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YANG Data Types and Groupings for Cryptography
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Abstract

This document presents a YANG 1.1 (RFC 7950) module defining identities, typedefs, and groupings useful to cryptographic applications.

Editorial Note (To be removed by RFC Editor)

This draft contains 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:

* "AAAA" --> the assigned RFC value for this draft

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

* "2020-07-10" --> the publication date of this draft

The following Appendix section is to be removed prior to publication:

* Appendix A. Change Log

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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This Internet-Draft will expire on 11 January 2021.

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Table of Contents

1. Introduction

This document presents a YANG 1.1 [RFC7950] module defining identities, typedefs, and groupings useful to cryptographic applications.

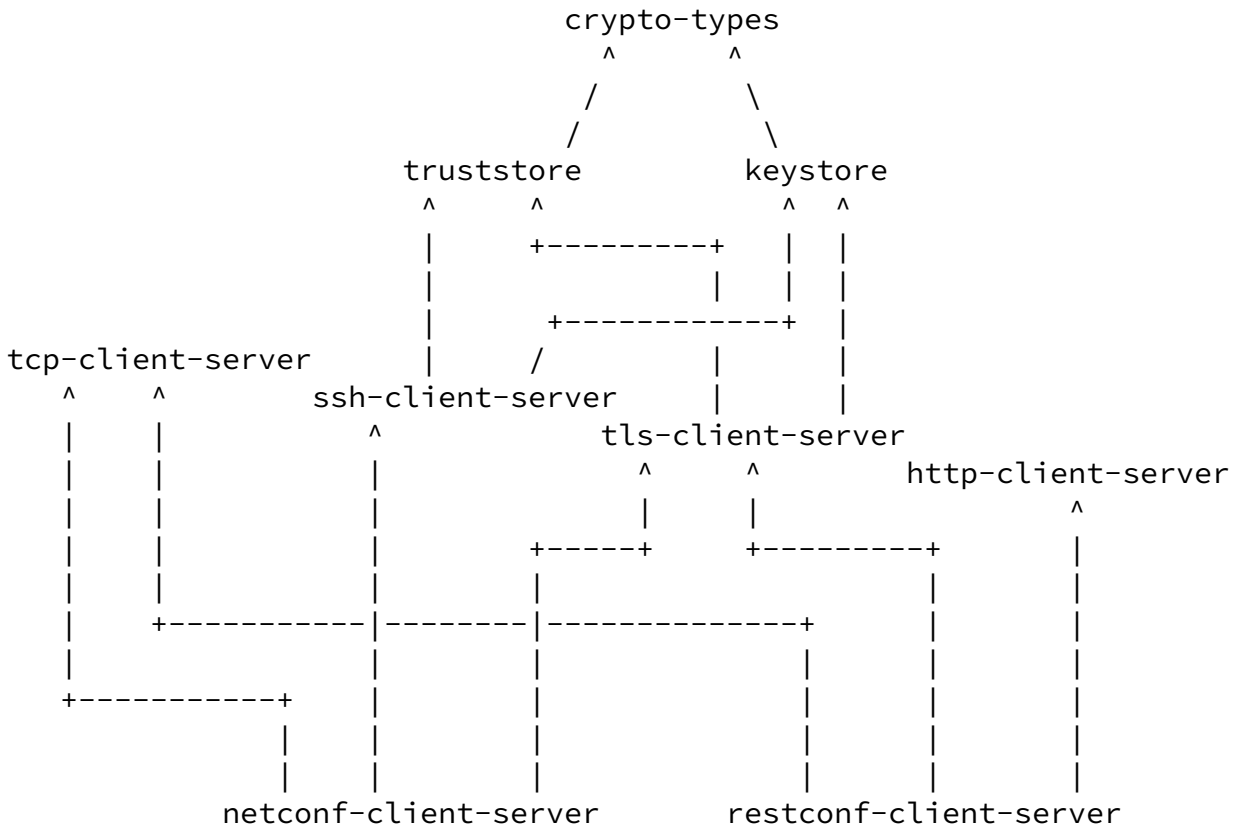
1.1. Relation to other RFCs

This document presents one or more YANG modules [RFC7950] that are part of a collection of RFCs that work together to define configuration modules for clients and servers of both the NETCONF [RFC6241] and RESTCONF [RFC8040] protocols.

The modules have been defined in a modular fashion to enable their use by other efforts, some of which are known to be in progress at the time of this writing, with many more expected to be defined in time.

The relationship between the various RFCs in the collection is

presented in the below diagram. The labels in the diagram represent the primary purpose provided by each RFC. Links the each RFC are provided below the diagram.



Label in Diagram	Originating RFC
crypto-types	[I-D.ietf-netconf-crypto-types]
truststore	[I-D.ietf-netconf-trust-anchors]

keystore	[I-D.ietf-netconf-keystore]
tcp-client-server	[I-D.ietf-netconf-tcp-client-server]
ssh-client-server	[I-D.ietf-netconf-ssh-client-server]
tls-client-server	[I-D.ietf-netconf-tls-client-server]
http-client-server	[I-D.ietf-netconf-http-client-server]
netconf-client-server	[I-D.ietf-netconf-netconf-client-server]
restconf-client-server	[I-D.ietf-netconf-restconf-client-server]

Table 1: Label to RFC Mapping

1.2. Specification 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.

1.3. Adherence to the NMDA

This document in compliant with the Network Management Datastore Architecture (NMDA) [RFC8342]. It does not define any protocol accessible nodes that are "config false".

2. The "ietf-crypto-types" Module

This section defines a YANG 1.1 [RFC7950] module that defines data types (typedefs and identities) and groupings supporting downstream models needing cryptographic primitives.

2.1. Data Model Overview

2.1.1. Features

The following diagram lists all the "feature" statements defined in the "ietf-crypt-types" module:

```
Features:
  +-- one-symmetric-key-format
  +-- one-asymmetric-key-format
  +-- encrypted-one-symmetric-key-format
  +-- encrypted-one-asymmetric-key-format
  +-- certificate-signing-request-generation
```

2.1.2. Identities

The following diagram illustrates the relationship amongst the "identity" statements defined in the "ietf-crypto-types" module:


```
Identities:
  +-- public-key-format
  |  +-- subject-public-key-info-format
  |  +-- ssh-public-key-format
  +-- private-key-format
  |  +-- rsa-private-key-format
  |  +-- ec-private-key-format
  |  +-- one-asymmetric-key-format
  |  |         {one-asymmetric-key-format}?
  |  +-- encrypted-one-asymmetric-key-format
  |            {encrypted-one-asymmetric-key-format}?
  +-- symmetric-key-format
     +-- octet-string-key-format
     +-- one-symmetric-key-format
     |         {one-symmetric-key-format}?
```

```
     +-- encrypted-one-symmetric-key-format
               {encrypted-one-symmetric-key-format}?
```

Comments:

* The diagram shows that there are three base identities. These identities are used by this module to define the format that key data is encoded in. The base identities are "abstract", in the object orientied programming sense, in that they only define a "class" of formats, rather than a specific format.

* The various derived identities define specific key encoding formats. The derived identities defined in this document are sufficient for the effort described in Section 1.1 but, by nature of them being identities, additional derived identities MAY be defined by future efforts.

* Identities use to specify uncommon formats are enabled by "feature" statements, enabling applications to support them when needed.

2.1.3. Typedefs

The following diagram illustrates the relationship amongst the "typedef" statements defined in the "ietf-crypto-types" module:


```
Typedefs:
  binary
    +-- csr-info
    +-- csr
    +-- x509
    |  +-- trust-anchor-cert-x509
    |  +-- end-entity-cert-x509
    +-- crl
```

```
      +-- ocsp-request
      +-- ocsp-response
      +-- cms
         +-- data-content-cms
         +-- signed-data-cms
         |  +-- trust-anchor-cert-cms
         |  +-- end-entity-cert-cms
         +-- enveloped-data-cms
         +-- digested-data-cms
         +-- encrypted-data-cms
         +-- authenticated-data-cms
```

Comments:

* All of the typedefs defined in the "ietf-crypto-types" module extend the "binary" type defined in [RFC7950].

* Additionally, all the typedefs define a type for encoding an ASN.1 [ITU.X680.2015] structure using DER [ITU.X690.2015].

* The "trust-anchor-*" and "end-entity-*" typedefs are syntactically identical to their base typedefs and only distiguish themselves by the expected nature of their content. These typedefs are defined to facilitate common modeling needs.

2.1.4. Groupings

The following diagram lists all the "grouping" statements defined in the "ietf-crypto-types" module:

```
Groupings:
  +-- encrypted-key-value-grouping
  +-- symmetric-key-grouping
  +-- public-key-grouping
  +-- asymmetric-key-pair-grouping
  +-- trust-anchor-cert-grouping
  +-- end-entity-cert-grouping
  +-- generate-csr-grouping
  +-- asymmetric-key-pair-with-cert-grouping
  +-- asymmetric-key-pair-with-certs-grouping
```


Each of these groupings are presented in the following subsections.

2.1.4.1. The "encrypted-key-value-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "encrypted-key-value-grouping" grouping:

```
  grouping encrypted-key-value-grouping
    +-- encrypted-by
    +-- encrypted-value    binary
```

Comments:

* The "encrypted-by" node is an empty container (difficult to see in the diagram) that a consuming module MUST augment key references into. The "ietf-crypto-types" module is unable to populate this container as the module only defines groupings. Section 2.2.1 presents an example illustrating a consuming module populating the "encrypted-by" container.

* The "encrypted-value" node is the key, encrypted by the other key referenced by the "encrypted-by" node, encoded in the format specified by the "format" identity Section 2.1.2 associated with the ancestor node using this grouping.

2.1.4.2. The "symmetric-key-grouping" Grouping

This section presents two tree diagrams [RFC8340] illustrating the "symmetric-key-grouping" grouping. The first tree diagram does not expand the internally used grouping statement(s):

```
  grouping symmetric-key-grouping
    +-- key-format?            identityref
    +-- (key-type)
       +--:(cleartext-key)
       |  +-- cleartext-key?   binary
       +--:(hidden-key)
       |  +-- hidden-key?      empty
       +--:(encrypted-key)
          +-- encrypted-key
             +---u encrypted-key-value-grouping
```

The following tree diagram expands the internally used grouping statement(s), enabling the grouping's full structure to be seen:

```
  grouping symmetric-key-grouping
    +-- key-format?            identityref
    +-- (key-type)
       +--:(cleartext-key)
       |  +-- cleartext-key?   binary
       +--:(hidden-key)
       |  +-- hidden-key?      empty
       +--:(encrypted-key)
          +-- encrypted-key
             +-- encrypted-by
             +-- encrypted-value    binary
```

Comments:

* For the referenced grouping statement(s):

  - The "encrypted-key-value-grouping" grouping is discussed in Section 2.1.4.1.

* The "key-format" node is an identity-reference to the "symmetric-key-format" abstract base identity discussed in Section 2.1.2, enabling the symmetric key to be encoded using the format defined by any of the derived identities.

* The "choice" statement enables the private key data to be plain-text, encrypted, or hidden, as follows:

  - The "key" node can encode any plain-text key value.
  - The "hidden-key" node is of type "empty" as the real value cannot be presented via the management interface.
  - The "encrypted-key" node's structure is discussed in Section 2.1.4.1.

2.1.4.3. The "public-key-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "public-key-grouping" grouping:

```
  grouping public-key-grouping
    +-- public-key-format    identityref
    +-- public-key           binary
```

Comments:

* The "public-key-format" node is an identity-reference to the "public-key-format" abstract base identity discussed in

Section 2.1.2, enabling the public key to be encoded using the format defined by any of the derived identities.

* The "public-key" node is the public key data in the selected format. No "choice" statement is used to hide or encrypt the public key data because it is unecessary to do so for public keys.

2.1.4.4. The "asymmetric-key-pair-grouping" Grouping

This section presents two tree diagrams [RFC8340] illustrating the "asymmetric-key-pair-grouping" grouping. The first tree diagram does not expand the internally used grouping statement(s):

```
  grouping asymmetric-key-pair-grouping
    +---u public-key-grouping
    +-- private-key-format?            identityref
    +-- (private-key-type)
       +--:(cleartext-private-key)
       |  +-- cleartext-private-key?   binary
       +--:(hidden-private-key)
       |  +-- hidden-private-key?      empty
       +--:(encrypted-private-key)
          +-- encrypted-private-key
             +---u encrypted-key-value-grouping
```

The following tree diagram expands the internally used grouping statement(s), enabling the grouping's full structure to be seen:

```
  grouping asymmetric-key-pair-grouping
    +-- public-key-format              identityref
    +-- public-key                     binary
    +-- private-key-format?            identityref
    +-- (private-key-type)
       +--:(cleartext-private-key)
       |  +-- cleartext-private-key?   binary
       +--:(hidden-private-key)
       |  +-- hidden-private-key?      empty
       +--:(encrypted-private-key)
          +-- encrypted-private-key
             +-- encrypted-by
             +-- encrypted-value    binary
```

Comments:

* For the referenced grouping statement(s):

  - The "public-key-grouping" grouping is discussed in Section 2.1.4.3.
  - The "encrypted-key-value-grouping" grouping is discussed in Section 2.1.4.1.

* The "private-key-format" node is an identity-reference to the "private-key-format" abstract base identity discussed in Section 2.1.2, enabling the private key to be encoded using the format defined by any of the derived identities.

* The "choice" statement enables the private key data to be plain-text, encrypted, or hidden, as follows:

  - The "private-key" node can encode any plain-text key value.
  - The "hidden-private-key" node is of type "empty" as the real value cannot be presented via the management interface.
  - The "encrypted-private-key" node's structure is discussed in Section 2.1.4.1.

2.1.4.5. The "certificate-expiration-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "certificate-expiration-grouping" grouping:

```
  grouping certificate-expiration-grouping
    +---n certificate-expiration
       +-- expiration-date    yang:date-and-time
```

Comments:

* This grouping's only purpose is to define the "certificate-expiration" notification statement, used by the groupings defined in Section 2.1.4.6 and Section 2.1.4.7.

* The "certificate-expiration" notification enables servers to notify clients when certificates are nearing expiration.

* The "expiration-date" node indicates when the designated certificate will (or did) expire.

* Identification of the certificate that is expiring is built into the notification itself. For an example, please see Section 2.2.3.

2.1.4.6. The "trust-anchor-cert-grouping" Grouping

This section presents two tree diagrams [RFC8340] illustrating the "trust-anchor-cert-grouping" grouping. The first tree diagram does not expand the internally used grouping statement(s):

```
  grouping trust-anchor-cert-grouping
    +-- cert-data?                          trust-anchor-cert-cms
    +---u certificate-expiration-grouping
```


The following tree diagram expands the internally used grouping statement(s), enabling the grouping's full structure to be seen:

```
  grouping trust-anchor-cert-grouping
    +-- cert-data?                trust-anchor-cert-cms
    +---n certificate-expiration
       +-- expiration-date    yang:date-and-time
```

Comments:

* For the referenced grouping statement(s):

  - The "certificate-expiration-grouping" grouping is discussed in Section 2.1.4.5.

* The "cert-data" node contains a chain of one or more certificates encoded using a "signed-data-cms" typedef discussed in Section 2.1.3.

2.1.4.7. The "end-entity-cert-grouping" Grouping

This section presents two tree diagrams [RFC8340] illustrating the "end-entity-cert-grouping" grouping. The first tree diagram does not expand the internally used grouping statement(s):

```
  grouping end-entity-cert-grouping
    +-- cert-data?                          end-entity-cert-cms
    +---u certificate-expiration-grouping
```

The following tree diagram expands the internally used grouping statement(s), enabling the grouping's full structure to be seen:

```
  grouping end-entity-cert-grouping
    +-- cert-data?                end-entity-cert-cms
    +---n certificate-expiration
       +-- expiration-date    yang:date-and-time
```

Comments:

* For the referenced grouping statement(s):

  - The "certificate-expiration-grouping" grouping is discussed in Section 2.1.4.5.

* The "cert-data" node contains a chain of one or more certificates encoded using a "signed-data-cms" typedef discussed in Section 2.1.3.

2.1.4.8. The "generate-csr-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "generate-csr-grouping" grouping:

```
  grouping generate-csr-grouping
    +---x generate-certificate-signing-request
            {certificate-signing-request-generation}?
       +---w input
       |  +---w csr-info    ct:csr-info
       +--ro output
          +--ro certificate-signing-request    ct:csr
```

Comments:

* This grouping's only purpose is to define the "generate-certificate-signing-request" action statement, used by the groupings defined in Section 2.1.4.9 and Section 2.1.4.10.

* This action takes as input a "csr-info" type and returns a "csr" type, both of which are discussed in Section 2.1.3.

* For an example, please see Section 2.2.2.

2.1.4.9. The "asymmetric-key-pair-with-cert-grouping" Grouping

This section presents two tree diagrams [RFC8340] illustrating the "asymmetric-key-pair-with-cert-grouping" grouping. The first tree diagram does not expand the internally used grouping statement(s):

```
grouping asymmetric-key-pair-with-cert-grouping
  +---u asymmetric-key-pair-grouping
  +---u end-entity-cert-grouping
  +---u generate-csr-grouping
```

The following tree diagram expands the internally used grouping statement(s), enabling the grouping's full structure to be seen:


```
grouping asymmetric-key-pair-with-cert-grouping
  +-- public-key-format                        identityref
  +-- public-key                               binary
  +-- private-key-format?                      identityref
  +-- (private-key-type)
  |  +--:(cleartext-private-key)
  |  |  +-- cleartext-private-key?             binary
  |  +--:(hidden-private-key)
  |  |  +-- hidden-private-key?                empty
  |  +--:(encrypted-private-key)
  |     +-- encrypted-private-key
```

```
      |        +-- encrypted-by
      |        +-- encrypted-value    binary
      +-- cert-data?                                  end-entity-cert-cms
      +---n certificate-expiration
      |  +-- expiration-date    yang:date-and-time
      +---x generate-certificate-signing-request
              {certificate-signing-request-generation}?
         +---w input
         |  +---w csr-info    ct:csr-info
         +--ro output
            +--ro certificate-signing-request    ct:csr
```

Comments:

* This grouping defines an asymmetric key with at most one associated certificate, a commonly needed combination in protocol models.

* For the referenced grouping statement(s):

  - The "asymmetric-key-pair-grouping" grouping is discussed in Section 2.1.4.4.
  - The "end-entity-cert-grouping" grouping is discussed in Section 2.1.4.7.
  - The "generate-csr-grouping" grouping is discussed in Section 2.1.4.8.

2.1.4.10. The "asymmetric-key-pair-with-certs-grouping" Grouping

This section presents two tree diagrams [RFC8340] illustrating the "asymmetric-key-pair-with-certs-grouping" grouping. The first tree diagram does not expand the internally used grouping statement(s):


```
  grouping asymmetric-key-pair-with-certs-grouping
    +---u asymmetric-key-pair-grouping
    +-- certificates
    |  +-- certificate* [name]
```

```
     |     +-- name?                          string
     |     +---u end-entity-cert-grouping
     +---u generate-csr-grouping
```

The following tree diagram expands the internally used grouping statement(s), enabling the grouping's full structure to be seen:

```
  grouping asymmetric-key-pair-with-certs-grouping
    +-- public-key-format                          identityref
    +-- public-key                                 binary
    +-- private-key-format?                        identityref
    +-- (private-key-type)
    |  +--:(cleartext-private-key)
    |  |  +-- cleartext-private-key?               binary
    |  +--:(hidden-private-key)
    |  |  +-- hidden-private-key?                  empty
    |  +--:(encrypted-private-key)
    |     +-- encrypted-private-key
    |        +-- encrypted-by
    |        +-- encrypted-value    binary
    +-- certificates
    |  +-- certificate* [name]
    |     +-- name?                        string
    |     +-- cert-data                    end-entity-cert-cms
    |     +---n certificate-expiration
    |        +-- expiration-date    yang:date-and-time
    +---x generate-certificate-signing-request
            {certificate-signing-request-generation}?
       +---w input
       |  +---w csr-info    ct:csr-info
       +--ro output
          +--ro certificate-signing-request    ct:csr
```

Comments:

* This grouping defines an asymmetric key with one or more associated certificates, a commonly needed combination in configuration models.

* For the referenced grouping statement(s):

  - The "asymmetric-key-pair-grouping" grouping is discussed in Section 2.1.4.4.

- The "end-entity-cert-grouping" grouping is discussed in Section 2.1.4.7.
- The "generate-csr-grouping" grouping is discussed in Section 2.1.4.8.

2.1.5. Protocol-accessible Nodes

The "ietf-crypto-types" module does not contain any protocol-accessible nodes, but the module needs to be "implemented", as described in Section 5.6.5 of [RFC7950], in order for the identities in Section 2.1.2 to be defined.

2.2. Example Usage

2.2.1. The "symmetric-key-grouping" and "asymmetric-key-pair-with-certs-grouping" Grouping

The following non-normative module is constructed in order to illustrate the use of the "symmetric-key-grouping" (Section 2.1.4.2) and the "asymmetric-key-pair-with-certs-grouping" (Section 2.1.4.10) grouping statements:

```
module ex-crypto-types-usage {
  yang-version 1.1;

  namespace "http://example.com/ns/example-crypto-types-usage";
  prefix "ectu";

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

  organization "Example Corporation";
  contact      "YANG Designer <mailto:yang.designer@example.com>";

  description
   "This module illustrates the 'symmetric-key-grouping'
    and 'asymmetric-key-grouping' groupings defined in
    the 'ietf-crypto-types' module defined in RFC AAAA.";

  revision "2020-07-10" {
    description
     "Initial version";
    reference
     "RFC AAAA: Common YANG Data Types for Cryptography";
```

```
    }
```



```
    container symmetric-keys {
      description
        "A container of symmetric keys.";
      list symmetric-key {
        key name;
        description
          "A symmetric key";
        leaf name {
          type string;
          description
            "An arbitrary name for this key.";
        }
        uses ct:symmetric-key-grouping {
          augment "key-type/encrypted-key/encrypted-key/"
                  + "encrypted-by" {
            description
              "Augments in a choice statement enabling the
               encrypting key to be any other symmetric or
               asymmetric key.";
            uses encrypted-by-choice-grouping;
          }
        }
      }
    }

    container asymmetric-keys {
      description
        "A container of asymmetric keys.";
      list asymmetric-key {
        key name;
        leaf name {
          type string;
          description
            "An arbitrary name for this key.";
        }
        uses ct:asymmetric-key-pair-with-certs-grouping {
          augment "private-key-type/encrypted-private-key/"
                  + "encrypted-private-key/encrypted-by" {
            description
              "Augments in a choice statement enabling the
```

```
              encrypting key to be any other symmetric or
              asymmetric key.";
            uses encrypted-by-choice-grouping;
          }
        }
        description
          "An asymmetric key pair with associated certificates.";
      }
```



```
    }

    grouping encrypted-by-choice-grouping {
      description
        "A grouping that defines a choice enabling references
         to other keys.";
      choice encrypted-by-choice {
        mandatory true;
        description
          "A choice amongst other symmetric or asymmetric keys.";
        case symmetric-key-ref {
          leaf symmetric-key-ref {
            type leafref {
              path "/ectu:symmetric-keys/ectu:symmetric-key/"
                   + "ectu:name";
            }
            description
             "Identifies the symmetric key used to encrypt this key.";
          }
        }
        case asymmetric-key-ref {
          leaf asymmetric-key-ref {
            type leafref {
              path "/ectu:asymmetric-keys/ectu:asymmetric-key/"
                   + "ectu:name";
            }
            description
             "Identifies the asymmetric key used to encrypt this key.";
          }
        }
      }
    }
  }
```

The tree diagram [RFC8340] for this example module follows:

```
module: ex-crypto-types-usage
  +--rw symmetric-keys
  |  +--rw symmetric-key* [name]
  |     +--rw name                    string
  |     +--rw key-format?             identityref
  |     +--rw (key-type)
  |        +--:(cleartext-key)
  |        |  +--rw cleartext-key?    binary
  |        +--:(hidden-key)
  |        |  +--rw hidden-key?       empty
  |        +--:(encrypted-key)
  |           +--rw encrypted-key
```



```
  |              +--rw encrypted-by
  |              |  +--rw (encrypted-by-choice)
  |              |     +--:(symmetric-key-ref)
  |              |     |  +--rw symmetric-key-ref?    leafref
  |              |     +--:(asymmetric-key-ref)
  |              |        +--rw asymmetric-key-ref?   leafref
  |              +--rw encrypted-value    binary
  +--rw asymmetric-keys
     +--rw asymmetric-key* [name]
        +--rw name                                    string
        +--rw public-key-format                       identityref
        +--rw public-key                              binary
        +--rw private-key-format?                     identityref
        +--rw (private-key-type)
        |  +--:(cleartext-private-key)
        |  |  +--rw cleartext-private-key?           binary
        |  +--:(hidden-private-key)
        |  |  +--rw hidden-private-key?              empty
        |  +--:(encrypted-private-key)
        |     +--rw encrypted-private-key
        |        +--rw encrypted-by
        |        |  +--rw (encrypted-by-choice)
        |        |     +--:(symmetric-key-ref)
        |        |     |  +--rw symmetric-key-ref?    leafref
        |        |     +--:(asymmetric-key-ref)
        |        |        +--rw asymmetric-key-ref?   leafref
```

```
          |        +--rw encrypted-value    binary
          +--rw certificates
          |  +--rw certificate* [name]
          |     +--rw name                       string
          |     +--rw cert-data                  end-entity-cert-cms
          |     +---n certificate-expiration
          |        +-- expiration-date    yang:date-and-time
          +---x generate-certificate-signing-request
                  {certificate-signing-request-generation}?
             +---w input
             |  +---w csr-info    ct:csr-info
             +--ro output
                +--ro certificate-signing-request    ct:csr

  grouping encrypted-by-choice-grouping
    +-- (encrypted-by-choice)
       +--:(symmetric-key-ref)
       |  +-- symmetric-key-ref?
       |          -> /symmetric-keys/symmetric-key/name
       +--:(asymmetric-key-ref)
          +-- asymmetric-key-ref?
                  -> /asymmetric-keys/asymmetric-key/name
```


Finally, the following example illustrates various symmetric and asymmetric keys as they might appear in confugration:

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

<symmetric-keys
  xmlns="http://example.com/ns/example-crypto-types-usage"
  xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-crypto-types">
  <symmetric-key>
    <name>ex-hidden-symmetric-key</name>
    <hidden-key/>
  </symmetric-key>
  <symmetric-key>
    <name>ex-octet-string-based-symmetric-key</name>
    <key-format>ct:octet-string-key-format</key-format>
    <cleartext-key>base64encodedvalue==</cleartext-key>
  </symmetric-key>
  <symmetric-key>
    <name>ex-one-symmetric-based-symmetric-key</name>
```

```
      <key-format>ct:one-symmetric-key-format</key-format>
      <cleartext-key>base64encodedvalue==</cleartext-key>
    </symmetric-key>
    <symmetric-key>
      <name>ex-encrypted-one-symmetric-based-symmetric-key</name>
      <key-format>ct:encrypted-one-symmetric-key-format</key-format>
      <encrypted-key>
        <encrypted-by>
          <asymmetric-key-ref>ex-hidden-asymmetric-key</asymmetric-key\
-ref>
        </encrypted-by>
        <encrypted-value>base64encodedvalue==</encrypted-value>
      </encrypted-key>
    </symmetric-key>
  </symmetric-keys>

  <asymmetric-keys
    xmlns="http://example.com/ns/example-crypto-types-usage"
    xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-crypto-types">
    <asymmetric-key>
      <name>ex-hidden-asymmetric-key</name>
      <public-key-format>
        ct:subject-public-key-info-format
      </public-key-format>
      <public-key>base64encodedvalue==</public-key>
      <hidden-private-key/>
      <certificates>
        <certificate>
          <name>ex-hidden-asymmetric-key-cert</name>
```



```
          <cert-data>base64encodedvalue==</cert-data>
        </certificate>
      </certificates>
    </asymmetric-key>
    <asymmetric-key>
      <name>ex-subject-public-info-based-asymmetric-key</name>
      <public-key-format>
        ct:subject-public-key-info-format
      </public-key-format>
      <public-key>base64encodedvalue==</public-key>
      <private-key-format>
        ct:rsa-private-key-format
```

```
      </private-key-format>
      <cleartext-private-key>base64encodedvalue==</cleartext-private-k\
ey>
      <certificates>
        <certificate>
          <name>ex-cert</name>
          <cert-data>base64encodedvalue==</cert-data>
        </certificate>
      </certificates>
    </asymmetric-key>
    <asymmetric-key>
      <name>ex-one-asymmetric-based-symmetric-key</name>
      <public-key-format>
        ct:subject-public-key-info-format
      </public-key-format>
      <public-key>base64encodedvalue==</public-key>
      <private-key-format>
        ct:one-asymmetric-key-format
      </private-key-format>
      <cleartext-private-key>base64encodedvalue==</cleartext-private-k\
ey>
    </asymmetric-key>
    <asymmetric-key>
      <name>ex-encrypted-one-asymmetric-based-symmetric-key</name>
      <public-key-format>
        ct:subject-public-key-info-format
      </public-key-format>
      <public-key>base64encodedvalue==</public-key>
      <private-key-format>
        ct:encrypted-one-asymmetric-key-format
      </private-key-format>
      <encrypted-private-key>
        <encrypted-by>
          <symmetric-key-ref>ex-encrypted-one-symmetric-based-symmetri\
c-key</symmetric-key-ref>
        </encrypted-by>
```



```
        <encrypted-value>base64encodedvalue==</encrypted-value>
      </encrypted-private-key>
    </asymmetric-key>
  </asymmetric-keys>
```

2.2.2. The "generate-certificate-signing-request" Action

The following example illustrates the "generate-certificate-signing-request" action, discussed in Section 2.1.4.8, 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">
    <asymmetric-keys
      xmlns="http://example.com/ns/example-crypto-types-usage">
      <asymmetric-key>
        <name>ex-key-sect571r1</name>
        <generate-certificate-signing-request>
          <csr-info>base64encodedvalue==</csr-info>
        </generate-certificate-signing-request>
      </asymmetric-key>
    </asymmetric-keys>
  </action>
</rpc>
```

RESPONSE

```
<rpc-reply message-id="101"
   xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
   <certificate-signing-request
     xmlns="http://example.com/ns/example-crypto-types-usage">
     base64encodedvalue==
   </certificate-signing-request>
</rpc-reply>
```

2.2.3. The "certificate-expiration" Notification

The following example illustrates the "certificate-expiration" notification, discussed in Section 2.1.4.5, with the NETCONF protocol.

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

<notification
  xmlns="urn:ietf:params:xml:ns:netconf:notification:1.0">
  <eventTime>2018-05-25T00:01:00Z</eventTime>
  <asymmetric-keys xmlns="http://example.com/ns/example-crypto-types\
-usage">
    <asymmetric-key>
      <name>ex-hidden-asymmetric-key</name>
      <certificates>
        <certificate>
          <name>ex-hidden-asymmetric-key</name>
          <certificate-expiration>
            <expiration-date>2018-08-05T14:18:53-05:00</expiration-d\
ate>
          </certificate-expiration>
        </certificate>
      </certificates>
    </asymmetric-key>
  </asymmetric-keys>
</notification>
```

2.3. YANG Module

This module has normative references to [RFC2119], [RFC2986], [RFC3447], [RFC4253], [RFC5280], [RFC5652], [RFC5915], [RFC5958], [RFC6031], [RFC6125], [RFC6991], [RFC8174], [RFC8341], and [ITU.X690.2015].

```
<CODE BEGINS> file "ietf-crypto-types@2020-07-10.yang"

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

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

  import ietf-netconf-acm {
    prefix nacm;
    reference
      "RFC 8341: Network Configuration Access Control Model";
  }
```

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

  contact
    "WG Web:   <http://datatracker.ietf.org/wg/netconf/>
     WG List:  <mailto:netconf@ietf.org>
     Author:   Kent Watsen <mailto:kent+ietf@watsen.net>";

  description
    "This module defines common YANG types for cryptographic
     applications.

     Copyright (c) 2020 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
     (https://trustee.ietf.org/license-info).

     This version of this YANG module is part of RFC AAAA
     (https://www.rfc-editor.org/info/rfcAAAA); 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 2020-07-10 {
    description
      "Initial version";
    reference
      "RFC AAAA: YANG Data Types and Groupings for Cryptography";
  }


  /****************/
```

```
  /*   Features   */
  /*****************/

  feature one-symmetric-key-format {
    description
      "Indicates that the server supports the
```



```
       'one-symmetric-key-format' identity.";
  }

  feature one-asymmetric-key-format {
    description
      "Indicates that the server supports the
       'one-asymmetric-key-format' identity.";
  }

  feature encrypted-one-symmetric-key-format {
    description
      "Indicates that the server supports the
       'encrypted-one-symmetric-key-format' identity.";
  }

  feature encrypted-one-asymmetric-key-format {
    description
      "Indicates that the server supports the
       'encrypted-one-asymmetric-key-format' identity.";
  }

  feature certificate-signing-request-generation {
    description
      "Indicates that the server implements the
       'generate-certificate-signing-request' action.";
  }


  /************************************************/
  /*   Base Identities for Key Format Structures   */
  /************************************************/

  identity symmetric-key-format {
    description "Base key-format identity for symmetric keys.";
  }
```

```
  identity public-key-format {
    description "Base key-format identity for public keys.";
  }

  identity private-key-format {
    description "Base key-format identity for private keys.";
  }


  /*************************************************/
  /*   Identities for Private Key Format Structures   */
  /*************************************************/
```



```
  identity rsa-private-key-format {
    base "private-key-format";
    description
      "Indicates that the private key value is encoded
       as an RSAPrivateKey (from RFC 3447).";
    reference
      "RFC 3447: PKCS #1: RSA Cryptography
                 Specifications Version 2.2";
  }

  identity ec-private-key-format {
    base "private-key-format";
    description
      "Indicates that the private key value is encoded
       as an ECPrivateKey (from RFC 5915)";
    reference
      "RFC 5915: Elliptic Curve Private Key Structure";
  }

  identity one-asymmetric-key-format {
    if-feature "one-asymmetric-key-format";
    base "private-key-format";
    description
      "Indicates that the private key value is a CMS
       OneAsymmetricKey structure, as defined in RFC 5958,
       encoded using 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).";
      }

      identity encrypted-one-asymmetric-key-format {
        if-feature "encrypted-one-asymmetric-key-format";
        base "private-key-format";
        description
          "Indicates that the private key value is a CMS EnvelopedData
           structure, per Section 8 in RFC 5652, containing a
           OneAsymmetricKey structure, as defined in RFC 5958,
           encoded using ASN.1 distinguished encoding rules (DER),
           as specified in ITU-T X.690.";
        reference
          "RFC 5652: Cryptographic Message Syntax (CMS)
           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).";
       }


      /****************************************************/
      /*   Identities for Public Key Format Structures    */
      /****************************************************/

      identity ssh-public-key-format {
        base "public-key-format";
        description
          "Indicates that the public key value is an SSH public key,
           as specified by RFC 4253, Section 6.6, i.e.:

             string    certificate or public key format
                       identifier
             byte[n]   key/certificate data.";
```

```
      reference
        "RFC 4253: The Secure Shell (SSH) Transport Layer Protocol";
    }

    identity subject-public-key-info-format {
      base "public-key-format";
      description
        "Indicates that the public key value is a SubjectPublicKeyInfo
         structure, as described in RFC 5280 encoded using 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).";
    }


    /*****************************************************/
    /*   Identities for Symmetric Key Format Structures   */
    /*****************************************************/
```



```
    identity octet-string-key-format {
      base "symmetric-key-format";
      description
        "Indicates that the key is encoded as a raw octet string.
         The length of the octet string MUST be appropriate for
         the associated algorithm's block size.";
    }

    identity one-symmetric-key-format {
      if-feature "one-symmetric-key-format";
      base "symmetric-key-format";
      description
        "Indicates that the private key value is a CMS
         OneSymmetricKey structure, as defined in RFC 6031,
```

```
       encoded using ASN.1 distinguished encoding rules
       (DER), as specified in ITU-T X.690.";
    reference
      "RFC 6031: Cryptographic Message Syntax (CMS)
                 Symmetric Key Package Content Type
       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).";
  }

  identity encrypted-one-symmetric-key-format {
    if-feature "encrypted-one-symmetric-key-format";
    base "symmetric-key-format";
    description
      "Indicates that the private key value is a CMS
       EnvelopedData structure, per Section 8 in RFC 5652,
       containing a OneSymmetricKey structure, as defined
       in RFC 6031, encoded using ASN.1 distinguished
       encoding rules (DER), as specified in ITU-T X.690.";
    reference
      "RFC 5652: Cryptographic Message Syntax (CMS)
       RFC 6031: Cryptographic Message Syntax (CMS)
                 Symmetric Key Package Content Type
       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).";
  }


  /*************************************************/
```



```
  /*   Typedefs for ASN.1 structures from RFC 2986   */
  /*************************************************/

  typedef csr-info {
    type binary;
    description
      "A CertificationRequestInfo structure, 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).";
  }

  typedef csr {
    type binary;
    description
      "A CertificationRequest structure, as specified 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).";
  }

  /*************************************************/
  /*   Typedefs for ASN.1 structures from RFC 5280   */
  /*************************************************/

  typedef x509 {
    type binary;
    description
      "A Certificate structure, as specified in RFC 5280,
       encoded using 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).";
}

typedef crl {
  type binary;
  description
    "A CertificateList structure, as specified in RFC 5280,
     encoded using 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).";
}


/*************************************************/
/*   Typedefs for ASN.1 structures from RFC 6960   */
/*************************************************/

typedef oscp-request {
  type binary;
  description
    "A OCSPRequest structure, as specified in RFC 6960,
     encoded using ASN.1 distinguished encoding rules
     (DER), as specified in ITU-T X.690.";
  reference
    "RFC 6960:
        X.509 Internet Public Key Infrastructure Online
        Certificate Status Protocol - OCSP
      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).";
}
```

```
typedef oscp-response {
  type binary;
  description
    "A OCSPResponse structure, as specified in RFC 6960,
     encoded using ASN.1 distinguished encoding rules
     (DER), as specified in ITU-T X.690.";
  reference
    "RFC 6960:
       X.509 Internet Public Key Infrastructure Online
       Certificate Status Protocol - OCSP
     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).";
}


/*********************************************/
/*   Typedefs for ASN.1 structures from 5652   */
/*********************************************/

typedef cms {
  type binary;
  description
    "A ContentInfo structure, as specified in RFC 5652,
     encoded using ASN.1 distinguished encoding rules (DER),
     as specified in ITU-T X.690.";
  reference
    "RFC 5652:
       Cryptographic Message Syntax (CMS)
     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).";
}

typedef data-content-cms {
  type cms;
  description
    "A CMS structure whose top-most content type MUST be the
     data content type, as described by Section 4 in RFC 5652.";
```

```
      reference
        "RFC 5652: Cryptographic Message Syntax (CMS)";
    }

    typedef signed-data-cms {
```



```
      type cms;
      description
        "A CMS structure whose top-most content type MUST be the
         signed-data content type, as described by Section 5 in
         RFC 5652.";
      reference
        "RFC 5652: Cryptographic Message Syntax (CMS)";
    }

    typedef enveloped-data-cms {
      type cms;
      description
        "A CMS structure whose top-most content type MUST be the
         enveloped-data content type, as described by Section 6
         in RFC 5652.";
      reference
        "RFC 5652: Cryptographic Message Syntax (CMS)";
    }

    typedef digested-data-cms {
      type cms;
      description
        "A CMS structure whose top-most content type MUST be the
         digested-data content type, as described by Section 7
         in RFC 5652.";
      reference
        "RFC 5652: Cryptographic Message Syntax (CMS)";
    }

    typedef encrypted-data-cms {
      type cms;
      description
        "A CMS structure whose top-most content type MUST be the
         encrypted-data content type, as described by Section 8
         in RFC 5652.";
      reference
```

```
        "RFC 5652: Cryptographic Message Syntax (CMS)";
    }

    typedef authenticated-data-cms {
      type cms;
      description
        "A CMS structure whose top-most content type MUST be the
         authenticated-data content type, as described by Section 9
         in RFC 5652.";
      reference
        "RFC 5652: Cryptographic Message Syntax (CMS)";
    }
```



```
    /****************************************************/
    /*   Typedefs for ASN.1 structures related to RFC 5280   */
    /****************************************************/

    typedef trust-anchor-cert-x509 {
      type x509;
      description
        "A Certificate structure that MUST encode a self-signed
         root certificate.";
    }

    typedef end-entity-cert-x509 {
      type x509;
      description
        "A Certificate structure that MUST encode a certificate
         that is neither self-signed nor having Basic constraint
         CA true.";
    }


    /****************************************************/
    /*   Typedefs for ASN.1 structures related to RFC 5652   */
    /****************************************************/

    typedef trust-anchor-cert-cms {
      type signed-data-cms;
      description
        "A CMS SignedData structure that MUST contain the chain of
         X.509 certificates needed to authenticate the certificate
```

```
        presented by a client or end-entity.

        The CMS MUST contain only a single chain of certificates.
        The client or end-entity certificate MUST only authenticate
        to last intermediate CA certificate listed in the chain.

        In all cases, the chain MUST include a self-signed root
        certificate.  In the case where the root certificate is
        itself the issuer of the client or end-entity certificate,
        only one certificate is present.

        This CMS structure MAY (as applicable where this type is
        used) also contain suitably fresh (as defined by local
        policy) revocation objects with which the device can
        verify the revocation status of the certificates.

        This CMS encodes the degenerate form of the SignedData
        structure that is commonly used to disseminate X.509
        certificates and revocation objects (RFC 5280).";
```



```
      reference
        "RFC 5280:
           Internet X.509 Public Key Infrastructure Certificate
           and Certificate Revocation List (CRL) Profile.";
    }

    typedef end-entity-cert-cms {
      type signed-data-cms;
      description
        "A CMS SignedData structure that MUST contain the end
         entity certificate itself, and MAY contain any number
         of intermediate certificates leading up to a trust
         anchor certificate.  The trust anchor certificate
         MAY be included as well.

         The CMS MUST contain a single end entity certificate.
         The CMS MUST NOT contain any spurious certificates.

         This CMS structure MAY (as applicable where this type is
         used) also contain suitably fresh (as defined by local
         policy) revocation objects with which the device can
         verify the revocation status of the certificates.
```

```
         This CMS encodes the degenerate form of the SignedData
         structure that is commonly used to disseminate X.509
         certificates and revocation objects (RFC 5280).";
      reference
        "RFC 5280:
          Internet X.509 Public Key Infrastructure Certificate
          and Certificate Revocation List (CRL) Profile.";
    }


    /*********************************************/
    /*   Groupings for keys and/or certificates   */
    /*********************************************/

    grouping encrypted-key-value-grouping {
      description
        "A reusable grouping for a value that has been encrypted by
         a symmetric or asymmetric key in the Keystore.";
      container encrypted-by {
        nacm:default-deny-write;
        description
          "An empty container enabling references to other keys that
           encrypt these keys to be augmented in.  The referenced key
           MAY be a symmetric or an asymmetric key.";
      }
```



```
      leaf encrypted-value {
        nacm:default-deny-write;
        type binary;
        must "../encrypted-by";
        mandatory true;
        description
          "The key data, encrypted using the referenced symmetric
           or asymmetric key.  The format of the encrypted value
           is identicated by the associated key format identity.";
      }
    }

    grouping symmetric-key-grouping {
      description
        "A symmetric key.";
```

```
      leaf key-format {
        nacm:default-deny-write;
        type identityref {
          base symmetric-key-format;
        }
        description "Identifies the symmetric key's format.";
      }
      choice key-type {
        nacm:default-deny-write;
        mandatory true;
        description
          "Choice between key types.";
        case cleartext-key {
          leaf cleartext-key {
            nacm:default-deny-all;
            type binary;
            must "../key-format";
            description
              "The binary value of the key.  The interpretation of
               the value is defined by the 'key-format' field.";
          }
        }
        case hidden-key {
          leaf hidden-key {
            type empty;
            must "not(../key-format)";
            description
              "A hidden key.  How such keys are created is outside
               the scope of this module.";
          }
        }
        case encrypted-key {
          container encrypted-key {
```



```
            must "../key-format";
            description
              "A container for the encrypted symmetric key value.";
            uses encrypted-key-value-grouping;
          }
        }
      }
    }
```

```
grouping public-key-grouping {
  description
    "A public key.";
  leaf public-key-format {
    nacm:default-deny-write;
    type identityref {
      base public-key-format;
    }
    mandatory true;
    description "Identifies the key's format.";
  }
  leaf public-key {
    nacm:default-deny-write;
    type binary;
    mandatory true;
    description
      "The binary value of the public key.  The interpretation
       of the value is defined by 'public-key-format' field.";
  }
}

grouping asymmetric-key-pair-grouping {
  description
    "A private key and its associated public key.";
  uses public-key-grouping;
  leaf private-key-format {
    nacm:default-deny-write;
    type identityref {
      base private-key-format;
    }
    description "Identifies the key's format.";
  }
  choice private-key-type {
    nacm:default-deny-write;
    mandatory true;
    description
      "Choice between key types.";
    case cleartext-private-key {
      leaf cleartext-private-key {
```



```
        nacm:default-deny-all;
```

```
          type binary;
          must "../private-key-format";
          description
            "The value of the binary key  The key's value is
             interpreted by the 'private-key-format' field.";
        }
      }
      case hidden-private-key {
        leaf hidden-private-key {
          type empty;
          must "not(../private-key-format)";
          description
            "A hidden key.  How such keys are created is
             outside the scope of this module.";
        }
      }
      case encrypted-private-key {
        container encrypted-private-key {
          must "../private-key-format";
          description
           "A container for the encrypted asymmetric private
             key value.";
          uses encrypted-key-value-grouping;
        }
      }
    }
  }

  grouping certificate-expiration-grouping {
    description
      "A notification for when a certificate is about to, or
      already has, expired.";
    notification certificate-expiration {
      description
        "A notification indicating that the 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 until the issue is resolved.";
      leaf expiration-date {
        type yang:date-and-time;
        mandatory true;
        description
          "Identifies the expiration date on the certificate.";
      }
    }
```

```
    }

    grouping trust-anchor-cert-grouping {
      description
        "A trust anchor certificate, and a notification for when
         it is about to (or already has) expire.";
      leaf cert-data {
        nacm:default-deny-write;
        type trust-anchor-cert-cms;
        description
          "The binary certificate data for this certificate.";
      }
      uses certificate-expiration-grouping;
    }

    grouping end-entity-cert-grouping {
      description
        "An end entity certificate, and a notification for when
         it is about to (or already has) expire.  Implementations
         SHOULD assert that, where used, the end entity certificate
         contains the expected public key.";
      leaf cert-data {
        nacm:default-deny-write;
        type end-entity-cert-cms;
        description
          "The binary certificate data for this certificate.";
      }
      uses certificate-expiration-grouping;
    }

    grouping generate-csr-grouping {
      description
        "Defines the 'generate-certificate-signing-request' action.";
      action generate-certificate-signing-request {
        if-feature certificate-signing-request-generation;
        nacm:default-deny-all;
        description
          "Generates a certificate signing request structure for
           the associated asymmetric key using the passed subject
           and attribute values.

           This action statement is only available when the
           associated 'public-key-format' node's value is
           'subject-public-key-info-format'.";
        reference
          "RFC 6125:
```

```
        Infrastructure Using X.509 (PKIX) Certificates in the
        Context of Transport Layer Security (TLS)";
      input {
        leaf csr-info {
          type ct:csr-info;
          mandatory true;
          description
            "A CertificationRequestInfo structure, as defined in
             RFC 2986.

             Enables the client to provide a fully-populated
             CertificationRequestInfo structure that the server
             only needs to sign in order to generate the complete
             'CertificationRequest' structure to return in the
             'output'.

             The 'AlgorithmIdentifier' field contained inside
             the 'SubjectPublicKeyInfo' field MUST be one known
             to be supported by the device.";
          reference
            "RFC 2986:
               PKCS #10: Certification Request Syntax Specification
             RFC AAAA:
               YANG Data Types and Groupings for Cryptography";
        }
      }
      output {
        leaf certificate-signing-request {
          type ct:csr;
          mandatory true;
          description
            "A CertificationRequest structure, as defined in
             RFC 2986.";
          reference
            "RFC 2986:
               PKCS #10: Certification Request Syntax Specification
             RFC AAAA:
               YANG Data Types and Groupings for Cryptography";
        }
```

```
      }
    }
  } // generate-csr-grouping

  grouping asymmetric-key-pair-with-cert-grouping {
    description
      "A private/public key pair and an associated certificate.
       Implementations SHOULD assert that certificates contain
       the matching public key.";
```



```
    uses asymmetric-key-pair-grouping;
    uses end-entity-cert-grouping;
    uses generate-csr-grouping;
  } // asymmetric-key-pair-with-cert-grouping

  grouping asymmetric-key-pair-with-certs-grouping {
    description
      "A private/public key pair and associated certificates.
       Implementations SHOULD assert that certificates contain
       the matching public key.";
    uses asymmetric-key-pair-grouping;
    container certificates {
      nacm:default-deny-write;
      description
        "Certificates associated with this asymmetric key.
         More than one certificate supports, for instance,
         a TPM-protected asymmetric key that has both IDevID
         and LDevID certificates associated.";
      list certificate {
        key "name";
        description
          "A certificate for this asymmetric key.";
        leaf name {
          type string;
          description
            "An arbitrary name for the certificate.  If the name
             matches the name of a certificate that exists
             independently in <operational> (i.e., an IDevID),
             then the 'cert' node MUST NOT be configured.";
        }
        uses end-entity-cert-grouping {
          refine cert-data {
```

```
              mandatory true;
            }
          }
        }
      }
      uses generate-csr-grouping;
    } // asymmetric-key-pair-with-certs-grouping

  }

  <CODE ENDS>
```

3. Security Considerations

3.1. No Support for CRMF

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. If it is desired to support CRMF in the future, a backwards compatible solution can be defined at that time.

3.2. No Support for Key Generation

Early revisions of this document included "rpc" statements for generating symmetric and asymmetric keys. There statements were removed due to an inability to obtain consensus for how to identify the key-algorithm to use. Thusly, the solution presented in this document only supports keys to be configured via an external client, which does not support Security best practice.

3.3. Strength of Keys Configured

When configuring key values, implementations SHOULD ensure that the strength of the key being configured is not greater than the strength of the underlying secure transport connection over which it is communicated. Implementations SHOULD fail the write-request if ever the strength of the private key is greater then the strength of the underlying transport.

3.4. Deletion of Cleartext Key Values

This module defines storage for cleartext key values that SHOULD be zeroized when deleted, so as to prevent the remnants of their persisted storage locations from being analyzed in any meaningful way.

The cleartext key nodes are the "key" node defined in the "symmetric-key-grouping" grouping (Section 2.1.4.2) and the "private-key" node defined in the "asymmetric-key-pair-grouping" grouping ("Section 2.1.4.4).

3.5. The "ietf-crypto-types" YANG Module

The YANG module in this document defines "grouping" statements that are designed to be accessed via YANG based management protocols, such as NETCONF [RFC6241] and RESTCONF [RFC8040]. Both of these protocols have mandatory-to-implement secure transport layers (e.g., SSH, TLS) with mutual authentication.

The NETCONF access control model (NACM) [RFC8341] provides the means to restrict access for particular users to a pre-configured subset of all available protocol operations and content.

Since the module in this document only define groupings, these considerations are primarily for the designers of other modules that use these groupings.

Some of the readable data nodes defined in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. These are the subtrees and data nodes and their sensitivity/vulnerability:

* The "key" node:

  The cleartext "key" node defined in the "symmetric-key-grouping" grouping is additionally sensitive to read operations

such that, in normal use cases, it should never be returned to a client. For this reason, the NACM extension "default-deny-all" has been applied to it.

* The "private-key" node:

  The cleartext "private-key" node defined in the "asymmetric-key-pair-grouping" grouping is additionally sensitive to read operations such that, in normal use cases, it should never be returned to a client. For this reason, the NACM extension "default-deny-all" has been applied.

All of the writable data nodes defined by all the groupings defined in this module may be considered sensitive or vulnerable in some network environments. For instance, even the modification of a public key or a certificate can dramatically alter the implemented security policy. For this reason, the NACM extension "default-deny-write" has been applied to all the data nodes defined in the module.

Some of the operations in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control access to these operations. These are the operations and their sensitivity/vulnerability:

* generate-certificate-signing-request:

  This "action" statement SHOULD only be executed by authorized users. For this reason, the NACM extension "default-deny-all" has been applied. Note that NACM uses "default-deny-all" to protect "RPC" and "action" statements; it does not define, e.g., an extension called "default-deny-execute".

  For this action, it is RECOMMENDED that implementations assert channel binding [RFC5056], so as to ensure that the application layer that sent the request is the same as the device authenticated when the secure transport layer was established.

4. IANA Considerations

4.1. The "IETF XML" Registry

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

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

4.2. 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-crypto-types
namespace:    urn:ietf:params:xml:ns:yang:ietf-crypto-types
prefix:       ct
reference:    RFC AAAA
```

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Appendix A. Change Log

This section is to be removed before publishing as an RFC.

A.1. I-D to 00

* Removed groupings and notifications.

* Added typedefs for identityrefs.

* Added typedefs for other RFC 5280 structures.

* Added typedefs for other RFC 5652 structures.

* Added convenience typedefs for RFC 4253, RFC 5280, and RFC 5652.

A.2. 00 to 01

* Moved groupings from the draft-ietf-netconf-keystore here.

A.3. 01 to 02

* Removed unwanted "mandatory" and "must" statements.

* Added many new crypto algorithms (thanks Haiguang!)

* Clarified in asymmetric-key-pair-with-certs-grouping, in certificates/certificate/name/description, that if the name MUST NOT match the name of a certificate that exists independently in <operational>, enabling certs installed by the manufacturer (e.g., an IDevID).

A.4. 02 to 03

* renamed base identity 'asymmetric-key-encryption-algorithm' to 'asymmetric-key-algorithm'.

* added new 'asymmetric-key-algorithm' identities for secp192r1, secp224r1, secp256r1, secp384r1, and secp521r1.

* removed 'mac-algorithm' identities for mac-aes-128-ccm, mac-aes-192-ccm, mac-aes-256-ccm, mac-aes-128-gcm, mac-aes-192-gcm, mac-aes-256-gcm, and mac-chacha20-poly1305.

* for all -cbc and -ctr identities, renamed base identity 'symmetric-key-encryption-algorithm' to 'encryption-algorithm'.

* for all -ccm and -gcm identities, renamed base identity 'symmetric-key-encryption-algorithm' to 'encryption-and-mac-algorithm' and renamed the identity to remove the "enc-" prefix.

* for all the 'signature-algorithm' based identities, renamed from 'rsa-*' to 'rsassa-*'.

* removed all of the "x509v3-" prefixed 'signature-algorithm' based identities.

* added 'key-exchange-algorithm' based identities for 'rsaes-oaep' and 'rsaes-pkcs1-v1_5'.

* renamed typedef 'symmetric-key-encryption-algorithm-ref' to 'symmetric-key-algorithm-ref'.

* renamed typedef 'asymmetric-key-encryption-algorithm-ref' to 'asymmetric-key-algorithm-ref'.

* added typedef 'encryption-and-mac-algorithm-ref'.

* Updated copyright date, boilerplate template, affiliation, and folding algorithm.

A.5. 03 to 04

* ran YANG module through formatter.

A.6. 04 to 05

* fixed broken symlink causing reformatted YANG module to not show.

A.7. 05 to 06

* Added NACM annotations.

* Updated Security Considerations section.

* Added 'asymmetric-key-pair-with-cert-grouping' grouping.

* Removed text from 'permanently-hidden' enum regarding such keys not being backed up or restored.

* Updated the boilerplate text in module-level "description" statement to match copyeditor convention.

* Added an explanation to the 'public-key-grouping' and 'asymmetric-key-pair-grouping' statements as for why the nodes are not mandatory (e.g., because they may exist only in <operational>.

* Added 'must' expressions to the 'public-key-grouping' and 'asymmetric-key-pair-grouping' statements ensuring sibling nodes are either all exist or do not all exist.

* Added an explanation to the 'permanently-hidden' that the value cannot be configured directly by clients and servers MUST fail any attempt to do so.

* Added 'trust-anchor-certs-grouping' and 'end-entity-certs-grouping' (the plural form of existing groupings).

* Now states that keys created in <operational> by the *-hidden-key actions are bound to the lifetime of the parent 'config true' node, and that subsequent invocations of either action results in a failure.

A.8. 06 to 07

* Added clarifications that implementations SHOULD assert that configured certificates contain the matching public key.

* Replaced the 'generate-hidden-key' and 'install-hidden-key' actions with special 'crypt-hash' -like input/output values.

A.9. 07 to 08

* Removed the 'generate-key and 'hidden-key' features.

* Added grouping symmetric-key-grouping

* Modified 'asymmetric-key-pair-grouping' to have a 'choice' statement for the keystone module to augment into, as well as replacing the 'union' with leafs (having different NACM settings.

A.10. 08 to 09

* Converting algorithm from identities to enumerations.

A.11. 09 to 10

* All of the below changes are to the algorithm enumerations defined in ietf-crypto-types.

* Add in support for key exchange over x.25519 and x.448 based on RFC 8418.

* Add in SHAKE-128, SHAKE-224, SHAKE-256, SHAKE-384 and SHAKE 512

* Revise/add in enum of signature algorithm for x25519 and x448

* Add in des3-cbc-sha1 for IPSec

* Add in sha1-des3-kd for IPSec

* Add in definit for rc4-hmac and rc4-hmac-exp. These two algorithms have been deprecated in RFC 8429. But some existing draft in i2nsf may still want to use them.

* Add x25519 and x448 curve for asymmetric algorithms

* Add signature algorithms ed25519, ed25519-cts, ed25519ph

* add signature algorithms ed448, ed448ph

* Add in rsa-sha2-256 and rsa-sha2-512 for SSH protocols (rfc8332)

A.12. 10 to 11

* Added a "key-format" identity.

* Added symmetric keys to the example in Section 2.2.

A.13. 11 to 12

* Removed all non-essential (to NC/RC) algorithm types.

* Moved remaining algorithm types each into its own module.

* Added a 'config false' "algorithms-supported" list to each of the algorithm-type modules.

A.14. 12 to 13

* Added the four features: "[encrypted-]one-[a]symmetric-key-format", each protecting a 'key-format' identity of the same name.

* Added 'must' expressions asserting that the 'key-format' leaf exists whenever a non-hidden key is specified.

* Improved the 'description' statements and added 'reference' statements for the 'key-format' identities.

* Added a questionable forward reference to "encrypted-*" leafs in a couple 'when' expressions.

* Did NOT move "config false" alg-supported lists to SSH/TLS drafts.

A.15. 13 to 14

* Resolved the "FIXME: forward ref" issue by modulating 'must', 'when', and 'mandatory' expressions.

* Moved the 'generatesymmetric-key' and 'generate-asymmetric-key' actions from ietf-keystore to ietf-crypto-types, now as RPCs.

* Cleaned up various description statements and removed lingering FIXMEs.

* Converted the "iana-<alg-type>-algs" YANG modules to IANA registries with instructions for how to generate modules from the registries, whenever they may be updated.

A.16. 14 to 15

* Removed the IANA-maintained registries for symmetric, asymmetric, and hash algorithms.

* Removed the "generate-symmetric-key" and "generate-asymmetric-key" RPCs.

* Removed the "algorithm" node in the various symmetric and asymmetric key groupings.

* Added 'typedef csr' and 'feature certificate-signing-request-generation'.

* Refined a usage of "end-entity-cert-grouping" to make the "cert" node mandatory true.

* Added a "Note to Reviewers" note to first page.

A.17. 15 to 16

* Updated draft title (refer to "Groupings" too).

* Removed 'end-entity-certs-grouping' as it wasn't being used anywhere.

* Removed 'trust-anchor-certs-grouping' as it was no longer being used after modifying 'local-or-truststore-certs-grouping' to use lists (not leaf-lists).

* Renamed "cert" to "cert-data" in trust-anchor-cert-grouping.

* Added "csr-info" typedef, to complement the existing "csr" typedef.

* Added "ocsp-request" and "ocsp-response" typedefs, to complement the existing "crl" typedef.

* Added "encrypted" cases to both symmetric-key-grouping and asymmetric-key-pair-grouping (Moved from Keystore draft).

* Expanded "Data Model Overview section(s) [remove "wall" of tree diagrams].

* Updated the Security Considerations section.

A.18. 16 to 17

* [Re]-added a "Strength of Keys Configured" Security Consideration

* Prefixed "cleartext-" in the "key" and "private-key" node names.

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