Workgroup: NETCONF Working Group
Internet-Draft: draft-ietf-netconf-sztp-csr-14
Updates: 8572 (if approved)
Published: 2 March 2022
Intended Status: Standards Track
Expires: 3 September 2022
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Conveying a Certificate Signing Request (CSR) in a Secure Zero Touch Provisioning (SZTP) Bootstrapping Request

Abstract

This draft 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., an LDevID from IEEE 802.1AR) as part of the "onboarding information" response provided in the RPC-reply.

Editorial Note (To be removed by RFC Editor)

This draft contains many placeholder values that need to be replaced with finalized values at the time of publication. This note summarizes all of the substitutions that are needed. No other RFC Editor instructions are specified elsewhere in this document.

Artwork in this document contains shorthand references to drafts in progress. Please apply the following replacements:

*XXXX --> the assigned numerical RFC value for this draft

*AAAA --> the assigned RFC value for I-D.ietf-netconf-crypto-types

Artwork in this document contains a placeholder value for the publication date of this draft. Please apply the following replacement:

*2022-03-02 --> the publication date of this draft

This document contains references to other drafts in progress, both in the Normative References section, as well as in body text throughout. Please update the following references to reflect their final RFC assignments:

*I-D.ietf-netconf-crypto-types

*I-D.ietf-netconf-keystore

*I-D.ietf-netconf-trust-anchors

Status of This Memo

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1. Introduction

1.1. Overview

This draft 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 [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 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 used in this document use a placeholder value for binary data that has been base64 encoded (e.g., "BASE64VALUE="). This placeholder value is used as real base64 encoded structures are often many lines long and hence distracting to the example being presented.

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:

* The "csr-support" node is used by the SZTP-client to signal to the SZTP-server that it supports the ability to generate CSRs. This 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 conveys what kinds of CSR structures the SZTP-client is able to generate.

* The "csr-request" structure is used by the SZTP-server 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.

*The various "csr" nodes are used by the SZTP-client to communicate a CSR to the SZTP-server.

No data model is defined enabling an SZTP-server 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

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 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 "onboarding-information" (encoded inside the "conveyed-information" node, shown below) 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 [I-D.ietf-netconf-keystore].

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 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 [I-D.ietf-netconf-trust-anchors].

2.3. YANG Module

This module augments an RPC defined in [RFC8572]. The module uses a data types and groupings defined in [RFC8572], [RFC8791], and [I-D.ietf-netconf-crypto-types]. 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 XXXX: 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.

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     BSD License set forth in Section 4.c of the IETF Trust's
```

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

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

   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
   in all capitals, as shown here.";

revision 2022-03-02 {
  description
    "Initial version";
  reference
    "RFC XXXX: 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 HTTP code 400 Bad Request 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 each for messages sent between a ZTP-client and ZTP-server. This module is defined independently of the "ietf-sztp-csr" module so that it's 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 a data types and groupings [RFC8791] and [I-D.ietf-netconf-crypto-types]. The module has additional normative references to [RFC2986], [RFC4210], [RFC5272], and [ITU.X690.2015], 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 AAAA: 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.

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     subject to the license terms contained in, the Revised
     BSD License set forth in Section 4.c of the IETF Trust's
     Legal Provisions Relating to IETF Documents
     (https://trustee.ietf.org/license-info).

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

     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
     in all capitals, as shown here.";

  revision 2022-03-02 {
    description
```

```
    "Initial version";
  reference
    "RFC XXXX: 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 structure
     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 a 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 AAAA.

     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 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
       RFC AAAA:
         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:csr;
        description
          "A CertificationRequest structure, per RFC 2986.
           Encoding details are defined in the 'ct:csr'
           typedef defined in RFC AAAA.

           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
           RFC AAAA: 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
       encapsulates 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 encapsulates 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 encapsulates 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 contains one
        PKIMessage with the header and body elements, no
        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
        contains 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 contains 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 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 RFC 8572 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 [RFC7235] 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 an HSM (hardware security module), such as a TPM (trusted platform module), 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, an 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 pseudo-random 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 RFC 8572.

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 pass instead 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 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 a 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 in 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

This document registers two URIs in the "ns" subregistry of the IETF XML Registry [RFC3688] maintained at https://www.iana.org/assignments/xml-registry/xml-registry.xhtml#ns. Following the format in [RFC3688], the following registrations are requested:

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

This document registers two YANG modules in the YANG Module Names registry [RFC6020] maintained at https://www.iana.org/assignments/yang-parameters/yang-parameters.xhtml. Following the format defined in [RFC6020], the below registrations are requested:

```
name:      ietf-sztp-csr
namespace: urn:ietf:params:xml:ns:yang:ietf-sztp-csr
prefix:    sztp-csr
reference: RFC XXXX

name:      ietf-ztp-types
namespace: urn:ietf:params:xml:ns:yang:ietf-ztp-types
prefix:    ztp-types
reference: RFC XXXX
```

6. References

6.1. Normative References

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Acknowledgements

The authors would like to thank for following for lively discussions on list and in the halls (ordered by first name): Benjamin Kaduk, David von Oheimb, Dan Romascanu, Eric Vyncke, Hendrik Brockhaus, Guy Fedorkow, Joe Clarke, Meral Shirazipour, Murray Kucherawy, Rich Salz, Rob Wilton, Roman Danyliw, Qin Wu, Yaron Sheffer, and Zaheduzzaman Sarkar.

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Special thanks go to David von Oheimb and Hendrik Brockhaus for helping with the descriptions for the "cmc-csr" and "cmp-csr" nodes.

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