats
       |     |           +---w sztp-csr:format-identifier*   identit\
yref
       |     +--:(sztp-csr:csr)
       |        +---w (sztp-csr:csr-type)
       |           +--:(sztp-csr:p10-csr)
       |           |  +---w sztp-csr:p10-csr?   ct:csr
       |           +--:(sztp-csr:cmc-csr)
       |           |  +---w sztp-csr:cmc-csr?   binary
       |           +--:(sztp-csr:cmp-csr)
       |              +---w sztp-csr:cmp-csr?   binary
       +--ro output
          +--ro reporting-level?    enumeration {onboarding-server}?
          +--ro conveyed-information    cms
          +--ro owner-certificate?      cms
          +--ro ownership-voucher?      cms
```

The following tree diagram [RFC8340] illustrates RESTCONF's "errors" RPC-reply message with the "csr-request" structure in place.

```
module: ietf-restconf
  +--ro errors
     +--ro error* []
        +--ro error-type       enumeration
        +--ro error-tag        string
        +--ro error-app-tag?   string
        +--ro error-path?      instance-identifier
        +--ro error-message?   string
        +--ro error-info
           +--ro sztp-csr:csr-request
              +--ro sztp-csr:key-generation!
              |  +--ro sztp-csr:selected-algorithm
              |     +--ro sztp-csr:algorithm-identifier    binary
              +--ro sztp-csr:csr-generation
              |  +--ro sztp-csr:selected-format
              |     +--ro sztp-csr:format-identifier    identityref
              +--ro sztp-csr:cert-req-info?    ct:csr-info
```

2.2. Example Usage

> NOTE: The examples below are encoded using JSON, but they could equally well be encoded using XML, as is supported by SZTP.

An SZTP-client implementing this specification would signal to the bootstrap server its willingness to generate a CSR by including the "csr-support" node in its "get-bootstrapping-data" RPC. In the example below, the SZTP-client additionally indicates that it is able to generate keys and provides a list of key algorithms it supports, as well as provide a list of certificate formats it supports.

REQUEST

```
=============== NOTE: '\' line wrapping per RFC 8792 ================

POST /restconf/operations/ietf-sztp-bootstrap-server:get-bootstrappi\
ng-data HTTP/1.1
HOST: example.com
Content-Type: application/yang-data+json

{
  "ietf-sztp-bootstrap-server:input" : {
    "hw-model": "model-x",
    "os-name": "vendor-os",
    "os-version": "17.3R2.1",
    "nonce": "extralongbase64encodedvalue=",
    "ietf-sztp-csr:csr-support": {
      "key-generation": {
        "supported-algorithms": {
          "algorithm-identifier": [
            "BASE64VALUE1",
            "BASE64VALUE2",
            "BASE64VALUE3"
          ]
        }
      },
      "csr-generation": {
        "supported-formats": {
          "format-identifier": [
            "ietf-ztp-types:p10-csr",
            "ietf-ztp-types:cmc-csr",
            "ietf-ztp-types:cmp-csr"
          ]
        }
      }
    }
  }
}
```

Assuming the SZTP-server wishes to prompt the SZTP-client to provide a CSR, then it would respond with an HTTP 400 Bad Request error code. In the example below, the SZTP-server specifies that it wishes the SZTP-client to generate a key using a specific algorithm and generate a PKCS#10-based CSR containing specific content.

RESPONSE

```
HTTP/1.1 400 Bad Request
Date: Sat, 31 Oct 2021 17:02:40 GMT
Server: example-server
Content-Type: application/yang-data+json

{
  "ietf-restconf:errors" : {
    "error" : [
      {
        "error-type": "application",
        "error-tag": "missing-attribute",
        "error-message": "Missing input parameter",
        "error-info": {
          "ietf-sztp-csr:csr-request": {
            "key-generation": {
              "selected-algorithm": {
                "algorithm-identifier": "BASE64VALUE="
              }
            },
            "csr-generation": {
              "selected-format": {
                "format-identifier": "ietf-ztp-types:p10-csr"
              }
            },
            "cert-req-info": "BASE64VALUE="
          }
        }
      }
    ]
  }
}
```

Upon being prompted to provide a CSR, the SZTP-client would POST another "get-bootstrapping-data" request but this time including one of the "csr" nodes to convey its CSR to the SZTP-server:

REQUEST

```
=============== NOTE: '\' line wrapping per RFC 8792 ================

POST /restconf/operations/ietf-sztp-bootstrap-server:get-bootstrappi\
ng-data HTTP/1.1
HOST: example.com
Content-Type: application/yang-data+json

{
  "ietf-sztp-bootstrap-server:input" : {
    "hw-model": "model-x",
    "os-name": "vendor-os",
    "os-version": "17.3R2.1",
    "nonce": "extralongbase64encodedvalue=",
    "ietf-sztp-csr:p10-csr": "BASE64VALUE="
  }
}
```

At this point, it is expected that the SZTP-server, perhaps in conjunction with other systems, such as a backend CA or registration authority (RA), will validate the CSR's origin and proof-of-possession and, assuming the CSR is approved, issue a signed certificate for the bootstrapping device.

The SZTP-server responds with conveyed information (the "conveyed-information" node shown below) that encodes "onboarding-information" (inside the base64 value) containing a signed identity certificate for the CSR provided by the SZTP-client:

RESPONSE

```
HTTP/1.1 200 OK
Date: Sat, 31 Oct 2021 17:02:40 GMT
Server: example-server
Content-Type: application/yang-data+json

{
  "ietf-sztp-bootstrap-server:output" : {
    "reporting-level": "verbose",
    "conveyed-information": "BASE64VALUE="
  }
}
```

How the signed certificate is conveyed inside the onboarding information is outside the scope of this document. Some implementations may choose to convey it inside a script (e.g., SZTP's "pre-configuration-script"), while other implementations may choose to convey it inside the SZTP "configuration" node. SZTP onboarding information is described in Section 2.2 of [RFC8572].

Below are two examples of conveying the signed certificate inside the "configuration" node. Both examples assume that the SZTP-client understands the "ietf-keystore" module defined in [RFC9642].

This first example illustrates the case where the signed certificate is for the same asymmetric key used by the SZTP-client's manufacturer-generated identity certificate (e.g., an Initial Device Identifier (IDevID) from [Std-802.1AR-2018]). As such, the configuration needs to associate the newly signed certificate with the existing asymmetric key:


```
=============== NOTE: '\' line wrapping per RFC 8792 ================

{
  "ietf-keystore:keystore": {
    "asymmetric-keys": {
      "asymmetric-key": [
        {
          "name": "Manufacturer-Generated Hidden Key",
          "public-key-format": "ietf-crypto-types:subject-public-key\
-info-format",
          "public-key": "BASE64VALUE=",
          "hidden-private-key": [null],
          "certificates": {
            "certificate": [
              {
                "name": "Manufacturer-Generated IDevID Cert",
                "cert-data": "BASE64VALUE="
              },
              {
                "name": "Newly-Generated LDevID Cert",
                "cert-data": "BASE64VALUE="
              }
            ]
          }
        }
      ]
    }
  }
}
```


This second example illustrates the case where the signed certificate is for a newly generated asymmetric key. As such, the configuration needs to associate the newly signed certificate with the newly generated asymmetric key:

```
=============== NOTE: '\' line wrapping per RFC 8792 ================

{
  "ietf-keystore:keystore": {
    "asymmetric-keys": {
      "asymmetric-key": [
        {
          "name": "Manufacturer-Generated Hidden Key",
          "public-key-format": "ietf-crypto-types:subject-public-key\
-info-format",
          "public-key": "BASE64VALUE=",
          "hidden-private-key": [null],
          "certificates": {
            "certificate": [
              {
                "name": "Manufacturer-Generated IDevID Cert",
                "cert-data": "BASE64VALUE="
              }
            ]
          }
        },
        {
          "name": "Newly-Generated Hidden Key",
          "public-key-format": "ietf-crypto-types:subject-public-key\
-info-format",
          "public-key": "BASE64VALUE=",
          "hidden-private-key": [null],
          "certificates": {
            "certificate": [
              {
                "name": "Newly-Generated LDevID Cert",
                "cert-data": "BASE64VALUE="
              }
            ]
          }
        }
      ]
    }
  }
}
```


In addition to configuring the signed certificate, it is often necessary to also configure the issuer's signing certificate so that the device (i.e., STZP-client) can authenticate certificates presented by peer devices signed by the same issuer as its own. While outside the scope of this document, one way to do this would be to use the "ietf-truststore" module defined in [RFC9641].

2.3. YANG Module

This module augments an RPC defined in [RFC8572]. The module uses data types and groupings defined in [RFC8572], [RFC8791], and [RFC9640]. The module also has an informative reference to [Std-802.1AR-2018].

```
<CODE BEGINS> file "ietf-sztp-csr@2022-03-02.yang"

module ietf-sztp-csr {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-sztp-csr";
  prefix sztp-csr;

  import ietf-sztp-bootstrap-server {
    prefix sztp-svr;
    reference
      "RFC 8572: Secure Zero Touch Provisioning (SZTP)";
  }

  import ietf-yang-structure-ext {
    prefix sx;
    reference
      "RFC 8791: YANG Data Structure Extensions";
  }

  import ietf-ztp-types {
    prefix zt;
    reference
      "RFC 9646: Conveying a Certificate Signing Request (CSR)
                 in a Secure Zero-Touch Provisioning (SZTP)
                 Bootstrapping Request";
  }

  organization
    "IETF NETCONF (Network Configuration) Working Group";

  contact
    "WG Web:   https://datatracker.ietf.org/wg/netconf
     WG List:  NETCONF WG list <mailto:netconf@ietf.org>
     Authors:  Kent Watsen <mailto:kent+ietf@watsen.net>
               Russ Housley <mailto:housley@vigilsec.com>
               Sean Turner <mailto:sean@sn3rd.com>";

  description
    "This module augments the 'get-bootstrapping-data' RPC,
     defined in the 'ietf-sztp-bootstrap-server' module from
     SZTP (RFC 8572), enabling the SZTP-client to obtain a
     signed identity certificate (e.g., an LDevID from IEEE
     802.1AR) as part of the SZTP onboarding information
     response.

     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
     (RFC 2119) (RFC 8174) when, and only when, they appear
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     without modification, is permitted pursuant to, and subject to
```

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        Relating to IETF Documents
        (https://trustee.ietf.org/license-info).

        This version of this YANG module is part of RFC 9646
        (https://www.rfc-editor.org/info/rfc9646); see the
        RFC itself for full legal notices.";

     revision 2022-03-02 {
       description
         "Initial version.";
       reference
         "RFC 9646: Conveying a Certificate Signing Request (CSR)
                    in a Secure Zero-Touch Provisioning (SZTP)
                    Bootstrapping Request";
     }

     // Protocol-accessible nodes

     augment "/sztp-svr:get-bootstrapping-data/sztp-svr:input" {
       description
         "This augmentation adds the 'csr-support' and 'csr' nodes to
          the SZTP (RFC 8572) 'get-bootstrapping-data' request message,
          enabling the SZTP-client to obtain an identity certificate
          (e.g., an LDevID from IEEE 802.1AR) as part of the onboarding
          information response provided by the SZTP-server.

          The 'csr-support' node enables the SZTP-client to indicate
          that it supports generating certificate signing requests
          (CSRs) and to provide details around the CSRs it is able
          to generate.

          The 'csr' node enables the SZTP-client to relay a CSR to
          the SZTP-server.";
       reference
         "IEEE 802.1AR: IEEE Standard for Local and Metropolitan
                        Area Networks - Secure Device Identity
          RFC 8572: Secure Zero Touch Provisioning (SZTP)";
       choice msg-type {
         description
           "Messages are mutually exclusive.";
         case csr-support {
           description
             "Indicates how the SZTP-client supports generating CSRs.

              If present and a SZTP-server wishes to request the
              SZTP-client generate a CSR, the SZTP-server MUST
              respond with an HTTP 400 Bad Request error code with an
              'ietf-restconf:errors' message having the 'error-tag'
              value 'missing-attribute' and the 'error-info' node
              containing the 'csr-request' structure described
              in this module.";
           uses zt:csr-support-grouping;
         }
         case csr {
           description
             "Provides the CSR generated by the SZTP-client.
```

```
           When present, the SZTP-server SHOULD respond with
           an SZTP onboarding information message containing
           a signed certificate for the conveyed CSR.  The
           SZTP-server MAY alternatively respond with another
           HTTP error containing another 'csr-request'; in
           which case, the SZTP-client MUST delete any key
           generated for the previously generated CSR.";
        uses zt:csr-grouping;
      }
    }
  }

  sx:structure csr-request {
    description
      "A YANG data structure, per RFC 8791, that specifies
       details for the CSR that the ZTP-client is to generate.";
    reference
      "RFC 8791: YANG Data Structure Extensions";
    uses zt:csr-request-grouping;
  }

}

<CODE ENDS>
```

3. The "ietf-ztp-types" Module

This section defines a YANG 1.1 [RFC7950] module that defines three YANG groupings, one for each message sent between a ZTP-client and ZTP-server. This module is defined independently of the "ietf-sztp-csr" module so that its groupings may be used by bootstrapping protocols other than SZTP [RFC8572].

3.1. Data Model Overview

The following tree diagram [RFC8340] illustrates the three groupings defined in the "ietf-ztp-types" module.

```
module: ietf-ztp-types

  grouping csr-support-grouping
    +-- csr-support
       +-- key-generation!
       |  +-- supported-algorithms
       |     +-- algorithm-identifier*   binary
       +-- csr-generation
          +-- supported-formats
             +-- format-identifier*   identityref
  grouping csr-request-grouping
    +-- key-generation!
    |  +-- selected-algorithm
    |     +-- algorithm-identifier    binary
    +-- csr-generation
    |  +-- selected-format
    |     +-- format-identifier    identityref
    +-- cert-req-info?    ct:csr-info
  grouping csr-grouping
    +-- (csr-type)
       +--:(p10-csr)
       |  +-- p10-csr?   ct:csr
       +--:(cmc-csr)
       |  +-- cmc-csr?   binary
       +--:(cmp-csr)
          +-- cmp-csr?   binary
```

3.2. YANG Module

This module uses data types and groupings defined in [RFC8791] and [RFC9640]. The module has additional normative references to [RFC2986], [RFC4210], [RFC5272], and [ITU.X690.2021] and an informative reference to [Std-802.1AR-2018].

```
<CODE BEGINS> file "ietf-ztp-types@2022-03-02.yang"

module ietf-ztp-types {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-ztp-types";
  prefix zt;

  import ietf-crypto-types {
    prefix ct;
    reference
      "RFC 9640: YANG Data Types and Groupings for Cryptography";
  }

  organization
    "IETF NETCONF (Network Configuration) Working Group";

  contact
    "WG Web:   https://datatracker.ietf.org/wg/netconf
     WG List:  NETCONF WG list <mailto:netconf@ietf.org>
     Authors:  Kent Watsen <mailto:kent+ietf@watsen.net>
               Russ Housley <mailto:housley@vigilsec.com>
```

```
                 Sean Turner <mailto:sean@sn3rd.com>";

    description
      "This module defines three groupings that enable
       bootstrapping devices to 1) indicate if and how they
       support generating CSRs, 2) obtain a request to
       generate a CSR, and 3) communicate the requested CSR.

       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
       (RFC 2119) (RFC 8174) when, and only when, they appear
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       Relating to IETF Documents
       (https://trustee.ietf.org/license-info).

       This version of this YANG module is part of RFC 9646
       (https://www.rfc-editor.org/info/rfc9646); see the
       RFC itself for full legal notices.";

    revision 2022-03-02 {
      description
        "Initial version.";
      reference
        "RFC 9646: Conveying a Certificate Signing Request (CSR)
                   in a Secure Zero-Touch Provisioning (SZTP)
                   Bootstrapping Request";
    }

    identity certificate-request-format {
      description
        "A base identity for the request formats supported
         by the ZTP-client.

         Additional derived identities MAY be defined by
         future efforts.";
    }

    identity p10-csr {
      base certificate-request-format;
      description
        "Indicates that the ZTP-client supports generating
         requests using the 'CertificationRequest' structure
         defined in RFC 2986.";
      reference
        "RFC 2986: PKCS #10: Certification Request Syntax
                   Specification Version 1.7";
    }
```

```
   identity cmp-csr {
     base certificate-request-format;
     description
       "Indicates that the ZTP-client supports generating
        requests using a profiled version of the PKIMessage
        that MUST contain a PKIHeader followed by a PKIBody
        containing only the ir, cr, kur, or p10cr structures
        defined in RFC 4210.";
     reference
       "RFC 4210: Internet X.509 Public Key Infrastructure
                  Certificate Management Protocol (CMP)";
   }

   identity cmc-csr {
     base certificate-request-format;
     description
       "Indicates that the ZTP-client supports generating
        requests using a profiled version of the 'Full
        PKI Request' structure defined in RFC 5272.";
     reference
       "RFC 5272: Certificate Management over CMS (CMC)";
   }

   // Protocol-accessible nodes

   grouping csr-support-grouping {
     description
       "A grouping enabling use by other efforts.";
     container csr-support {
       description
         "Enables a ZTP-client to indicate that it supports
          generating certificate signing requests (CSRs) and
          provides details about the CSRs it is able to
          generate.";
       container key-generation {
         presence "Indicates that the ZTP-client is capable of
                   generating a new asymmetric key pair.

                   If this node is not present, the ZTP-server MAY
                   request a CSR using the asymmetric key associated
                   with the device's existing identity certificate
                   (e.g., an IDevID from IEEE 802.1AR).";
         description
           "Specifies details for the ZTP-client's ability to
            generate a new asymmetric key pair.";
         container supported-algorithms {
           description
             "A list of public key algorithms supported by the
              ZTP-client for generating a new asymmetric key.";
           leaf-list algorithm-identifier {
             type binary;
             min-elements 1;
             description
               "An AlgorithmIdentifier, as defined in RFC 2986,
                encoded using ASN.1 Distinguished Encoding Rules
                (DER), as specified in ITU-T X.690.";
             reference
               "RFC 2986: PKCS #10: Certification Request Syntax
```

```
                          Specification Version 1.7
                ITU-T X.690:
                  Information technology - ASN.1 encoding rules:
                  Specification of Basic Encoding Rules (BER),
                  Canonical Encoding Rules (CER) and Distinguished
                  Encoding Rules (DER)";
           }
         }
       }
       container csr-generation {
         description
           "Specifies details for the ZTP-client's ability to
            generate certificate signing requests.";
         container supported-formats {
           description
             "A list of certificate request formats supported
              by the ZTP-client for generating a new key.";
           leaf-list format-identifier {
             type identityref {
               base zt:certificate-request-format;
             }
             min-elements 1;
             description
               "A certificate request format supported by the
                ZTP-client.";
           }
         }
       }
     }
   }

   grouping csr-request-grouping {
     description
       "A grouping enabling use by other efforts.";
     container key-generation {
       presence "Provided by a ZTP-server to indicate that it wishes
                 the ZTP-client to generate a new asymmetric key.

                 This statement is present so the mandatory
                 descendant nodes do not imply that this node must
                 be configured.";
       description
         "The key generation parameters selected by the ZTP-server.

          This leaf MUST only appear if the ZTP-client's
          'csr-support' included the 'key-generation' node.";
       container selected-algorithm {
         description
           "The key algorithm selected by the ZTP-server.  The
            algorithm MUST be one of the algorithms specified by
            the 'supported-algorithms' node in the ZTP-client's
            message containing the 'csr-support' structure.";
         leaf algorithm-identifier {
           type binary;
           mandatory true;
           description
             "An AlgorithmIdentifier, as defined in RFC 2986,
              encoded using ASN.1 Distinguished Encoding Rules
```

```
            (DER), as specified in ITU-T X.690.";
         reference
           "RFC 2986: PKCS #10: Certification Request Syntax
                      Specification Version 1.7
            ITU-T X.690:
              Information technology - ASN.1 encoding rules:
              Specification of Basic Encoding Rules (BER),
              Canonical Encoding Rules (CER) and Distinguished
              Encoding Rules (DER)";
       }
     }
   }
   container csr-generation {
     description
       "Specifies details for the CSR that the ZTP-client
        is to generate.";
     container selected-format {
       description
         "The CSR format selected by the ZTP-server.  The
          format MUST be one of the formats specified by
          the 'supported-formats' node in the ZTP-client's
          request message.";
       leaf format-identifier {
         type identityref {
           base zt:certificate-request-format;
         }
         mandatory true;
         description
           "A certificate request format to be used by the
            ZTP-client.";
       }
     }
   }
   leaf cert-req-info {
     type ct:csr-info;
     description
       "A CertificationRequestInfo structure, as defined in
        RFC 2986, and modeled via a 'typedef' statement by
        RFC 9640.

        Enables the ZTP-server to provide a fully populated
        CertificationRequestInfo structure that the ZTP-client
        only needs to sign in order to generate the complete
        'CertificationRequest' structure to send to the ZTP-server
        in its next 'get-bootstrapping-data' request message.

        When provided, the ZTP-client MUST use this structure
        to generate its CSR; failure to do so will result in a
        400 Bad Request response containing another 'csr-request'
        structure.

        When not provided, the ZTP-client SHOULD generate a CSR
        using the same structure defined in its existing identity
        certificate (e.g., an IDevID from IEEE 802.1AR).

        If the 'AlgorithmIdentifier' field contained inside the
        certificate 'SubjectPublicKeyInfo' field does not match
        the algorithm identified by the 'selected-algorithm' node,
```

```
          then the client MUST reject the certificate and raise an
          error.";

       reference
         "RFC 2986:
            PKCS #10: Certification Request Syntax Specification
            Version 1.7
          RFC 9640:
            YANG Data Types and Groupings for Cryptography";
     }
   }

   grouping csr-grouping {
     description
       "Enables a ZTP-client to convey a certificate signing
        request, using the encoding format selected by a
        ZTP-server's 'csr-request' response to the ZTP-client's
        previously sent request containing the 'csr-support'
        node.";
     choice csr-type {
       mandatory true;
       description
         "A choice amongst certificate signing request formats.

          Additional formats MAY be augmented into this 'choice'
          statement by future efforts.";
       case p10-csr {
         leaf p10-csr {
           type ct:p10-csr;
           description
             "A CertificationRequest structure, per RFC 2986.
              Encoding details are defined in the 'ct:csr'
              typedef defined in RFC 9640.

              A raw P10 does not support origin authentication in
              the CSR structure.  External origin authentication
              may be provided via the ZTP-client's authentication
              to the ZTP-server at the transport layer (e.g., TLS).";
           reference
             "RFC 2986: PKCS #10: Certification Request Syntax
                        Specification Version 1.7
              RFC 9640: YANG Data Types and Groupings for
                        Cryptography";
         }
       }
       case cmc-csr {
         leaf cmc-csr {
           type binary;
           description
             "A profiled version of the 'Full PKI Request'
              message defined in RFC 5272, encoded using ASN.1
              Distinguished Encoding Rules (DER), as specified
              in ITU-T X.690.

              For asymmetric-key-based origin authentication of a
              CSR based on the initial device identity certificate's
              private key for the associated identity certificate's
              public key, the PKIData contains one reqSequence
```

```
              element and no cmsSequence or otherMsgSequence
              elements.  The reqSequence is the TaggedRequest,
              and it is the tcr CHOICE branch.  The tcr is the
              TaggedCertificationRequest, and it is the bodyPartID
              and the certificateRequest elements.  The
              certificateRequest is signed with the initial device
              identity certificate's private key.  The initial device
              identity certificate, and optionally its certificate
              chain is included in the SignedData certificates that
              encapsulate the PKIData.

              For asymmetric-key-based origin authentication based on
              the initial device identity certificate's private key
              that signs the encapsulated CSR signed by the local
              device identity certificate's private key, the
              PKIData contains one cmsSequence element and no
              reqSequence or otherMsgSequence
              elements.  The cmsSequence is the TaggedContentInfo,
              and it includes a bodyPartID element and a contentInfo.
              The contentInfo is a SignedData encapsulating a PKIData
              with one reqSequence element and no cmsSequence or
              otherMsgSequence elements.  The reqSequence is the
              TaggedRequest, and it is the tcr CHOICE.  The tcr is the
              TaggedCertificationRequest, and it is the bodyPartID and
              the certificateRequest elements.  PKIData contains one
              cmsSequence element and no controlSequence, reqSequence,
              or otherMsgSequence elements.  The certificateRequest
              is signed with the local device identity certificate's
              private key.  The initial device identity certificate
              and optionally its certificate chain is included in
              the SignedData certificates that encapsulate the
              PKIData.

              For shared-secret-based origin authentication of a
              CSR signed by the local device identity certificate's
              private key, the PKIData contains one cmsSequence
              element and no reqSequence or otherMsgSequence
              elements.  The cmsSequence is the TaggedContentInfo,
              and it includes a bodyPartID element and a contentInfo.
              The contentInfo is an AuthenticatedData encapsulating
              a PKIData with one reqSequence element and no
              cmsSequences or otherMsgSequence elements.  The
              reqSequence is the TaggedRequest, and it is the tcr
              CHOICE.  The tcr is the TaggedCertificationRequest,
              and it is the bodyPartID and the certificateRequest
              elements.  The certificateRequest is signed with the
              local device identity certificate's private key.  The
              initial device identity certificate and optionally its
              certificate chain is included in the SignedData
              certificates that encapsulate the PKIData.";
           reference
             "RFC 5272: Certificate Management over CMS (CMC)
              ITU-T X.690:
                Information technology - ASN.1 encoding rules:
                Specification of Basic Encoding Rules (BER),
                Canonical Encoding Rules (CER) and Distinguished
                Encoding Rules (DER)";
         }
```

```
        }
        case cmp-csr {
          leaf cmp-csr {
            type binary;
            description
              "A PKIMessage structure, as defined in RFC 4210,
               encoded using ASN.1 Distinguished Encoding Rules
               (DER), as specified in ITU-T X.690.

               For asymmetric-key-based origin authentication of a
               CSR based on the initial device identity certificate's
               private key for the associated initial device identity
               certificate's public key, PKIMessages contain one
               PKIMessage with the header and body elements, do not
               contain a protection element, and SHOULD contain the
               extraCerts element.  The header element contains the
               pvno, sender, and recipient elements.  The pvno contains
               cmp2000, and the sender contains the subject of the
               initial device identity certificate. The body element
               contains an ir, cr, kur, or p10cr CHOICE of type
               CertificationRequest.  It is signed with the initial
               device identity certificate's private key.  The
               extraCerts element contains the initial device identity
               certificate, optionally followed by its certificate
               chain excluding the trust anchor.

               For asymmetric-key-based origin authentication based
               on the initial device identity certificate's private
               key that signs the encapsulated CSR signed by the local
               device identity certificate's private key, PKIMessages
               contain one PKIMessage with the header, body, and
               protection elements and SHOULD contain the extraCerts
               element.  The header element contains the pvno, sender,
               recipient, protectionAlg, and optionally senderKID
               elements.  The pvno contains cmp2000, the sender
               contains the subject of the initial device identity
               certificate, the protectionAlg contains the
               AlgorithmIdentifier of the used signature algorithm,
               and the senderKID contains the subject key identifier
               of the initial device identity certificate. The body
               element contains an ir, cr, kur, or p10cr CHOICE of
               type CertificationRequest.  It is signed with the local
               device identity certificate's private key.  The
               protection element contains the digital signature
               generated with the initial device identity
               certificate's private key.  The extraCerts element
               contains the initial device identity certificate,
               optionally followed by its certificate chain excluding
               the trust anchor.

               For shared-secret-based origin authentication of a
               CSR signed by the local device identity certificate's
               private key, PKIMessages contain one PKIMessage with
               the header, body, and protection element and no
               extraCerts element.  The header element contains the
               pvno, sender, recipient, protectionAlg, and senderKID
               elements.  The pvno contains cmp2000, the protectionAlg
               contains the AlgorithmIdentifier of the used Message
```

```
               Authentication Code (MAC) algorithm, and the senderKID
               contains a reference the recipient can use to identify
               the shared secret.  The body element contains an ir, cr,
               kur, or p10cr CHOICE of type CertificationRequest.  It
               is signed with the local device identity certificate's
               private key.  The protection element contains the MAC
               value generated with the shared secret.";
            reference
              "RFC 4210:
                 Internet X.509 Public Key Infrastructure
                 Certificate Management Protocol (CMP)
               ITU-T X.690:
                 Information technology - ASN.1 encoding rules:
                 Specification of Basic Encoding Rules (BER),
                 Canonical Encoding Rules (CER) and Distinguished
                 Encoding Rules (DER)";
          }
        }
      }
    }

  }

<CODE ENDS>
```

4. Security Considerations

This document builds on top of the solution presented in [RFC8572], and therefore all the security considerations discussed in [RFC8572] apply here as well.

For the various CSR formats, when using PKCS#10, the security considerations in [RFC2986] apply; when using CMP, the security considerations in [RFC4210] apply; and when using CMC, the security considerations in [RFC5272] apply.

For the various authentication mechanisms, when using TLS-level authentication, the security considerations in [RFC8446] apply, and when using HTTP-level authentication, the security considerations in [RFC9110] apply.

4.1. SZTP-Client Considerations

4.1.1. Ensuring the Integrity of Asymmetric Private Keys

The private key the SZTP-client uses for the dynamically generated identity certificate **MUST** be protected from inadvertent disclosure in order to prevent identity fraud.

The security of this private key is essential in order to ensure the associated identity certificate can be used to authenticate the device it is issued to.

It is **RECOMMENDED** that devices are manufactured with a hardware security module (HSM), such as a trusted platform module (TPM), to generate and contain the private key within the security perimeter of the HSM. In such cases, the private key and its associated certificates **MAY** have long validity periods.

In cases where the SZTP-client does not possess an HSM or is unable to use an HSM to protect the private key, it is **RECOMMENDED** to periodically reset the private key (and associated identity certificates) in order to minimize the lifetime of unprotected private keys. For instance, a Network Management System (NMS) controller/orchestrator application could periodically prompt the SZTP-client to generate a new private key and provide a certificate signing request (CSR) or, alternatively, push both the key and an identity certificate to the SZTP-client using, e.g., a PKCS#12 message [RFC7292]. In another example, the SZTP-client could be configured to periodically reset the configuration to its factory default, thus causing removal of the private key and associated identity certificates and re-execution of the SZTP protocol.

4.1.2. Reuse of a Manufacturer-Generated Private Key

It is **RECOMMENDED** that a new private key is generated for each CSR described in this document.

Implementations must randomly generate nonces and private keys. The use of inadequate pseudorandom number generators (PRNGs) to generate cryptographic keys can result in little or no security. An attacker may find it much easier to reproduce the PRNG environment that produced the keys, searching the resulting small set of possibilities, rather than brute force searching the whole key space. As an example of predictable random numbers, see CVE-2008-0166 [CVE-2008-0166], and some consequences of low-entropy random numbers are discussed in "Mining Your Ps and Qs" [MiningPsQs]. The generation of quality random numbers is difficult. [ISO.20543-2019], [NIST.SP.800-90Ar1], BSI AIS 31 [AIS31], BCP 106 [RFC4086], and others offer valuable guidance in this area.

This private key **SHOULD** be protected as well as the built-in private key associated with the SZTP-client's initial device identity certificate (e.g., the IDevID from [Std-802.1AR-2018]).

In cases where it is not possible to generate a new private key that is protected as well as the built-in private key, it is **RECOMMENDED** to reuse the built-in private key rather than generate a new private key that is not as well protected.

4.1.3. Replay Attack Protection

This RFC enables an SZTP-client to announce an ability to generate a new key to use for its CSR.

When the SZTP-server responds with a request for the SZTP-client to generate a new key, it is essential that the SZTP-client actually generates a new key.

Generating a new key each time enables the random bytes used to create the key to also serve the dual-purpose of acting like a "nonce" used in other mechanisms to detect replay attacks.

When a fresh public/private key pair is generated for the request, confirmation to the SZTP-client that the response has not been replayed is enabled by the SZTP-client's fresh public key appearing in the signed certificate provided by the SZTP-server.

When a public/private key pair associated with the manufacturer-generated identity certificate (e.g., IDevID) is used for the request, there may not be confirmation to the SZTP-client that the response has not been replayed; however, the worst case result is a lost certificate that is associated to the private key known only to the SZTP-client. Protection of the private-key information is vital to public-key cryptography. Disclosure of the private-key material to another entity can lead to masquerades.

4.1.4. Connecting to an Untrusted Bootstrap Server

[RFC8572] allows SZTP-clients to connect to untrusted SZTP-servers by blindly authenticating the SZTP-server's TLS end-entity certificate.

As is discussed in Section 9.5 of [RFC8572], in such cases, the SZTP-client **MUST** assert that the bootstrapping data returned is signed if the SZTP-client is to trust it.

However, the HTTP error message used in this document cannot be signed data, as described in [RFC8572].

Therefore, the solution presented in this document cannot be used when the SZTP-client connects to an untrusted SZTP-server.

Consistent with the recommendation presented in Section 9.6 of [RFC8572], SZTP-clients **SHOULD NOT** pass the "csr-support" input parameter to an untrusted SZTP-server. SZTP-clients **SHOULD** instead pass the "signed-data-preferred" input parameter, as discussed in Appendix B of [RFC8572].

4.1.5. Selecting the Best Origin Authentication Mechanism

The origin of the CSR must be verified before a certificate is issued.

When generating a new key, it is important that the SZTP-client be able to provide additional proof that it was the entity that generated the key.

The CMP and CMC certificate request formats defined in this document support origin authentication. A raw PKCS#10 CSR does not support origin authentication.

The CMP and CMC request formats support origin authentication using both PKI and a shared secret.

Typically, only one possible origin authentication mechanism can possibly be used, but in the case that the SZTP-client authenticates itself using both TLS-level (e.g., IDevID) and HTTP-level credentials (e.g., Basic), as is allowed by Section 5.3 of [RFC8572], then the SZTP-client may need to choose between the two options.

In the case that the SZTP-client must choose between an asymmetric key option versus a shared secret for origin authentication, it is **RECOMMENDED** that the SZTP-client choose using the asymmetric key.

4.1.6. Clearing the Private Key and Associated Certificate

Unlike a manufacturer-generated identity certificate (e.g., IDevID), the deployment-generated identity certificate (e.g., LDevID) and the associated private key (assuming a new private key was generated for the purpose) are considered user data and **SHOULD** be cleared whenever the SZTP-client is reset to its factory default state, such as by the "factory-reset" RPC defined in [RFC8808].

4.2. SZTP-Server Considerations

4.2.1. Verifying Proof-of-Possession

Regardless, if using a new asymmetric key or the bootstrapping device's manufacturer-generated key (e.g., the IDevID key), the public key is placed in the CSR and the CSR is signed by that private key. Proof-of-possession of the private key is verified by ensuring the signature over the CSR using the public key placed in the CSR.

4.2.2. Verifying Proof-of-Origin

When the bootstrapping device's manufacturer-generated private key (e.g., the IDevID key) is reused for the CSR, proof-of-origin is verified by validating the IDevID-issuer cert and ensuring that the CSR uses the same key pair.

When the bootstrapping device's manufacturer-generated private key (e.g., an IDevID key from IEEE 802.1AR) is reused for the CSR, proof-of-origin is verified by validating the IDevID certification path and ensuring that the CSR uses the same key pair.

When a fresh asymmetric key is used with the CMP or CMC formats, the authentication is part of the protocols, which could employ either the manufacturer-generated private key or a shared secret. In addition, CMP and CMC support processing by an RA before the request is passed to the CA, which allows for more robust handling of errors.

4.2.3. Supporting SZTP-Clients That Don't Trust the SZTP-Server

[RFC8572] allows SZTP-clients to connect to untrusted SZTP-servers by blindly authenticating the SZTP-server's TLS end-entity certificate.

As is recommended in Section 4.1.4 of this document, in such cases, SZTP-clients **SHOULD** pass the "signed-data-preferred" input parameter.

The reciprocal of this statement is that SZTP-servers, wanting to support SZTP-clients that don't trust them, **SHOULD** support the "signed-data-preferred" input parameter, as discussed in Appendix B of [RFC8572].

4.3. Security Considerations for the "ietf-sztp-csr" YANG Module

The recommended format for documenting the security considerations for YANG modules is described in Section 3.7 of [RFC8407]. However, this module only augments two input parameters into the "get-bootstrapping-data" RPC in [RFC8572] and therefore only needs to point to the relevant Security Considerations sections in that RFC.

- Security considerations for the "get-bootstrapping-data" RPC are described in Section 9.16 of [RFC8572].
- Security considerations for the "input" parameters passed inside the "get-bootstrapping-data" RPC are described in Section 9.6 of [RFC8572].

4.4. Security Considerations for the "ietf-ztp-types" YANG Module

The recommended format for documenting the security considerations for YANG modules is described in Section 3.7 of [RFC8407]. However, this module does not define any protocol-accessible nodes (it only defines "identity" and "grouping" statements), and therefore there are no security considerations to report.

5. IANA Considerations

5.1. The IETF XML Registry

IANA has registered two URIs in the "ns" registry of the "IETF XML Registry" [RFC3688] maintained at <https://www.iana.org/assignments/xml-registry/>.

URI: urn:ietf:params:xml:ns:yang:ietf-sztp-csr
Registrant Contact: The NETCONF WG of the IETF.
XML: N/A; the requested URI is an XML namespace.

URI: urn:ietf:params:xml:ns:yang:ietf-ztp-types
Registrant Contact: The NETCONF WG of the IETF.
XML: N/A; the requested URI is an XML namespace.

5.2. The YANG Module Names Registry

IANA has registered two YANG modules in the "YANG Module Names" registry [RFC6020] maintained at <https://www.iana.org/assignments/yang-parameters/>.

Name: ietf-sztp-csr
Namespace: urn:ietf:params:xml:ns:yang:ietf-sztp-csr
Prefix: sztp-csr
Reference: RFC 9646

Name: ietf-ztp-types
Namespace: urn:ietf:params:xml:ns:yang:ietf-ztp-types
Prefix: ztp-types
Reference: RFC 9646

6. References

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