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Keystore Model
draft-ietf-netconf-keystore-00

Abstract

This document defines a YANG data module for a system-level keystore mechanism, that might be used to hold onto private keys and certificates that are trusted by the system advertising support for this module.

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.

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:

- draft-ietf-netconf-restconf

- draft-ietf-netconf-call-home

- draft-ietf-rtgwg-yang-key-chain

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

- "VVVV" --> the assigned RFC value for this draft

- "XXXX" --> the assigned RFC value for draft-ietf-netconf-restconf

- "YYYY" --> the assigned RFC value for draft-ietf-netconf-call-home

Artwork in this document contains placeholder values for ports pending IANA assignment from "draft-ietf-netconf-call-home". Please apply the following replacements:

- o "7777" --> the assigned port value for "netconf-ch-ssh"

- o "8888" --> the assigned port value for "netconf-ch-tls"

- o "9999" --> the assigned port value for "restconf-ch-tls"

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

- o "2016-10-31" --> the publication date of this draft

The following two Appendix sections are to be removed prior to publication:

- o Appendix A. Change Log

- o Appendix B. Open Issues

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

This document defines a YANG [RFC6020] data module for a system-level keystore mechanism, which can be used to hold onto private keys and certificates that are trusted by the system advertising support for this module.

This module provides a centralized location for security sensitive data, so that the data can be then referenced by other modules. There are two types of data that are maintained by this module:

o Private keys, and any associated public certificates.

o Sets of trusted certificates.

This document extends special consideration for systems that have Trusted Protection Modules (TPMs). These systems are unique in that the TPM must be directed to generate new private keys (it is not possible to load a private key into a TPM) and it is not possible to backup/restore the TPM's private keys as configuration.

It is not required that a system has an operating system level keystore utility to implement this module.

1.1. Requirements Language

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

1.2. Tree Diagram Notation

A simplified graphical representation of the data models is used in this document. The meaning of the symbols in these diagrams is as follows:

- o Brackets "[" and "]" enclose list keys.
- o Braces "{" and "}" enclose feature names, and indicate that the named feature must be present for the subtree to be present.
- o Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).
- o Symbols after data node names: "?" means an optional node, "!" means a presence container, and "*" denotes a list and leaf-list.
- o Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").
- o Ellipsis ("...") stands for contents of subtrees that are not shown.

2. The Keystore Model

The keystore module defined in this section provides a configurable object having the following characteristics:

- o A semi-configurable list of private keys, each with one or more associated certificates. Private keys MUST be either preinstalled (e.g., a key associated to an IDevID [Std-802.1AR-2009] certificate), be generated by request, or be loaded by request. Each private key is MAY have associated certificates, either preinstalled or configured after creation.
- o A configurable list of lists of trust anchor certificates. This enables the server to have use-case specific trust anchors. For instance, one list of trust anchors might be used to authenticate management connections (e.g., client certificate-based

authentication for NETCONF or RESTCONF connections), and a different list of trust anchors might be used for when connecting to a specific Internet-based service (e.g., a zero touch bootstrap server).

- o An RPC to generate a certificate signing request for an existing private key, a passed subject, and an optional attributes. The signed certificate returned from an external certificate authority (CA) can be later set using a standard configuration change request (e.g., <edit-config>).

- o An RPC to request the server to generate a new private key using the specified algorithm and key length.

- o An RPC to request the server to load a new private key.

2.1. Overview

The keystore module has the following tree diagram. Please see Section 1.2 for information on how to interpret this diagram.

```
module: ietf-keystore
    +--rw keystore
       +--rw private-keys
       |  +--rw private-key* [name]
       |  |  +--rw name                                    string
       |  |  +--ro algorithm?                              identityref
       |  |  +--ro key-length?                             uint32
       |  |  +--ro public-key                              binary
       |  |  +--rw certificate-chains
       |  |  |  +--rw certificate-chain* [name]
       |  |  |     +--rw name           string
       |  |  |     +--rw certificate*   binary
       |  |  +---x generate-certificate-signing-request
       |  |     +---w input
       |  |     |  +---w subject       binary
       |  |     |  +---w attributes?   binary
       |  |     +--ro output
       |  |        +--ro certificate-signing-request    binary
       |  +---x generate-private-key
       |  |  +---w input
       |  |     +---w name          string
       |  |     +---w algorithm     identityref
       |  |     +---w key-length?   uint32
       |  +---x load-private-key
       |     +---w input
       |        +---w name           string
       |        +---w private-key    binary
```

```
        +--rw trusted-certificates* [name]
        |  +--rw name                   string
        |  +--rw description?           string
        |  +--rw trusted-certificate* [name]
        |     +--rw name           string
        |     +--rw certificate?   binary
        +--rw trusted-ssh-host-keys* [name]
        |  +--rw name                string
        |  +--rw description?        string
        |  +--rw trusted-host-key* [name]
        |     +--rw name        string
        |     +--rw host-key    binary
        +--rw user-auth-credentials
           +--rw user-auth-credential* [username]
              +--rw username       string
              +--rw auth-method* [priority]
                 +--rw priority               uint8
                 +--rw (auth-type)?
                    +--:(certificate)
                    |  +--rw certificate*           -> /keystore/private
 -keys/private-key/certificate-chains/certificate-chain/name
                    +--:(public-key)
                    |  +--rw public-key*            -> /keystore/private
 -keys/private-key/name
                    +--:(ciphertext-password)
                    |  +--rw ciphertext-password?   string
                    +--:(cleartext-password)
                       +--rw cleartext-password?    string

  notifications:
    +---n certificate-expiration
       +--ro certificate        instance-identifier
       +--ro expiration-date    yang:date-and-time
```

2.2. Example Usage

The following example illustrates the "generate-private-key" action in use with the RESTCONF protocol and JSON encoding.

REQUEST

```
['\' line wrapping added for formatting only]

POST https://example.com/restconf/data/ietf-keystore:keystore/\
private-keys/generate-private-key HTTP/1.1
HOST: example.com
Content-Type: application/yang.operation+json

{
  "ietf-keystore:input" : {
    "name" : "ex-key-sect571r1",
    "algorithm" : "sect571r1"
  }
}
```

RESPONSE

```
HTTP/1.1 204 No Content
Date: Mon, 31 Oct 2015 11:01:00 GMT
Server: example-server
```

The following example illustrates the "load-private-key" action in use with the RESTCONF protocol and JSON encoding.

REQUEST

['\' line wrapping added for formatting only]

```
POST https://example.com/restconf/data/ietf-keystore:keystore/\
private-keys/load-private-key HTTP/1.1
HOST: example.com
Content-Type: application/yang.operation+xml
```


```
<input xmlns="urn:ietf:params:xml:ns:yang:ietf-keystore">
  <name>ex-key-sect571r1</name>
  <private-key>
    NGcEk3UE90cnNFVjRwTUNBd0VBQWFPQ0FSSXdnZ0VPCk1CMEdBMVVkRGd\
    VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER\
    V6QVJCZ05WQkFNVENrTlNUQ0JKYzNOMVpYS0NDUUNVRHBNSll6UG8zREF\
    Z05WSFI4RVlqQmdNRjZnSXFBZ2hoNW9kSFJ3T2k4dlpYaGgKYlhCc1pTN\
    QmdOVkJBWVRBbFZUTVJBd0RnWURWUVFLRXdkbAplR0Z0Y0d4bE1RNHdEQ\
    MkF6a3hqUDlVQWtHR0dvS1U1eUc1SVR0Wm0vK3B0R2FieXVDMjBRd2kvZ\
    NQmdOVkhSTUJBZjhFCkFqQUFNQTRHQTFVZER3RUIvd1FFQXdJSGdEQnBC\
    WmdsK2gyTTg3QmtGMjhWbW1CdFFVaWc3OEgrRkYyRTFwdSt4ZVRJbVFFM\
    lLQllsdWpOcjFTMnRLR05EMUc2OVJpK2FWNGw2NTdZNCtadVJMZgpRYjk\
    zSFNwSDdwVXBCYnA4dmtNanFtZjJma3RqZHBxeFppUUtTbndWZTF2Zwot\
    25PZnpZNEhONApXY0pTaUpZK2xtYWs3RTRORUZXZS9RdGp4NUlXZmdvN2\
    WpiMjB2WlhoaGJYQnNaUzVqY215aU9L=
  </private-key>
</input>
```


RESPONSE

```
HTTP/1.1 204 No Content
Date: Mon, 31 Oct 2015 11:01:00 GMT
Server: example-server
```

The following example illustrates the "generate-certificate-signing-request" action in use with the NETCONF protocol.

REQUEST

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <action xmlns="urn:ietf:params:xml:ns:yang:1">
    <keystore
      xmlns="urn:ietf:params:xml:ns:yang:ietf-keystore">
```

```
          <private-keys>
            <private-key>
              <name>ex-key-sect571r1</name>
              <generate-certificate-signing-request>
                <subject>
                 cztvaWRoc2RmZ2tqaHNkZmdramRzZnZzZGtmam5idnNvO2R
                 manZvO3NkZmJpdmhzZGZpbHVidjtvc2lkZmhidml1bHNlmO
                 Z2aXNiZGZpYmhzZG87ZmJvO3NkZ25iO29pLmR6Zgo=
                </subject>
                <attributes>
                 bwtakWRoc2RmZ2tqaHNkZmdramRzZnZzZGtmam5idnNvut4
                 arnZvO3NkZmJpdmhzZGZpbHVidjtvc2lkZmhidml1bHNkYm
                 Z2aXNiZGZpYmhzZG87ZmJvO3NkZ25iO29pLmC6Rhp=
                </attributes>
              </generate-certificate-signing-request>
            </private-key>
          </private-keys>
        </keystore>
      </action>
    </rpc>
```

RESPONSE

```
    <rpc-reply message-id="101"
       xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
       <certificate-signing-request
         xmlns="urn:ietf:params:xml:ns:yang:ietf-keystore">
         LS0tLS1CRUdJTiBDRVJUSUZJQ0FURS0tLS0tCk1JSUNrekNDQWZ5Z
         0F3SUJBZ0lKQUpRT2t3bGpNK2pjTUEwR0NTcUdTSWIzRFFFQkJRVU
         FNRFF4Q3pBSkJnTlYKQkFZVEFsVlRNUkF3RGdZRFZRUUtFd2RsZUd
         GdGNHeGxNUk13RVFZRFZRUURFd3BEVWt3Z1NYTnpkV1Z5TUI0WApE
         diR1V4RXpBUkJnTlZCQU1UQ2tOU1RDQkpjM04xWlhJd2daOHdEUVl
         KS29aSWh2Y04KQVFFQkJRQURnWTBBTUlHSkFvR0JBTXVvZmFPNEV3
         El1QWMrQ1RsTkNmc0d6cEw1Um5ydXZsOFRIcUJTdGZQY3N0Zk1KT1
         FaNzlnNlNWVldsMldzaHE1bUViCkJNNitGNzdjbTAvU25FcFE0TnV
         bXBDT2YKQWdNQkFBR2pnYXd3Z2Frd0hRWURWUjBPQkJZRUZKY1o2W
         URiR0lPNDB4ajlPb3JtREdsRUNCVTFNR1FHQTFVZApJd1JkTUZ1QU
         ZKY1o2WURiR0lPNDB4ajlPb3JtREdsRUNCVTFvVGlrTmpBME1Rc3d
         mMKTUE0R0ExVWREd0VCL3dRRUF3SUNCREFTQmdOVkhSTUJBZjhFQ0
         RBR0FRSC9BZ0VBTUEwR0NTcUdTSWIzRFFFQgpCUVVBQTRHQkFMMmx
         rWmFGNWcyaGR6MVNhZnZPbnBneHA4eG00SHRhbStadHpLazFlS3Bx
         TXp4YXJCbFpDSHlLCklVbC9GVzRtV1RQS1VDeEtFTE40NEY2Zmk2d
         c4d0tSSElkYW1WL0pGTmlQS0VXSTF4K1I1aDZmazcrQzQ1QXg1RWV
         SWHgzZjdVM2xZTgotLS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
       </certificate-signing-request>
    </rpc-reply>
```

The following example illustrates what a fully configured keystore object might look like. The private-key shown below is consistent with the generate-private-key and generate-certificate-signing-request examples above. This example also assumes that the resulting CA-signed certificate has been configured back onto the server. Lastly, this example shows that three lists of trusted certificates having been configured.


```
<keystore xmlns="urn:ietf:params:xml:ns:yang:ietf-keystore">

  <!-- private keys and associated certificates -->
  <private-keys>
    <private-key>
      <name>my-rsa-user-key</name>
      <algorithm>rsa</algorithm>
      <public-key>
        cztvaWRoc2RmZ2tqaHNkZmdramRzZnZzZGtmam5idnNvO2RmanZvO3NkZ
        mJpdmhzZGZpbHVidjtvc2lkZmhidml1bHNkYmZ2aXNiZGZpYmhzZG87Zm
        JvO3NkZ25iO29pLmR6Zgo=
      </public-key>
      <certificate-chains>
        <certificate-chain>
          <name>my-rsa-chain</name>
          <certificate>
            ZKY1o2WURiR0lPNDB4ajlPb3JtREdsRUNCVTFvVGlrTmpBME1Rc3d
            diR1V4RXpBUkJnTlZCQU1UQ2tOU1RDQkpjM04xWlhJd2daOHdEUVl
            LS0tLS1CRUdJTiBDRVJUSUZJQ0FURS0tLS0tCk1JSUNrekNDQWZ5Z
            KS29aSWh2Y04KQVFFQkJRQURnWTBBTUlHSkFvR0JBTXVvZmFPNEV3
            0F3SUJBZ0lKQUpRT2t3bGpNK2pjTUEwR0NTcUdTSWIzRFFFQkJRVU
            FNRFF4Q3pBSkJnTlYKQkFZVEFsVlRNUkF3RGdZRFZRUUtFd2RsZUd
            GdGNHeGxNUk13RVFZRFZRUURFd3BEVWt3Z1NYTnpkV1Z5TUI0WApE
            mMKTUE0R0ExVWREd0VCL3dRRUF3SUNCREFTQmdOVkhSTUJBZjhFQ0
            RBR0FRSC9BZ0VBTUEwR0NTcUdTSWIzRFFFQgpCUVVBQTRHQkFMMmx
            rWmFGNWcyaGR6MVNhZnZPbnBneHA4eG00SHRhbStadHpLazFlS3Bx
            TXp4YXJCbFpDSHlLCklVbC9GVzRtV1RQS1VDeEtFTE40NEY2Zmk2d
            c4d0tSSElkYW1WL0pGTmlQS0VXSTF4K1I1aDZmazcrQzQ1QXg1RWV
            SWM2xZTgotLS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
          </certificate>
        </certificate-chain>
      </certificate-chains>
    </private-key>

    <private-key>
      <name>my-ec-user-key</name>
      <algorithm>secp256r1</algorithm>
      <public-key>
        mJpdmhzZGZpbHVidjtvc2lkZmhidml1bHNkYmZ2aXNiZGZpYmhzZG87Zm
        cztvaWRoc2RmZ2tqaHNkZmdramRzZnZzZGtmam5idnNvO2RmanZvO3NkZ
```

```
          JvO3NkZ25iO29pLmR6Zgo=
        </public-key>
        <certificate-chains>
          <certificate-chain>
            <name>my-ec-chain</name>
            <certificate>
              0F3SUJBZ0lKQUpRT2t3bGpNK2pjTUEwR0NTcUdTSWIzRFFFQkJRVU
              ZKY1o2WURiR0lPNDB4ajlPb3JtREdsRUNCVTFvVGlrTmpBME1Rc3d
              diR1V4RXpBUkJnTlZCQU1UQ2tOU1RDQkpjM04xWlhJd2daOHdEUVl
              LS0tLS1CRUdJTiBDRVJUSUZJQ0FURS0tLS0tCk1JSUNrekNDQWZ5Z
              KS29aSWh2Y04KQVFFQkJRQURnWTBBTUlHSkFvR0JBTXVvZmFPNEV3
              FNRFF4Q3pBSkJnTlYKQkFZVEFsVlRNUkF3RGdZRFZRUUtFd2RsZUd
              GdGNHeGxNUk13RVFZRFZRUURFd3BEVWt3Z1NYTnpkV1Z5TUI0WApE
              mMKTUE0R0ExVWREd0VCL3dRRUF3SUNCREFTQmdOVkhSTUJBZjhFQ0
              RBR0FRSC9BZ0VBTUEwR0NTcUdTSWIzRFFFQgpCUVVBQTRHQkFMMmx
              rWmFGNWcyaGR6MVNhZnZPbnBneHA4eG00SHRhbStadHpLazFlS3Bx
              TXp4YXJCbFpDSHlLCklVbC9GVzRtV1RQS1VDeEtFTE40NEY2Zmk2d
              c4d0tSSElkYW1WL0pGTmlQS0VXSTF4K1I1aDZmazcrQzQ1QXg1RWV
              SWM2xZTgotLS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
            </certificate>
          </certificate-chain>
        </certificate-chains>
      </private-key>

      <private-key>
        <name>tpm-protected-key</name>
        <algorithm>sect571r1</algorithm>
        <public-key>
          cztvaWRoc2RmZ2tqaHNkZmdramRzZnZzZGtmam5idnNvO2RmanZvO3NkZ
          mJpdmhzZGZpbHVidjtvc2lkZmhidml1bHNkYmZ2aXNiZGZpYmhzZG87Zm
          JvO3NkZ25iO29pLmR6Zgo=
        </public-key>
        <certificate-chains>
          <certificate-chain>
            <name>default-idevid-chain</name>
            <certificate>
              diR1V4RXpBUkJnTlZCQU1UQ2tOU1RDQkpjM04xWlhJd2daOHdEUVl
              LS0tLS1CRUdJTiBDRVJUSUZJQ0FURS0tLS0tCk1JSUNrekNDQWZ5Z
              KS29aSWh2Y04KQVFFQkJRQURnWTBBTUlHSkFvR0JBTXVvZmFPNEV3
              0F3SUJBZ0lKQUpRT2t3bGpNK2pjTUEwR0NTcUdTSWIzRFFFQkJRVU
              FNRFF4Q3pBSkJnTlYKQkFZVEFsVlRNUkF3RGdZRFZRUUtFd2RsZUd
              GdGNHeGxNUk13RVFZRFZRUURFd3BEVWt3Z1NYTnpkV1Z5TUI0WApE
              ZKY1o2WURiR0lPNDB4ajlPb3JtREdsRUNCVTFvVGlrTmpBME1Rc3d
              mMKTUE0R0ExVWREd0VCL3dRRUF3SUNCREFTQmdOVkhSTUJBZjhFQ0
              RBR0FRSC9BZ0VBTUEwR0NTcUdTSWIzRFFFQgpCUVVBQTRHQkFMMmx
              rWmFGNWcyaGR6MVNhZnZPbnBneHA4eG00SHRhbStadHpLazFlS3Bx
              TXp4YXJCbFpDSHlLCklVbC9GVzRtV1RQS1VDeEtFTE40NEY2Zmk2d
              c4d0tSSElkYW1WL0pGTmlQS0VXSTF4K1I1aDZmazcrQzQ1QXg1RWV
```

```
            SWM2xZTgotLS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
          </certificate>
          <certificate>
            KS29aSWh2Y04KQVFFQkJRQURnWTBBTUlHSkFvR0JBTXVvZmFPNEV3
            El1QWMrQ1RsTkNmc0d6cEw1Um5ydXZsOFRIcUJTdGZQY3N0Zk1KT1
            FaNzlnNlNWVldsMldzaHE1bUViCkJNNitGNzdjbTAvU25FcFE0TnV
            bXBDT2YKQWdNQkFBR2pnYXd3Z2Frd0hRWURWUjBPQkJZRUZKY1o2W
            LS0tLS1CRUdJTiBDRVJUSUZJQ0FURS0tLS0tCk1JSUNrekNDQWZ5Z
            0F3SUJBZ0lKQUpRT2t3bGpNK2pjTUEwR0NTcUdTSWIzRFFFQkJRVU
            FNRFF4Q3pBSkJnTlYKQkFZVEFsVlRNUkF3RGdZRFZRUUtFd2RsZUd
            GdGNHeGxNUk13RVFZRFZRUURFd3BEVWt3Z1NYTnpkV1Z5TUI0WApE
            diR1V4RXpBUkJnTlZCQU1UQ2tOU1RDQkpjM04xWlhJd2daOHdEUVl
            URiR0lPNDB4ajlPb3JtREdsRUNCVTFNR1FHQTFVZApJd1JkTUZ1QU
            RBR0FRSC9BZ0VBTUEwR0NTcUdTSWIzRFFFQgpCUVVBQTRHQkFMMmx
            rWmFGNWcyaGR6MVNhZnZPbnBneHA4eG00SHRhbStadHpLazFlS3Bx
            c4d0tSSElkYW1WL0pGTmlQS0VXSTF4K1I1aDZmazcrQzQ1QXg1RWV
            SSUZJQ0FURS0tLS0tCg==
          </certificate>
        </certificate-chain>
        <certificate-chain>
          <name>my-ldevid-chain</name>
          <certificate>
            0F3SUJBZ0lKQUpRT2t3bGpNK2pjTUEwR0NTcUdTSWIzRFFFQkJRVU
            FNRFF4Q3pBSkJnTlYKQkFZVEFsVlRNUkF3RGdZRFZRUUtFd2RsZUd
            GdGNHeGxNUk13RVFZRFZRUURFd3BEVWt3Z1NYTnpkV1Z5TUI0WApE
            diR1V4RXpBUkJnTlZCQU1UQ2tOU1RDQkpjM04xWlhJd2daOHdEUVl
            LS0tLS1CRUdJTiBDRVJUSUZJQ0FURS0tLS0tCk1JSUNrekNDQWZ5Z
            KS29aSWh2Y04KQVFFQkJRQURnWTBBTUlHSkFvR0JBTXVvZmFPNEV3
            El1QWMrQ1RsTkNmc0d6cEw1Um5ydXZsOFRIcUJTdGZQY3N0Zk1KT1
            FaNzlnNlNWVldsMldzaHE1bUViCkJNNitGNzdjbTAvU25FcFE0TnV
            ZKY1o2WURiR0lPNDB4ajlPb3JtREdsRUNCVTFvVGlrTmpBME1Rc3d
            mMKTUE0R0ExVWREd0VCL3dRRUF3SUNCREFTQmdOVkhSTUJBZjhFQ0
            RBR0FRSC9BZ0VBTUEwR0NTcUdTSWIzRFFFQgpCUVVBQTRHQkFMMmx
            rWmFGNWcyaGR6MVNhZnZPbnBneHA4eG00SHRhbStadHpLazFlS3Bx
            TXp4YXJCbFpDSHlLCklVbC9GVzRtV1RQS1VDeEtFTE40NEY2Zmk2d
            c4d0tSSElkYW1WL0pGTmlQS0VXSTF4K1I1aDZmazcrQzQ1QXg1RWV
            SWM2xZTgotLS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
          </certificate>
          <certificate>
            LS0tLS1CRUdJTiBDRVJUSUZJQ0FURS0tLS0tCk1JSUNrekNDQWZ5Z
            0F3SUJBZ0lKQUpRT2t3bGpNK2pjTUEwR0NTcUdTSWIzRFFFQkJRVU
            FNRFF4Q3pBSkJnTlYKQkFZVEFsVlRNUkF3RGdZRFZRUUtFd2RsZUd
            GdGNHeGxNUk13RVFZRFZRUURFd3BEVWt3Z1NYTnpkV1Z5TUI0WApE
            diR1V4RXpBUkJnTlZCQU1UQ2tOU1RDQkpjM04xWlhJd2daOHdEUVl
            KS29aSWh2Y04KQVFFQkJRQURnWTBBTUlHSkFvR0JBTXVvZmFPNEV3
            El1QWMrQ1RsTkNmc0d6cEw1Um5ydXZsOFRIcUJTdGZQY3N0Zk1KT1
            FaNzlnNlNWVldsMldzaHE1bUViCkJNNitGNzdjbTAvU25FcFE0TnV
            bXBDT2YKQWdNQkFBR2pnYXd3Z2Frd0hRWURWUjBPQkJZRUZKY1o2W
```

```
              URiR0lPNDB4ajlPb3JtREdsRUNCVTFNR1FHQTFVZApJd1JkTUZ1QU
              ZKY1o2WURiR0lPNDB4ajlPb3JtREdsRUNCVTFvVGlrTmpBME1Rc3d
              mMKTUE0R0ExVWREd0VCL3dRRUF3SUNCREFTQmdOVkhSTUJBZjhFQ0
              RBR0FRSC9BZ0VBTUEwR0NTcUdTSWIzRFFFQgpCUVVBQTRHQkFMMmx
              rWmFGNWcyaGR6MVNhZnZPbnBneHA4eG00SHRhbStadHpLazFlS3Bx
              TXp4YXJCbFpDSHlLCklVbC9GVzRtV1RQS1VDeEtFTE40NEY2Zmk2d
              c4d0tSSElkYW1WL0pGTmlQS0VXSTF4K1I1aDZmazcrQzQ1QXg1RWV
              SWHgzZjdVM2xZTgotLS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
            </certificate>
          </certificate-chain>
        </certificate-chains>
      </private-key>
    </private-keys>

    <!-- trusted netconf/restconf client certificates -->
    <trusted-certificates>
      <name>explicitly-trusted-client-certs</name>
      <description>
        Specific client authentication certificates that are to be
        explicitly trusted NETCONF/RESTCONF clients.  These are
        needed for client certificates not signed by our CA.
      </description>
      <trusted-certificate>
        <name>George Jetson</name>
        <certificate>
          QmdOVkJBWVRBbFZUTVJBd0RnWURWUVFLRXdkbAplR0Z0Y0d4bE1RNHdEQ
          MkF6a3hqUDlVQWtHR0dvS1U1eUc1SVR0Wm0vK3B0R2FieXVDMjBRd2kvZ
          25PZnpZNEhONApXY0pTaUpZK2xtYWs3RTRORUZXZS9RdGp4NUlXZmdvN2
          RV0JCU2t2MXI2SFNHeUFUVkpwSmYyOWtXbUU0NEo5akJrQmdOVkhTTUVY
          VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER
          UxNQWtHQTFVRUJoTUNWVk14RURBT0JnTlZCQW9UQjJWNApZVzF3YkdVeE
          V6QVJCZ05WQkFNVENrTlNUQ0JKYzNOMVpYS0NDUUNVRHBNSll6UG8zREF
          NQmdOVkhSTUJBZjhFCkFqQUFNQTRHQTFVZER3RUIvd1FFQXdJSGdEQnBC
          Z05WSFI4RVlqQmdNRjZnSXFBZ2hoNW9kSFJ3T2k4dlpYaGgKYlhCc1pTN
          WpiMjB2WlhoaGJYQnNaUzVqY215aU9LUTJNRFF4Q3pBSkJnTlZCQVlUQW
          xWVE1SQXdEZ1lEVlFRSwpFd2RsZUdGdGNHeGxNUk13RVFZRFZRUURFd3B
          EVWt3Z1NYTnpkV1Z5TUEwR0NTcUdTSWIzRFFFQkJRVUFBNEdCCkFFc3BK
          WmdsK2gyTTg3QmtGMjhWbW1CdFFVaWc3OEgrRkYyRTFwdSt4ZVRJbVFFM
          TQzcjFZSjk0M1FQLzV5eGUKN2QxMkxCV0dxUjUrbEl5N01YL21ka2M4al
          zSFNwSDdwVXBCYnA4dmtNanFtZjJma3RqZHBxeFppUUtTbndWZTF2Zwot
          LS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
        </certificate>
      </trusted-certificate>
      <trusted-certificate>
        <name>Fred Flintstone</name>
        <certificate>
          VlEVlFRREV3Vm9ZWEJ3ZVRDQm56QU5CZ2txaGtpRzl3MEJBUUVGQUFPQm
          pRQXdnWWtDCmdZRUE1RzRFSWZsS1p2bDlXTW44eUhyM2hObUFRaUhVUzV
```

```
          rRUpPQy9hSFA3eGJXQW1ra054ZStUa2hrZnBsL3UKbVhsTjhSZUd1ODhG
          NGcEk3UE90cnNFVjRwTUNBd0VBQWFPQ0FSSXdnZ0VPCk1CMEdBMVVkRGd
          VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER
          V6QVJCZ05WQkFNVENrTlNUQ0JKYzNOMVpYS0NDUUNVRHBNSll6UG8zREF
          NQmdOVkhSTUJBZjhFCkFqQUFNQTRHQTFVZER3RUIvd1FFQXdJSGdEQnBC
          Z05WSFI4RVlqQmdNRjZnSXFBZ2hoNW9kSFJ3T2k4dlpYaGgKYlhCc1pTN
          WpiMjB2WlhoaGJYQnNaUzVqY215aU9LUTJNRFF4Q3pBSkJnTlZCQVlUQW
          xWVE1SQXdEZ1lEVlFRSwpFd2RsZUdGdGNHeGxNUk13RVFZRFZRUURFd3B
          EVWt3Z1NYTnpkV1Z5TUEwR0NTcUdTSWIzRFFFQkJRVUFBNEdCCkFFc3BK
          WmdsK2gyTTg3QmtGMjhWbW1CdFFVaWc3OEgrRkYyRTFwdSt4ZVRJbVFFM
          lLQllsdWpOcjFTMnRLR05EMUc2OVJpK2FWNGw2NTdZNCtadVJMZgpRYjk
          zSFNwSDdwVXBCYnA4dmtNanFtZjJma3RqZHBxeFppUUtTbndWZTF2Zwot
          QWtUOCBDRVUUZJ0RUF==
        </certificate>
      </trusted-certificate>
    </trusted-certificates>

    <!-- trust anchors (CA certs) for netconf/restconf clients -->
    <trusted-certificates>
      <name>deployment-specific-ca-certs</name>
      <description>
        Trust anchors used only to authenticate NETCONF/RESTCONF
        client connections.  Since our security policy only allows
        authentication for clients having a certificate signed by
        our CA, we only configure its certificate below.
      </description>
      <trusted-certificate>
        <name>ca.example.com</name>
        <certificate>
          WmdsK2gyTTg3QmtGMjhWbW1CdFFVaWc3OEgrRkYyRTFwdSt4ZVRJbVFFM
          lLQllsdWpOcjFTMnRLR05EMUc2OVJpK2FWNGw2NTdZNCtadVJMZgpRYjk
          zSFNwSDdwVXBCYnA4dmtNanFtZjJma3RqZHBxeFppUUtTbndWZTF2Zwot
          NGcEk3UE90cnNFVjRwTUNBd0VBQWFPQ0FSSXdnZ0VPCk1CMEdBMVVkRGd
          VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER
          V6QVJCZ05WQkFNVENrTlNUQ0JKYzNOMVpYS0NDUUNVRHBNSll6UG8zREF
          NQmdOVkhSTUJBZjhFCkFqQUFNQTRHQTFVZER3RUIvd1FFQXdJSGdEQnBC
          Z05WSFI4RVlqQmdNRjZnSXFBZ2hoNW9kSFJ3T2k4dlpYaGgKYlhCc1pTN
          WpiMjB2WlhoaGJYQnNaUzVqY215aU9LUTJNRFF4Q3pBSkJnTlZCQVlUQW
          QmdOVkJBWVRBbFZUTVJBd0RnWURWUVFLRXdkbAplR0Z0Y0d4bE1RNHdEQ
          MkF6a3hqUDlVQWtHR0dvS1U1eUc1SVR0Wm0vK3B0R2FieXVDMjBRd2kvZ
          25PZnpZNEhONApXY0pTaUpZK2xtYWs3RTRORUZXZS9RdGp4NUlXZmdvN2
          RJSUJQFRStS0Cg==
        </certificate>
      </trusted-certificate>
    </trusted-certificates>

    <!-- trust anchors for random HTTPS servers on Internet -->
    <trusted-certificates>
```

```
        <name>common-ca-certs</name>
        <description>
          Trusted certificates to authenticate common HTTPS servers.
          These certificates are similar to those that might be
          shipped with a web browser.
        </description>
        <trusted-certificate>
          <name>ex-certificate-authority</name>
          <certificate>
            NGcEk3UE90cnNFVjRwTUNBd0VBQWFPQ0FSSXdnZ0VPCk1CMEdBMVVkRGd
            VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER
            V6QVJCZ05WQkFNVENrTlNUQ0JKYzNOMVpYS0NDUUNVRHBNSll6UG8zREF
            Z05WSFI4RVlqQmdNRjZnSXFBZ2hoNW9kSFJ3T2k4dlpYaGgKYlhCc1pTN
            QmdOVkJBWVRBbFZUTVJBd0RnWURWUVFLRXdkbAplR0Z0Y0d4bE1RNHdEQ
            MkF6a3hqUDlVQWtHR0dvS1U1eUc1SVR0Wm0vK3B0R2FieXVDMjBRd2kvZ
            NQmdOVkhSTUJBZjhFCkFqQUFNQTRHQTFVZER3RUIvd1FFQXdJSGdEQnBC
            WmdsK2gyTTg3QmtGMjhWbW1CdFFVaWc3OEgrRkYyRTFwdSt4ZVRJbVFFM
            lLQllsdWpOcjFTMnRLR05EMUc2OVJpK2FWNGw2NTdZNCtadVJMZgpRYjk
            zSFNwSDdwVXBCYnA4dmtNanFtZjJma3RqZHBxeFppUUtTbndWZTF2Zwot
            25PZnpZNEhONApXY0pTaUpZK2xtYWs3RTRORUZXZS9RdGp4NUlXZmdvN2
            WpiMjB2WlhoaGJYQnNaUzVqY215aU9L=
          </certificate>
        </trusted-certificate>
      </trusted-certificates>

      <!-- trusted SSH host keys -->
      <trusted-ssh-host-keys>
        <name>explicitly-trusted-ssh-host-keys</name>
        <description>
          Trusted SSH host keys used to authenticate SSH servers.
          These host keys would be analogous to those stored in
          a known_hosts file in OpenSSH.
        </description>
        <trusted-host-key>
          <name>corp-fw1</name>
          <host-key>
            VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER
            NGcEk3UE90cnNFVjRwTUNBd0VBQWFPQ0FSSXdnZ0VPCk1CMEdBMVVkRGd
            WpiMjB2WlhoaGJYQnNaUzVqY215aU9L=
          </host-key>
        </trusted-host-key>
      </trusted-ssh-host-keys>

      <!-- user credentials and associated authentication methods -->
      <user-auth-credentials>
        <user-auth-credential>
          <username>admin</username>
          <auth-method>
```

```
          <priority>1</priority>
          <certificate-chain>my-ec-chain</certificate-chain>
          <certificate-chain>my-rsa-chain</certificate-chain>
        </auth-method>
        <auth-method>
          <priority>2</priority>
          <public-key>my-rsa-user-key</public-key>
        </auth-method>
      </user-auth-credential>
      <user-auth-credential>
        <username>tester</username>
        <auth-method>
          <priority>1</priority>
          <cleartext-password>testing123</cleartext-password>
        </auth-method>
      </user-auth-credential>
      <user-auth-credential>
        <username>ldevid</username>
        <auth-method>
          <priority>1</priority>
          <certificate-chain>my-ldevid-chain</certificate-chain>
        </auth-method>
      </user-auth-credential>
    </user-auth-credentials>

  </keystore>
```

The following example illustrates a "certificate-expiration" notification in XML.

['\' line wrapping added for formatting only]

```
<notification
  xmlns="urn:ietf:params:xml:ns:netconf:notification:1.0">
  <eventTime>2016-07-08T00:01:00Z</eventTime>
  <certificate-expiration
    xmlns="urn:ietf:params:xml:ns:yang:ietf-keystore">
    <certificate>
      /ks:keystore/ks:private-keys/ks:private-key/ks:certificate-chains\
      /ks:certificate-chain/ks:certificate[3]
    </certificate>
    <expiration-date>2016-08-08T14:18:53-05:00</expiration-date>
  </certificate-expiration>
</notification>
```

2.3. YANG Module

This YANG module makes extensive use of data types defined in [RFC5280] and [RFC5958].

```
<CODE BEGINS> file "ietf-keystore@2016-10-31.yang"

module ietf-keystore {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-keystore";
  prefix "ks";

  import ietf-yang-types {
    prefix yang;
    reference
      "RFC 6991: Common YANG Data Types";
  }

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

  contact
   "WG Web:   <http://tools.ietf.org/wg/netconf/>
    WG List:  <mailto:netconf@ietf.org>

    WG Chair: Mehmet Ersue
              <mailto:mehmet.ersue@nsn.com>

    WG Chair: Mahesh Jethanandani
              <mailto:mjethanandani@gmail.com>

    Editor:   Kent Watsen
              <mailto:kwatsen@juniper.net>";


  description
   "This module defines a keystore to centralize management of
    security credentials.

    Copyright (c) 2014 IETF Trust and the persons identified as
    authors of the code. All rights reserved.

    Redistribution and use in source and binary forms, with or
    without modification, is permitted pursuant to, and subject
    to the license terms contained in, the Simplified BSD
    License set forth in Section 4.c of the IETF Trust's
```

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

    This version of this YANG module is part of RFC VVVV; see
    the RFC itself for full legal notices.";

  revision "2016-10-31" {
    description
     "Initial version";
    reference
     "RFC VVVV: NETCONF Server and RESTCONF Server Configuration
                Models";
  }


  identity key-algorithm {
    description
      "Base identity from which all key-algorithms are derived.";
  }

  identity rsa {
    base key-algorithm;
    description
      "The RSA algorithm.";
    reference
      "RFC3447: Public-Key Cryptography Standards (PKCS) #1:
                RSA Cryptography Specifications Version 2.1.";
  }

  identity secp192r1 {
    base key-algorithm;
    description
      "The secp192r1 algorithm.";
    reference
      "RFC5480:
         Elliptic Curve Cryptography Subject Public Key Information.";
  }

  identity secp256r1 {
    base key-algorithm;
    description
      "The secp256r1 algorithm.";
    reference
      "RFC5480:
         Elliptic Curve Cryptography Subject Public Key Information.";
  }

  identity secp384r1 {
```

```
    base key-algorithm;
    description
      "The secp384r1 algorithm.";
    reference
      "RFC5480:
         Elliptic Curve Cryptography Subject Public Key Information.";
  }

  identity secp521r1 {
    base key-algorithm;
    description
      "The secp521r1 algorithm.";
    reference
      "RFC5480:
         Elliptic Curve Cryptography Subject Public Key Information.";
  }

  container keystore {
    description
      "A list of private-keys and their associated certificates, as
       well as lists of trusted certificates for client certificate
       authentication.  RPCs are provided to generate a new private
       key and to generate a certificate signing requests.";

    container private-keys {
      description
        "A list of private key maintained by the keystore.";
      list private-key {
        key name;
        description
          "A private key.";
        leaf name {
          type string;
          description
            "An arbitrary name for the private key.";
        }
        leaf algorithm {
          type identityref {
            base "key-algorithm";
          }
          config false;
          description
            "The algorithm used by the private key.";
        }
        leaf key-length {
          type uint32;
          config false;
          description
```

```
            "The key-length used by the private key.";
        }
        leaf public-key {
          type binary;
          config false;
          mandatory true;
          description
            "An OneAsymmetricKey 'publicKey' structure as specified
             by RFC 5958, Section 2 encoded using the ASN.1
             distinguished encoding rules (DER), as specified
             in ITU-T X.690.";
          reference
            "RFC 5958:
                Asymmetric Key Packages
             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 certificate-chains {
          description
            "Certificate chains associated with this private key.
             More than one chain per key is enabled to support,
             for instance, a TPM-protected key that has associated
             both IDevID and LDevID certificates.";
          list certificate-chain {
            key name;
            description
              "A certificate chain for this public key.";
            leaf name {
              type string;
              description
                "An arbitrary name for the certificate chain.  The
                 name must be a unique across all private keys, not
                 just within this private key.";
            }
            leaf-list certificate {
              type binary;
              ordered-by user;
              description
                "An X.509 v3 certificate structure as specified by RFC
                 5280, Section 4 encoded using the ASN.1 distinguished
                 encoding rules (DER), as specified in ITU-T X.690.
                 The list of certificates that run from the server
                 certificate towards the trust anchor.  The chain MAY
                 include the trust anchor certificate itself.";
              reference
```

```
                "RFC 5280:
                   Internet X.509 Public Key Infrastructure Certificate
                   and Certificate Revocation List (CRL) Profile.
                 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).";
            }
          }
        }
        action generate-certificate-signing-request {
          description
            "Generates a certificate signing request structure for
             the associated private key using the passed subject and
             attribute values.  Please review both the Security
             Considerations and Design Considerations sections in
             RFC VVVV for more information regarding this action
             statement.";
          input {
            leaf subject {
              type binary;
              mandatory true;
              description
                "The 'subject' field from the CertificationRequestInfo
                 structure as specified by RFC 2986, Section 4.1 encoded
                 using the 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).";
            }
            leaf attributes {
              type binary;
              description
                "The 'attributes' field from the CertificationRequestInfo
                 structure as specified by RFC 2986, Section 4.1 encoded
                 using the 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).";
            }
          }
          output {
            leaf certificate-signing-request {
              type binary;
              mandatory true;
              description
                "A CertificationRequest structure as specified by RFC
                 2986, Section 4.1 encoded using the 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).";

            }
          }
        }
      }

      action generate-private-key {
        description
          "Requests the device to generate a private key using the
           specified algorithm and key length.";
        input {
          leaf name {
            type string;
            mandatory true;
            description
              "The name this private-key should have when listed
               in /keystore/private-keys.  As such, the passed
               value must not match any existing 'name' value.";
          }
          leaf algorithm {
            type identityref {
              base "key-algorithm";
            }
```

```
            mandatory true;
            description
              "The algorithm to be used when generating the key.";
          }
          leaf key-length {
            type uint32;
            description
              "For algorithms that need a key length specified
               when generating the key.";
          }
        }
      }

      action load-private-key {
        description
          "Requests the device to load a private key";
        input {
          leaf name {
            type string;
            mandatory true;
            description
              "The name this private-key should have when listed
               in /keystore/private-keys.  As such, the passed
               value must not match any existing 'name' value.";
          }
          leaf private-key {
            type binary;
            mandatory true;
              description
                "An OneAsymmetricKey structure as specified by RFC
                 5958, Section 2 encoded using the ASN.1 distinguished
                 encoding rules (DER), as specified in ITU-T X.690.
                 Note that this is the raw private with no shrouding
                 to protect it.  The strength of this private key
                 MUST NOT be greater than the strength of the secure
                 connection over which it is communicated.  Devices
                 SHOULD fail this request if ever that happens.";
              reference
                "RFC 5958:
                    Asymmetric Key Packages
                 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).";
          }
        }
      }
```

```
    }

    list trusted-certificates {
      key name;
      description
        "A list of trusted certificates.  These certificates
         can be used by a server to authenticate clients, or by clients
         to authenticate servers.  The certificates may be endpoint
         specific or for certificate authorities (to authenticate many
         clients at once.  Each list of certificates SHOULD be specific
         to a purpose, as the list as a whole may be referenced by other
         modules.  For instance, a NETCONF server model might point to
         a list of certificates to use when authenticating client
         certificates.";
      leaf name {
        type string;
        description
          "An arbitrary name for this list of trusted certificates.";
      }
      leaf description {
        type string;
        description
          "An arbitrary description for this list of trusted
           certificates.";
      }
      list trusted-certificate {
        key name;
        description
          "A trusted certificate for a specific use.  Note, this
           'certificate' is a list in order to encode any
           associated intermediate certificates.";
        leaf name {
          type string;
          description
            "An arbitrary name for this trusted certificate. Must
             be unique across all lists of trusted certificates
             (not just this list) so that a leafref to it from
             another module can resolve to unique values.";
        }
        leaf certificate {  // rename to 'data'?
          type binary;
          description
            "An X.509 v3 certificate structure as specified by RFC
             5280, Section 4 encoded using the ASN.1 distinguished
             encoding rules (DER), as specified in ITU-T X.690.";
          reference
            "RFC 5280:
               Internet X.509 Public Key Infrastructure Certificate
```

```
               and Certificate Revocation List (CRL) Profile.
             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).";
        }
      }
    }

    list trusted-ssh-host-keys {
      key name;
      description
        "A list of trusted host-keys.  These host-keys can be used
         by clients to authenticate SSH servers.  The host-keys are
         endpoint specific.  Each list of host-keys SHOULD be
         specific to a purpose, as the list as a whole may be
         referenced by other modules.  For instance, a NETCONF
         client model might point to a list of host-keys to use
         when authenticating servers host-keys.";
      leaf name {
        type string;
        description
          "An arbitrary name for this list of trusted SSH host keys.";
      }
      leaf description {
        type string;
        description
          "An arbitrary description for this list of trusted SSH host
           keys.";
      }
      list trusted-host-key {
        key name;
        description
          "A trusted host key.";
        leaf name {
          type string;
          description
            "An arbitrary name for this trusted host-key. Must be
             unique across all lists of trusted host-keys (not just
             this list) so that a leafref to it from another module
             can resolve to unique values.

             Note that, for when the SSH client is able to listen
             for call-home connections as well, there is no reference
             identifier (e.g., hostname, IP address, etc.) that it
             can use to uniquely identify the server with.  The
             call-home draft recommends SSH servers use X.509v3
```

```
             certificates (RFC6187) when calling home.";
        }
        leaf host-key {  // rename to 'data'?
          type binary;
          mandatory true;
          description
            "An OneAsymmetricKey 'publicKey' structure as specified
             by RFC 5958, Section 2 encoded using the ASN.1
             distinguished encoding rules (DER), as specified
             in ITU-T X.690.";
          reference
            "RFC 5958:
                Asymmetric Key Packages
             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).";
        }
      }
    }

/*
Are the auth credentials truly limited to SSH?
Could they be used by an HTTP client to log into an HTTP server?
If truly just for SSH, maybe rename?
*/
    container user-auth-credentials {
      description
        "A list of user authentication credentials that can be used
         by an SSH client to log into an SSH server, using any of
         the supported authentication methods (e.g., password,
         public key, client certificate, etc.).";
      list user-auth-credential {
        key username;
        description
          "The authentication credentials for a specific user.";
        leaf username {
          type string;
          description
            "The username of this user.  This will be the username
             used, for instance, to log into an SSH server.";
        }
        list auth-method {
          key priority;
          description
            "A method of authenticating as this user.";
          leaf priority {
```

```
            type uint8;
            description
              "When multiple authentication methods in this list are
               supported by the server, the one with the lowest priority
               value will be the one that is used.";
          }
          choice auth-type {
            description
              "The authentication type.";
            leaf-list certificate {
              type leafref {
                path "/keystore/private-keys/private-key/"
                     + "certificate-chains/certificate-chain/name";
              }
              ordered-by user;
              description
                "A list of references to certificates that can be used
                 for user authentication.  When multiple certificates
                 in this list supported by the server, the one that
                 comes before the others in the leaf-list will be
                 used.";
            }
            leaf-list public-key {
              type leafref {
                path "/keystore/private-keys/private-key/name";
              }
              ordered-by user;
              description
                "A list of references to public keys that can be used
                 for user authentication.  When multiple public keys
                 in this list supported by the server, the one that
                 comes before the others in the leaf-list will be
                 used.";
            }
            leaf ciphertext-password {
              type string;
              description
                "An ciphertext password.  The method of encipherment
                 and how that method can be determined from this
                 string is implementation-specific.";
            }
            leaf cleartext-password {
              type string;
              description
                "An cleartext password.";
            }
          }
        }
```

```
      }
    }
  }

  notification certificate-expiration {
    description
      "A notification indicating that a configured certificate is
       either about to expire or has already expired.  When to send
       notifications is an implementation specific decision, but
       it is RECOMMENDED that a notification be sent once a month
       for 3 months, then once a week for four weeks, and then once
       a day thereafter.";
    leaf certificate {
      type instance-identifier;
      mandatory true;
      description
        "Identifies which certificate is expiring or is expired.";
    }
    leaf expiration-date {
      type yang:date-and-time;
      mandatory true;
      description
        "Identifies the expiration date on the certificate.";
    }
  }

}


<CODE ENDS>
```

3. Design Considerations

This document, along with four other drafts, was split out from the original draft "draft-ietf-netconf-server-model". The split was made so that each draft would have better focus, and also becuase there was a desire to define client modules, in addition to server modules. The complete list of drafts that resulted from the split includes:

- draft-ietf-netconf-keystore

- draft-ietf-netconf-ssh-client-server

- draft-ietf-netconf-tls-client-server

- draft-ietf-netconf-netconf-client-server

- draft-ietf-netconf-restconf-client-server

This document uses PKCS #10 [RFC2986] for the "generate-certificate-signing-request" action. The use of Certificate Request Message Format (CRMF) [RFC4211] was considered, but is was unclear if there was market demand for it, and so support for CRMF has been left out of this specification. If it is desired to support CRMF in the future, placing a "choice" statement in both the input and output statements, along with an "if-feature" statement on the CRMF option, would enable a backwards compatible solution.

This document puts a limit of the number of elliptical curves supported by default. This was done to match industry trends in IETF best practice (e.g., matching work being done in TLS 1.3). If additional algorithms are needed, they MAY be augmented in by another module, or added directly in a future version of this document.

Both this document and Key Chain YANG Data Model [draft-ietf-rtgwg-yang-key-chain] regard a similar idea. The authors looked at this and agree that they two modules server different purposes and hence not worth merging into one document. To underscore this further, this document renamed its module from "ietf-keychain" to "ietf-keystore", to contrast it with the other document's module "ietf-key-chain".

For the trusted-certificates list, Trust Anchor Format [RFC5914] was evaluated and deemed inappropriate due to this document's need to also support pinning. That is, pinning a client-certificate to support NETCONF over TLS client authentication.

4. Security Considerations

This document defines a keystore mechanism that is entrusted with the safe keeping of private keys, and the safe keeping of trusted certificates. Nowhere in this API is there an ability to access (read out) a private key once it is known to the keystore. Further, associated public keys and attributes (e.g., algorithm name, key length, etc.) are read-only. That said, this document allows for the deletion of private keys and their certificates, as well the deletion of trusted certificates. Access control mechanisms (e.g., NACM [RFC6536]) MUST be in place so as to authorize such client actions. Further, whilst the data model allows for private keys and trusted certificates in general to be deleted, implementations should be well aware that some privates keys (e.g., those in a TPM) and some trusted certificates, should never be deleted, regardless if the authorization mechanisms would generally allow for such actions.

For the "generate-certificate-signing-request" action, it is RECOMMENDED that devices implement assert channel binding [RFC5056], so as to ensure that the application layer that sent the request is

the same as the device authenticated in the secure transport layer was established.

This document defines a data model that includes a list of private keys. These private keys MAY be deleted using standard NETCONF or RESTCONF operations (e.g., <edit-config>). Implementations SHOULD automatically (without explicit request) zeroize these keys in the most secure manner available, so as to prevent the remnants of their persisted storage locations from being analyzed in any meaningful way.

The keystore module define within this document defines the "load-private-key" action enabling a device to load a client-supplied private key. This is a private key with no shrouding to protect it. The strength of this private key MUST NOT be greater than the strength of the underlying secure transport connection over which it is communicated. Devices SHOULD fail this request if ever the strength of the private key is greater then the strength of the underlying transport.

5. IANA Considerations

5.1. The IETF XML Registry

This document registers one URI in the IETF XML registry [RFC2119]. Following the format in [RFC3688], the following registration is requested:

```
URI: urn:ietf:params:xml:ns:yang:ietf-keystore
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 one YANG module in the YANG Module Names registry [RFC6020]. Following the format in [RFC6020], the the following registration is requested:

```
name:         ietf-keystore
namespace:    urn:ietf:params:xml:ns:yang:ietf-keystore
prefix:       kc
reference:    RFC VVVV
```

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7. References

7.1. Normative References

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Appendix A. Change Log

A.1. server-model-09 to 00

- This draft was split out from draft-ietf-netconf-server-model-09.
- Removed key-usage parameter from generate-private-key action.
- Now /private-keys/private-key/certificates/certificate/name must be globally unique (unique across all private keys).
- Added top-level 'trusted-ssh-host-keys' and 'user-auth-credentials' to support SSH client modules.

Appendix B. Open Issues

Please see: https://github.com/netconf-wg/keystore/issues.

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