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NETCONF Client and Server Models
draft-ietf-netconf-netconf-client-server-08

Abstract

This document defines two YANG modules, one module to configure a NETCONF client and the other module to configure a NETCONF server. Both modules support both the SSH and TLS transport protocols, and support both standard NETCONF and NETCONF Call Home connections.

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:

- I-D.ietf-netconf-keystore
- I-D.ietf-netconf-ssh-client-server
- I-D.ietf-netconf-tls-client-server

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

- "XXXX" --> the assigned RFC value for this draft
- "YYYY" --> the assigned RFC value for I-D.ietf-netconf-ssh-client-server
- "ZZZZ" --> the assigned RFC value for I-D.ietf-netconf-tls-client-server

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

o "2018-10-22" --> the publication date of this draft

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

o Appendix A. Change Log

Status of This Memo

Copyright Notice

Table of Contents

1. Introduction

This document defines two YANG [RFC7950] modules, one module to configure a NETCONF [RFC6241] client and the other module to configure a NETCONF server. Both modules support both NETCONF over SSH [RFC6242] and NETCONF over TLS [RFC7589] and NETCONF Call Home connections [RFC8071].

2. Terminology

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

3. The NETCONF Client Model

The NETCONF client model presented in this section supports both clients initiating connections to servers, as well as clients listening for connections from servers calling home.

This model supports both the SSH and TLS transport protocols, using the SSH client and TLS client groupings defined in [I-D.ietf-netconf-ssh-client-server] and [I-D.ietf-netconf-tls-client-server] respectively.

All private keys and trusted certificates are held in the keystore model defined in [I-D.ietf-netconf-keystore].

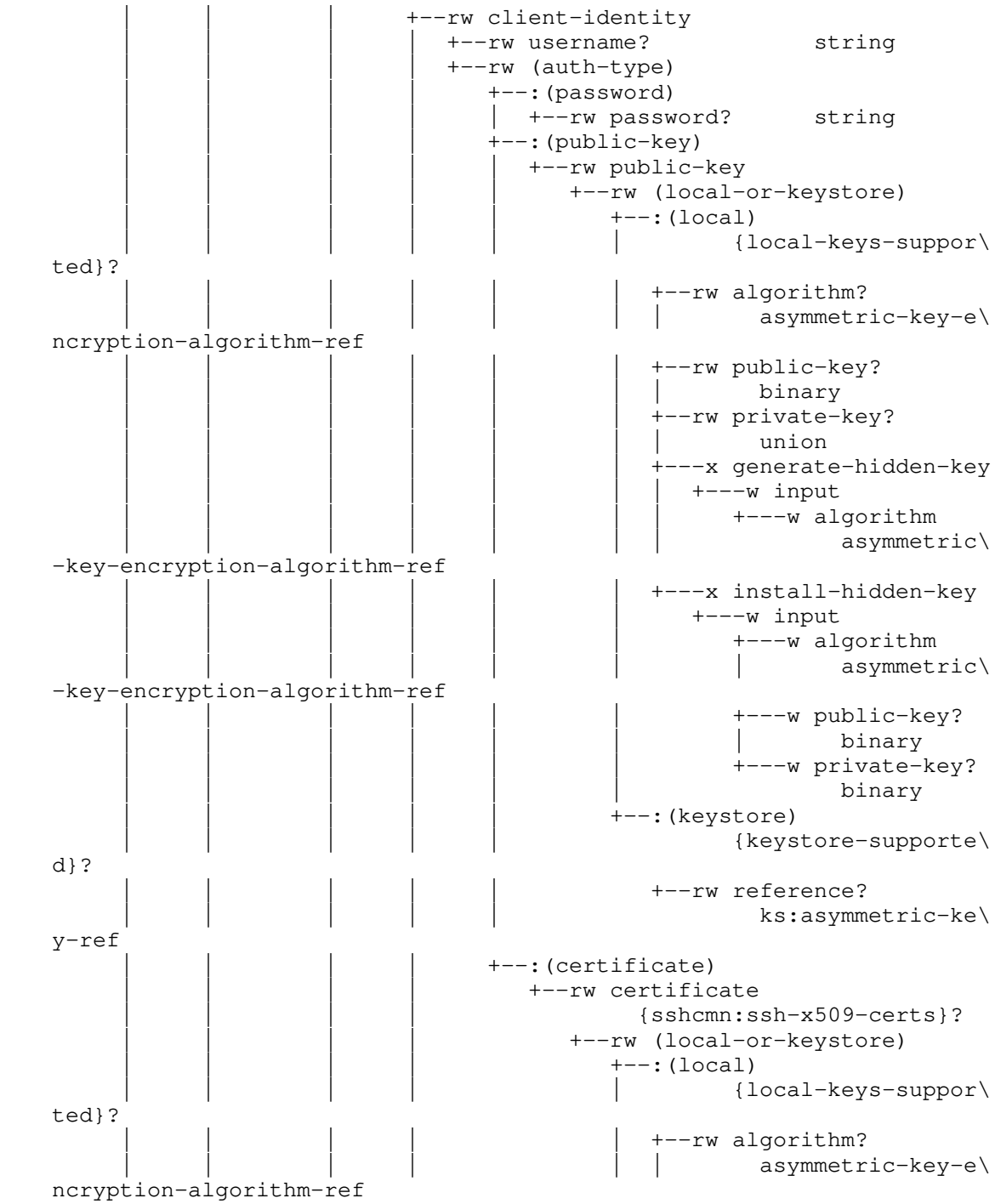
YANG feature statements are used to enable implementations to advertise which parts of the model the NETCONF client supports.

3.1. Tree Diagram

The following tree diagram [RFC8340] provides an overview of the data model for the "ietf-netconf-client" module. Just the container is displayed below, but there is also a reusable grouping called "netconf-client-grouping" that the container is using.

[Note: '\' line wrapping for formatting only]

```
module: ietf-netconf-client
  +--rw netconf-client
     +--rw initiate! {initiate}?
     |  +--rw netconf-server* [name]
     |     +--rw name                    string
     |     +--rw endpoints
     |     |  +--rw endpoint* [name]
     |     |     +--rw name         string
     |     |     +--rw (transport)
     |     |        +--:(ssh) {ssh-initiate}?
     |     |        |  +--rw ssh
     |     |        |     +--rw address?            inet:host
     |     |        |     +--rw port?               inet:port-number
```


+--rw client-identity
+--rw username? string
+--rw (auth-type)
+--:(password)
+--rw password? string
+--:(public-key)
+--rw public-key
+--rw (local-or-keystore)
+--:(local)
{local-keys-supported}?
+--rw algorithm?
asymmetric-key-encryption-algorithm-ref
+--rw public-key?
binary
+--rw private-key?
union
+---x generate-hidden-key
+---w input
+---w algorithm
asymmetric-key-encryption-algorithm-ref
+---x install-hidden-key
+---w input
+---w algorithm
asymmetric-key-encryption-algorithm-ref
+---w public-key?
binary
+---w private-key?
binary
+--:(keystore)
{keystore-supported}?
+--rw reference?
ks:asymmetric-key-ref
+--:(certificate)
+--rw certificate
{sshcmn:ssh-x509-certs}?
+--rw (local-or-keystore)
+--:(local)
{local-keys-supported}?
+--rw algorithm?
asymmetric-key-encryption-algorithm-ref

```
      |      |         |      |                |  +--rw public-key?
      |      |         |      |                |  |       binary
      |      |         |      |                |  +--rw private-key?
      |      |         |      |                |  |       union
      |      |         |      |                |  +---x generate-hidden-key
      |      |         |      |                |  |  +---w input
      |      |         |      |                |  |     +---w algorithm
      |      |         |      |                |  |             asymmetric\
   -key-encryption-algorithm-ref
      |      |         |      |                |  +---x install-hidden-key
      |      |         |      |                |  |  +---w input
      |      |         |      |                |  |     +---w algorithm
      |      |         |      |                |  |     |       asymmetric\
   -key-encryption-algorithm-ref
      |      |         |      |                |  |     +---w public-key?
      |      |         |      |                |  |     |       binary
      |      |         |      |                |  |     +---w private-key?
      |      |         |      |                |  |             binary
      |      |         |      |                |  +--rw cert?
      |      |         |      |                |  |       end-entity-cert-\
   cms
      |      |         |      |                |  +---n certificate-expira\
   tion
      |      |         |      |                |     +-- expiration-date
      |      |         |      |                |             yang:date-and\
   -time
      |      |         |      |              +--:(keystore)
      |      |         |      |                       {keystore-supporte\
   d}?
      |      |         |      |                   +--rw reference?
      |      |         |      |                           ks:asymmetric-ke\
   y-certificate-ref
      |      |         |    +--rw server-auth
      |      |         |    |  +--rw pinned-ssh-host-keys?
      |      |         |    |  |       ta:pinned-host-keys-ref
      |      |         |    |  |       {ta:ssh-host-keys}?
      |      |         |    |  +--rw pinned-ca-certs?
      |      |         |    |  |       ta:pinned-certificates-ref
      |      |         |    |  |       {sshcmn:ssh-x509-certs,ta:x509-\
   certificates}?
      |      |         |    |  +--rw pinned-server-certs?
      |      |         |    |          ta:pinned-certificates-ref
      |      |         |    |          {sshcmn:ssh-x509-certs,ta:x509-\
   certificates}?
      |      |         |    +--rw transport-params
      |      |         |           {ssh-client-transport-params-confi\
   g}?
      |      |         |       +--rw host-key
```

```
        |      |         |        |  +--rw host-key-alg*   identityref
        |      |         |        +--rw key-exchange
        |      |         |        |  +--rw key-exchange-alg*   identityref
        |      |         |        +--rw encryption
        |      |         |        |  +--rw encryption-alg*   identityref
        |      |         |        +--rw mac
        |      |         |           +--rw mac-alg*   identityref
        |      |         +--:(tls) {tls-initiate}?
        |      |            +--rw tls
        |      |               +--rw address?           inet:host
        |      |               +--rw port?              inet:port-number
        |      |               +--rw client-identity
        |      |                  +--rw (auth-type)
        |      |                     +--:(certificate)
        |      |                        +--rw certificate
        |      |                           +--rw (local-or-keystore)
        |      |                              +--:(local)
        |      |                                 |        {local-keys-suppor\
   ted}?
        |      |                                 |  +--rw algorithm?
        |      |                                 |  |       asymmetric-key-e\
   ncryption-algorithm-ref
        |      |                                 |  +--rw public-key?
        |      |                                 |  |       binary
        |      |                                 |  +--rw private-key?
        |      |                                 |  |       union
        |      |                                 |  +---x generate-hidden-key
        |      |                                 |  |  +---w input
        |      |                                 |  |     +---w algorithm
        |      |                                 |  |             asymmetric\
   -key-encryption-algorithm-ref
        |      |                                 |  +---x install-hidden-key
        |      |                                 |  |  +---w input
        |      |                                 |  |     +---w algorithm
        |      |                                 |  |     |       asymmetric\
   -key-encryption-algorithm-ref
        |      |                                 |  |     +---w public-key?
        |      |                                 |  |     |       binary
        |      |                                 |  |     +---w private-key?
        |      |                                 |  |             binary
        |      |                                 |  +--rw cert?
        |      |                                 |  |       end-entity-cert-\
   cms
        |      |                                 |  +---n certificate-expira\
   tion
        |      |                                 |     +-- expiration-date
        |      |                                 |             yang:date-and\
   -time
```

```
        |      |               |              +--:(keystore)
        |      |               |                       {keystore-supporte\
   d}?
        |      |               |                  +--rw reference?
        |      |               |                          ks:asymmetric-ke\
   y-certificate-ref
        |      |               +--rw server-auth
        |      |               |  +--rw pinned-ca-certs?
        |      |               |  |       ta:pinned-certificates-ref
        |      |               |  |       {ta:x509-certificates}?
        |      |               |  +--rw pinned-server-certs?
        |      |               |          ta:pinned-certificates-ref
        |      |               |          {ta:x509-certificates}?
        |      |               +--rw hello-params
        |      |                       {tls-client-hello-params-config}?
        |      |                  +--rw tls-versions
        |      |                  |  +--rw tls-version*   identityref
        |      |                  +--rw cipher-suites
        |      |                     +--rw cipher-suite*   identityref
        |      +--rw connection-type
        |      |  +--rw (connection-type)
        |      |     +--:(persistent-connection)
        |      |     |  +--rw persistent!
        |      |     |     +--rw keep-alives
        |      |     |        +--rw max-wait?       uint16
        |      |     |        +--rw max-attempts?   uint8
        |      |     +--:(periodic-connection)
        |      |        +--rw periodic!
        |      |           +--rw period?         uint16
        |      |           +--rw anchor-time?    yang:date-and-time
        |      |           +--rw idle-timeout?   uint16
        |      +--rw reconnect-strategy
        |         +--rw start-with?     enumeration
        |         +--rw max-attempts?   uint8
        +--rw listen! {listen}?
           +--rw idle-timeout?   uint16
           +--rw endpoint* [name]
              +--rw name         string
              +--rw (transport)
                 +--:(ssh) {ssh-listen}?
                 |  +--rw ssh
                 |     +--rw address?            inet:ip-address
                 |     +--rw port?               inet:port-number
                 |     +--rw client-identity
                 |     |  +--rw username?            string
                 |     |  +--rw (auth-type)
                 |     |     +--:(password)
                 |     |     |  +--rw password?      string
```

```
                  |      |     +--:(public-key)
                  |      |     |  +--rw public-key
                  |      |     |     +--rw (local-or-keystore)
                  |      |     |        +--:(local) {local-keys-supported\
   }?
                  |      |     |           |  +--rw algorithm?
                  |      |     |           |  |       asymmetric-key-encrypt\
   ion-algorithm-ref
                  |      |     |           |  +--rw public-key?
                  |      |     |           |  |       binary
                  |      |     |           |  +--rw private-key?
                  |      |     |           |  |       union
                  |      |     |           |  +---x generate-hidden-key
                  |      |     |           |  |  +---w input
                  |      |     |           |  |     +---w algorithm
                  |      |     |           |  |             asymmetric-key-e\
   ncryption-algorithm-ref
                  |      |     |           |  +---x install-hidden-key
                  |      |     |           |     +---w input
                  |      |     |           |        +---w algorithm
                  |      |     |           |        |       asymmetric-key-e\
   ncryption-algorithm-ref
                  |      |     |           |        +---w public-key?    bin\
   ary
                  |      |     |           |        +---w private-key?   bin\
   ary
                  |      |     |           +--:(keystore) {keystore-supporte\
   d}?
                  |      |     |              +--rw reference?
                  |      |     |                      ks:asymmetric-key-ref
                  |      |     +--:(certificate)
                  |      |        +--rw certificate {sshcmn:ssh-x509-cert\
   s}?
                  |      |           +--rw (local-or-keystore)
                  |      |              +--:(local) {local-keys-supported\
   }?
                  |      |                 |  +--rw algorithm?
                  |      |                 |  |       asymmetric-key-encrypt\
   ion-algorithm-ref
                  |      |                 |  +--rw public-key?
                  |      |                 |  |       binary
                  |      |                 |  +--rw private-key?
                  |      |                 |  |       union
                  |      |                 |  +---x generate-hidden-key
                  |      |                 |  |  +---w input
                  |      |                 |  |     +---w algorithm
                  |      |                 |  |             asymmetric-key-e\
   ncryption-algorithm-ref
```

```
                |      |              |  +---x install-hidden-key
                |      |              |  |  +---w input
                |      |              |  |     +---w algorithm
                |      |              |  |     |       asymmetric-key-e\
   ncryption-algorithm-ref
                |      |              |  |     +---w public-key?    bin\
   ary
                |      |              |  |     +---w private-key?   bin\
   ary
                |      |              |  +--rw cert?
                |      |              |  |       end-entity-cert-cms
                |      |              |  +---n certificate-expiration
                |      |              |     +-- expiration-date
                |      |              |                yang:date-and-time
                |      |             +--:(keystore) {keystore-supporte\
   d}?
                |      |                +--rw reference?
                |      |                        ks:asymmetric-key-cert\
   ificate-ref
                |      +--rw server-auth
                |      |  +--rw pinned-ssh-host-keys?
                |      |  |       ta:pinned-host-keys-ref
                |      |  |       {ta:ssh-host-keys}?
                |      |  +--rw pinned-ca-certs?
                |      |  |       ta:pinned-certificates-ref
                |      |  |       {sshcmn:ssh-x509-certs,ta:x509-certif\
   icates}?
                |      |  +--rw pinned-server-certs?
                |      |          ta:pinned-certificates-ref
                |      |          {sshcmn:ssh-x509-certs,ta:x509-certif\
   icates}?
                |      +--rw transport-params
                |             {ssh-client-transport-params-config}?
                |         +--rw host-key
                |         |  +--rw host-key-alg*   identityref
                |         +--rw key-exchange
                |         |  +--rw key-exchange-alg*   identityref
                |         +--rw encryption
                |         |  +--rw encryption-alg*   identityref
                |         +--rw mac
                |            +--rw mac-alg*   identityref
                |     +--:(tls) {tls-listen}?
                |        +--rw tls
                |           +--rw address?           inet:ip-address
                |           +--rw port?              inet:port-number
                |           +--rw client-identity
                |           |  +--rw (auth-type)
                |           |     +--:(certificate)
```

```
                        |        +--rw certificate
                        |           +--rw (local-or-keystore)
                        |              +--:(local) {local-keys-supported\
   }?
                        |                 |  +--rw algorithm?
                        |                 |  |       asymmetric-key-encrypt\
   ion-algorithm-ref
                        |                 |  +--rw public-key?
                        |                 |  |       binary
                        |                 |  +--rw private-key?
                        |                 |  |       union
                        |                 |  +---x generate-hidden-key
                        |                 |  |  +---w input
                        |                 |  |     +---w algorithm
                        |                 |  |             asymmetric-key-e\
   ncryption-algorithm-ref
                        |                 |  +---x install-hidden-key
                        |                 |  |  +---w input
                        |                 |  |     +---w algorithm
                        |                 |  |     |       asymmetric-key-e\
   ncryption-algorithm-ref
                        |                 |  |     +---w public-key?    bin\
   ary
                        |                 |  |     +---w private-key?   bin\
   ary
                        |                 |  +--rw cert?
                        |                 |  |       end-entity-cert-cms
                        |                 |  +---n certificate-expiration
                        |                 |     +-- expiration-date
                        |                 |                yang:date-and-time
                        |                 +--:(keystore) {keystore-supporte\
   d}?
                        |                    +--rw reference?
                        |                            ks:asymmetric-key-cert\
   ificate-ref
                        +--rw server-auth
                        |  +--rw pinned-ca-certs?
                        |  |       ta:pinned-certificates-ref
                        |  |       {ta:x509-certificates}?
                        |  +--rw pinned-server-certs?
                        |          ta:pinned-certificates-ref
                        |          {ta:x509-certificates}?
                        +--rw hello-params
                               {tls-client-hello-params-config}?
                           +--rw tls-versions
                           |  +--rw tls-version*   identityref
                           +--rw cipher-suites
                              +--rw cipher-suite*   identityref
```

3.2. Example Usage

The following example illustrates configuring a NETCONF client to initiate connections, using both the SSH and TLS transport protocols, as well as listening for call-home connections, again using both the SSH and TLS transport protocols.

This example is consistent with the examples presented in Section 3.2 of [I-D.ietf-netconf-keystore].

[Note: '\' line wrapping for formatting only]

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

  <!-- NETCONF servers to initiate connections to -->
  <initiate>
    <netconf-server>
      <name>corp-fw1</name>
      <endpoints>
        <endpoint>
          <name>corp-fw1.example.com</name>
          <ssh>
            <address>corp-fw1.example.com</address>
            <client-identity>
              <username>foobar</username>
              <public-key>
                <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:iet\
f-crypto-types">ct:rsa2048</algorithm>
                <private-key>base64encodedvalue==</private-key>
                <public-key>base64encodedvalue==</public-key>
              </public-key>
            </client-identity>
            <server-auth>
              <pinned-ca-certs>explicitly-trusted-server-ca-certs</p\
inned-ca-certs>
              <pinned-server-certs>explicitly-trusted-server-certs</\
pinned-server-certs>
            </server-auth>
          </ssh>
        </endpoint>
        <endpoint>
          <name>corp-fw2.example.com</name>
          <ssh>
            <address>corp-fw2.example.com</address>
            <client-identity>
              <username>foobar</username>
```

```
                <public-key>
                  <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:iet\
   f-crypto-types">ct:rsa2048</algorithm>
                  <private-key>base64encodedvalue==</private-key>
                  <public-key>base64encodedvalue==</public-key>
                </public-key>
              </client-identity>
              <server-auth>
                <pinned-ca-certs>explicitly-trusted-server-ca-certs</p\
   inned-ca-certs>
                <pinned-server-certs>explicitly-trusted-server-certs</\
   pinned-server-certs>
              </server-auth>
            </ssh>
          </endpoint>
        </endpoints>
        <connection-type>
          <persistent/>
        </connection-type>
        <reconnect-strategy>
          <start-with>last-connected</start-with>
        </reconnect-strategy>
      </netconf-server>
    </initiate>

    <!-- endpoints to listen for NETCONF Call Home connections on -->
    <listen>
      <endpoint>
        <name>Intranet-facing listener</name>
        <ssh>
          <address>192.0.2.7</address>
          <client-identity>
            <username>foobar</username>
            <public-key>
              <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-cr\
   ypto-types">ct:rsa2048</algorithm>
              <private-key>base64encodedvalue==</private-key>
              <public-key>base64encodedvalue==</public-key>
            </public-key>
          </client-identity>
          <server-auth>
            <pinned-ca-certs>explicitly-trusted-server-ca-certs</pinne\
   d-ca-certs>
            <pinned-server-certs>explicitly-trusted-server-certs</pinn\
   ed-server-certs>
            <pinned-ssh-host-keys>explicitly-trusted-ssh-host-keys</pi\
   nned-ssh-host-keys>
          </server-auth>
```

```
        </ssh>
      </endpoint>
    </listen>
  </netconf-client>
```

3.3. YANG Module

This YANG module has normative references to [RFC6242], [RFC6991], [RFC7589], [RFC8071], [I-D.ietf-netconf-ssh-client-server], and [I-D.ietf-netconf-tls-client-server].

```
<CODE BEGINS> file "ietf-netconf-client@2018-10-22.yang"
module ietf-netconf-client {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-netconf-client";
  prefix "ncc";

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

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

  import ietf-ssh-client {
    prefix ss;
    revision-date 2018-10-22; // stable grouping definitions
    reference
      "RFC YYYY: YANG Groupings for SSH Clients and SSH Servers";
  }

  import ietf-tls-client {
    prefix ts;
    revision-date 2018-10-22; // stable grouping definitions
    reference
      "RFC ZZZZ: YANG Groupings for TLS Clients and TLS Servers";
  }

  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:kwatsen@juniper.net>

        Author:   Gary Wu
                  <mailto:garywu@cisco.com>";


      description
       "This module contains a collection of YANG definitions for
        configuring NETCONF clients.

        Copyright (c) 2017 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 XXXX; see
        the RFC itself for full legal notices.";

      revision "2018-10-22" {
        description
         "Initial version";
        reference
         "RFC XXXX: NETCONF Client and Server Models";
      }

      // Features

      feature initiate {
        description
         "The 'initiate' feature indicates that the NETCONF client
          supports initiating NETCONF connections to NETCONF servers
          using at least one transport (e.g., SSH, TLS, etc.).";
      }

      feature ssh-initiate {
        description
         "The 'ssh-initiate' feature indicates that the NETCONF client
          supports initiating SSH connections to NETCONF servers.";
        reference
```

```
       "RFC 6242:
          Using the NETCONF Protocol over Secure Shell (SSH)";
    }

    feature tls-initiate {
      description
       "The 'tls-initiate' feature indicates that the NETCONF client
        supports initiating TLS connections to NETCONF servers.";
      reference
       "RFC 7589: Using the NETCONF Protocol over Transport
                  Layer Security (TLS) with Mutual X.509
                  Authentication";
    }

    feature listen {
      description
       "The 'listen' feature indicates that the NETCONF client
        supports opening a port to accept NETCONF server call
        home connections using at least one transport (e.g.,
        SSH, TLS, etc.).";
    }

    feature ssh-listen {
      description
       "The 'ssh-listen' feature indicates that the NETCONF client
        supports opening a port to listen for incoming NETCONF
        server call-home SSH connections.";
      reference
       "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
    }

    feature tls-listen {
      description
       "The 'tls-listen' feature indicates that the NETCONF client
        supports opening a port to listen for incoming NETCONF
        server call-home TLS connections.";
      reference
       "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
    }

    container netconf-client {
      uses netconf-client-grouping;
      description
        "Top-level container for NETCONF client configuration.";
    }

    grouping netconf-client-grouping {
      description
```

```
        "Top-level grouping for NETCONF client configuration.";

      container initiate {
        if-feature initiate;
        presence "Enables client to initiate TCP connections";
        description
          "Configures client initiating underlying TCP connections.";
        list netconf-server {
          key name;
          min-elements 1;
          description
            "List of NETCONF servers the NETCONF client is to
             initiate connections to in parallel.";
          leaf name {
            type string;
            description
              "An arbitrary name for the NETCONF server.";
          }
          container endpoints {
            description
              "Container for the list of endpoints.";
            list endpoint {
              key name;
              min-elements 1;
              ordered-by user;
              description
                "A user-ordered list of endpoints that the NETCONF
                 client will attempt to connect to in the specified
                 sequence.  Defining more than one enables
                 high-availability.";
              leaf name {
                type string;
                description
                  "An arbitrary name for the endpoint.";
              }
              choice transport {
                mandatory true;
                description
                  "Selects between available transports.";
                case ssh {
                  if-feature ssh-initiate;
                  container ssh {
                    description
                      "Specifies IP and SSH specific configuration
                       for the connection.";
                    leaf address {
                      type inet:host;
                      description
```

```
                    "The IP address or hostname of the endpoint.
                     If a domain name is configured, then the
                     DNS resolution should happen on each usage
                     attempt.  If the DNS resolution results in
                     multiple IP addresses, the IP addresses will
                     be tried according to local preference order
                     until a connection has been established or
                     until all IP addresses have failed.";
                  }
                  leaf port {
                    type inet:port-number;
                    default 830;
                    description
                      "The IP port for this endpoint.  The NETCONF
                       client will use the IANA-assigned well-known
                       port for 'netconf-ssh' (830) if no value is
                       specified.";
                  }
                  uses ss:ssh-client-grouping;
                }
              } // end ssh
              case tls {
                if-feature tls-initiate;
                container tls {
                  description
                    "Specifies IP and TLS specific configuration
                     for the connection.";
                  leaf address {
                    type inet:host;
                    description
                      "The IP address or hostname of the endpoint.
                       If a domain name is configured, then the
                       DNS resolution should happen on each usage
                       attempt.  If the DNS resolution results in
                       multiple IP addresses, the IP addresses will
                       be tried according to local preference order
                       until a connection has been established or
                       until all IP addresses have failed.";
                  }
                  leaf port {
                    type inet:port-number;
                    default 6513;
                    description
                      "The IP port for this endpoint. The NETCONF
                       client will use the IANA-assigned well-
                       known port for 'netconf-tls' (6513) if no
                       value is specified.";
                  }
```

```
                    uses ts:tls-client-grouping {
                      refine "client-identity/auth-type" {
                      mandatory true;
                       description
                         "NETCONF/TLS clients MUST pass some
                          authentication credentials.";
                      }
                    }
                  }
                } // end tls
              }
            }
          }

          container connection-type {
            description
             "Indicates the kind of connection to use.";
            choice connection-type {
              mandatory true;
              description
                "Selects between available connection types.";
              case persistent-connection {
                container persistent {
                  presence
                   "Indicates that a persistent connection is to be
                    maintained.";
                  description
                   "Maintain a persistent connection to the NETCONF
                    server. If the connection goes down, immediately
                    start trying to reconnect to it, using the
                    reconnection strategy.

                    This connection type minimizes any NETCONF server
                    to NETCONF client data-transfer delay, albeit at
                    the expense of holding resources longer.";
                  container keep-alives {
                    description
                      "Configures the keep-alive policy, to
                       proactively test the aliveness of the SSH/TLS
                       server.  An unresponsive SSH/TLS server will
                       be dropped after approximately max-attempts *
                       max-wait seconds.";
                    leaf max-wait {
                      type uint16 {
                        range "1..max";
                      }
                      units seconds;
                      default 30;
```

```
                    description
                     "Sets the amount of time in seconds after
                      which if no data has been received from the
                      SSH/TLS server, a SSH/TLS-level message will
                      be sent to test the aliveness of the SSH/TLS
                      server.";
                  }
                  leaf max-attempts {
                    type uint8;
                    default 3;
                    description
                     "Sets the maximum number of sequential keep-
                      alive messages that can fail to obtain a
                      response from the SSH/TLS server before
                      assuming the SSH/TLS server is no longer
                      alive.";
                  }
                }
              }
            }
            case periodic-connection {
              container periodic {
                presence
                 "Indicates that a periodic connection is to be
                  maintained.";
                description
                 "Periodically connect to the NETCONF server.  The
                  NETCONF server should close the connection upon
                  completing planned activities.

                  This connection type increases resource
                  utilization, albeit with increased delay in
                  NETCONF server to NETCONF client interactions.";
                leaf period {
                  type uint16;
                  units "minutes";
                  default 60;
                  description
                    "Duration of time between periodic connections.";
                }
                leaf anchor-time {
                  type yang:date-and-time {
                    // constrained to minute-level granularity
                    pattern '\d{4}-\d{2}-\d{2}T\d{2}:\d{2}'
                            + '(Z|[\+\-]\d{2}:\d{2})';
                  }
                  description
                    "Designates a timestamp before or after which a
```

```
                        series of periodic connections are determined.
                        The periodic connections occur at a whole
                        multiple interval from the anchor time.  For
                        example, for an anchor time is 15 minutes past
                        midnight and a period interval of 24 hours, then
                        a periodic connection will occur 15 minutes past
                        midnight everyday.";
                    }
                    leaf idle-timeout {
                      type uint16;
                      units "seconds";
                      default 120; // two minutes
                      description
                        "Specifies the maximum number of seconds that
                         a NETCONF session may remain idle. A NETCONF
                         session will be dropped if it is idle for an
                         interval longer than this number of seconds.
                         If set to zero, then the NETCONF client will
                         never drop a session because it is idle.";
                    }
                  }
                }
              }
            }
            container reconnect-strategy {
              description
               "The reconnection strategy directs how a NETCONF client
                reconnects to a NETCONF server, after discovering its
                connection to the server has dropped, even if due to a
                reboot.  The NETCONF client starts with the specified
                endpoint and tries to connect to it max-attempts times
                before trying the next endpoint in the list (round
                robin).";
              leaf start-with {
                type enumeration {
                  enum first-listed {
                    description
                      "Indicates that reconnections should start with
                       the first endpoint listed.";
                  }
                  enum last-connected {
                    description
                      "Indicates that reconnections should start with
                       the endpoint last connected to.  If no previous
                       connection has ever been established, then the
                       first endpoint configured is used.   NETCONF
                       clients SHOULD be able to remember the last
                       endpoint connected to across reboots.";
```

```
                }
                enum random-selection {
                  description
                    "Indicates that reconnections should start with
                     a random endpoint.";
                }
              }
              default first-listed;
              description
               "Specifies which of the NETCONF server's endpoints
                the NETCONF client should start with when trying
                to connect to the NETCONF server.";
            }
            leaf max-attempts {
              type uint8 {
                range "1..max";
              }
              default 3;
              description
               "Specifies the number times the NETCONF client tries
                to connect to a specific endpoint before moving on
                to the next endpoint in the list (round robin).";
            }
          }
        } // end netconf-server
      } // end initiate

      container listen {
        if-feature listen;
        presence "Enables client to accept call-home connections";
        description
          "Configures client accepting call-home TCP connections.";

        leaf idle-timeout {
          type uint16;
          units "seconds";
          default 3600; // one hour
          description
            "Specifies the maximum number of seconds that a NETCONF
             session may remain idle. A NETCONF session will be
             dropped if it is idle for an interval longer than this
             number of seconds.  If set to zero, then the server
             will never drop a session because it is idle.  Sessions
             that have a notification subscription active are never
             dropped.";
        }

        list endpoint {
```

```
          key name;
          min-elements 1;
          description
            "List of endpoints to listen for NETCONF connections.";
          leaf name {
            type string;
            description
              "An arbitrary name for the NETCONF listen endpoint.";
          }
          choice transport {
            mandatory true;
            description
              "Selects between available transports.";
            case ssh {
              if-feature ssh-listen;
              container ssh {
                description
                  "SSH-specific listening configuration for inbound
                   connections.";
                leaf address {
                  type inet:ip-address;
                  description
                   "The IP address to listen on for incoming call-
                    home connections.  The NETCONF client will listen
                    on all configured interfaces if no value is
                    specified.  INADDR_ANY (0.0.0.0) or INADDR6_ANY
                    (0:0:0:0:0:0:0:0 a.k.a. ::) MUST be used when
                    the server is to listen on all IPv4 or IPv6
                    addresses, respectively.";
                }
                leaf port {
                  type inet:port-number;
                  default 4334;
                  description
                   "The port number to listen on for call-home
                    connections.  The NETCONF client will listen
                    on the IANA-assigned well-known port for
                    'netconf-ch-ssh' (4334) if no value is
                    specified.";
                }
                uses ss:ssh-client-grouping;
              }
            }
            case tls {
              if-feature tls-listen;
              container tls {
                description
                  "TLS-specific listening configuration for inbound
```

```
                   connections.";
                leaf address {
                  type inet:ip-address;
                  description
                   "The IP address to listen on for incoming call-
                    home connections.  The NETCONF client will listen
                    on all configured interfaces if no value is
                    specified.  INADDR_ANY (0.0.0.0) or INADDR6_ANY
                    (0:0:0:0:0:0:0:0 a.k.a. ::) MUST be used when
                    the server is to listen on all IPv4 or IPv6
                    addresses, respectively.";
                }
                leaf port {
                  type inet:port-number;
                  default 4335;
                  description
                   "The port number to listen on for call-home
                    connections.  The NETCONF client will listen
                    on the IANA-assigned well-known port for
                    'netconf-ch-tls' (4335) if no value is
                    specified.";
                }
                uses ts:tls-client-grouping {
                  refine "client-identity/auth-type" {
                    mandatory true;
                    description
                      "NETCONF/TLS clients MUST pass some
                       authentication credentials.";
                  }
                }
              }
            }
          } // end transport
        } // end endpoint
      } // end listen

    } // end netconf-client
  }
  <CODE ENDS>
```

4. The NETCONF Server Model

The NETCONF server model presented in this section supports servers both listening for connections as well as initiating call-home connections.

This model supports both the SSH and TLS transport protocols, using the SSH server and TLS server groupings defined in

[I-D.ietf-netconf-ssh-client-server] and
[I-D.ietf-netconf-tls-client-server] respectively.

All private keys and trusted certificates are held in the keystore model defined in [I-D.ietf-netconf-keystore].

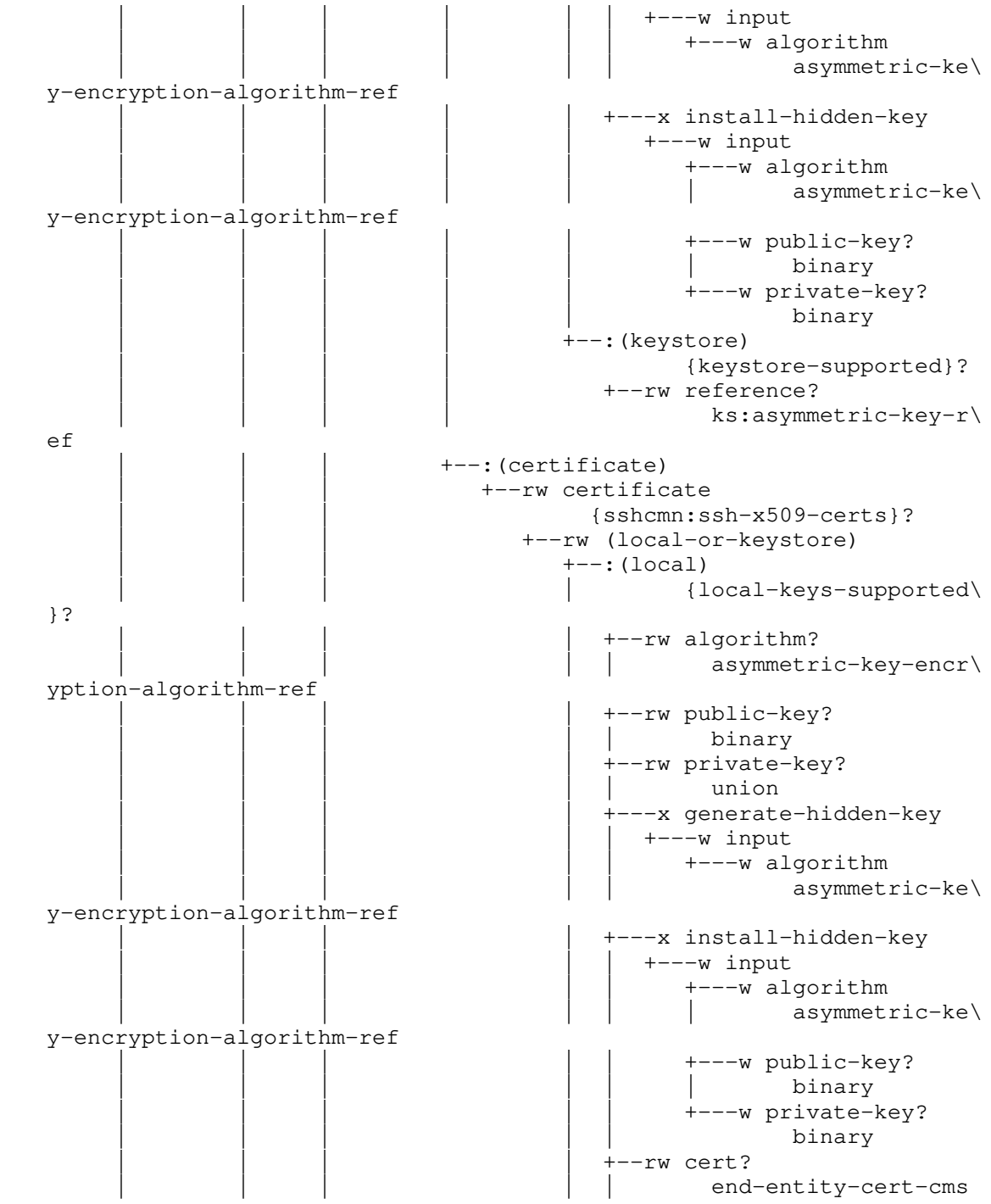
YANG feature statements are used to enable implementations to advertise which parts of the model the NETCONF server supports.

4.1. Tree Diagram

The following tree diagram [RFC8340] provides an overview of the data model for the "ietf-netconf-server" module. Just the container is displayed below, but there is also a reusable grouping called "netconf-server-grouping" that the container is using.

[Note: '\' line wrapping for formatting only]

```
module: ietf-netconf-server
  +--rw netconf-server
     +--rw listen! {listen}?
     |  +--rw idle-timeout?   uint16
     |  +--rw endpoint* [name]
     |     +--rw name         string
     |     +--rw (transport)
     |        +--:(ssh) {ssh-listen}?
     |           +--rw ssh
     |              +--rw address             inet:ip-address
     |              +--rw port?               inet:port-number
     |              +--rw server-identity
     |                 +--rw host-key* [name]
     |                    +--rw name                  string
     |                    +--rw (host-key-type)
     |                       +--:(public-key)
     |                          +--rw public-key
     |                             +--rw (local-or-keystore)
     |                                +--:(local)
     |                                   {local-keys-supported\
}?
     |                                   +--rw algorithm?
     |                                   |       asymmetric-key-encr\
yption-algorithm-ref
     |                                   +--rw public-key?
     |                                   |       binary
     |                                   +--rw private-key?
     |                                   |       union
     |                                   +---x generate-hidden-key
```


+---w input
+---w algorithm
asymmetric-ke\
y-encryption-algorithm-ref
+---x install-hidden-key
+---w input
+---w algorithm
asymmetric-ke\
y-encryption-algorithm-ref
+---w public-key?
binary
+---w private-key?
binary
+--:(keystore)
{keystore-supported}?
+--rw reference?
ks:asymmetric-key-r\
ef
+--:(certificate)
+--rw certificate
{sshcmn:ssh-x509-certs}?
+--rw (local-or-keystore)
+--:(local)
{local-keys-supported\
}?
+--rw algorithm?
asymmetric-key-encr\
yption-algorithm-ref
+--rw public-key?
binary
+--rw private-key?
union
+---x generate-hidden-key
+---w input
+---w algorithm
asymmetric-ke\
y-encryption-algorithm-ref
+---x install-hidden-key
+---w input
+---w algorithm
asymmetric-ke\
y-encryption-algorithm-ref
+---w public-key?
binary
+---w private-key?
binary
+--rw cert?
end-entity-cert-cms

```
      |          |      |                    |  +---n certificate-expiration
      |          |      |                    |     +-- expiration-date
      |          |      |                    |               yang:date-and-ti\
me
      |          |      |                   +--:(keystore)
      |          |      |                            {keystore-supported}?
      |          |      |                      +--rw reference?
      |          |      |                              ks:asymmetric-key-c\
ertificate-ref
      |          |      +--rw client-cert-auth {sshcmn:ssh-x509-certs}?
      |          |      |  +--rw pinned-ca-certs?
      |          |      |  |       ta:pinned-certificates-ref
      |          |      |  |       {ta:x509-certificates}?
      |          |      |  +--rw pinned-client-certs?
      |          |      |          ta:pinned-certificates-ref
      |          |      |          {ta:x509-certificates}?
      |          |      +--rw transport-params
      |          |             {ssh-server-transport-params-config}?
      |          |         +--rw host-key
      |          |         |  +--rw host-key-alg*   identityref
      |          |         +--rw key-exchange
      |          |         |  +--rw key-exchange-alg*   identityref
      |          |         +--rw encryption
      |          |         |  +--rw encryption-alg*   identityref
      |          |         +--rw mac
      |          |            +--rw mac-alg*   identityref
      |          +--:(tls) {tls-listen}?
      |             +--rw tls
      |                +--rw address            inet:ip-address
      |                +--rw port?              inet:port-number
      |                +--rw server-identity
      |                |  +--rw (local-or-keystore)
      |                |     +--:(local) {local-keys-supported}?
      |                |     |  +--rw algorithm?
      |                |     |  |       asymmetric-key-encryption-algor\
ithm-ref
      |                |     |  +--rw public-key?                binary
      |                |     |  +--rw private-key?               union
      |                |     |  +---x generate-hidden-key
      |                |     |  |  +---w input
      |                |     |  |     +---w algorithm
      |                |     |  |             asymmetric-key-encryption\
-algorithm-ref
      |                |     |  +---x install-hidden-key
      |                |     |  |  +---w input
      |                |     |  |     +---w algorithm
      |                |     |  |     |       asymmetric-key-encryption\
-algorithm-ref
```

```
          |                |      |  |     +---w public-key?    binary
          |                |      |  |     +---w private-key?   binary
          |                |      |  +--rw cert?
          |                |      |  |       end-entity-cert-cms
          |                |      |  +---n certificate-expiration
          |                |      |     +-- expiration-date
          |                |      |                yang:date-and-time
          |                |      +--:(keystore) {keystore-supported}?
          |                |         +--rw reference?
          |                |                   ks:asymmetric-key-certificate-r\
   ef
          |                +--rw client-auth
          |                |  +--rw pinned-ca-certs?
          |                |  |       ta:pinned-certificates-ref
          |                |  |       {ta:x509-certificates}?
          |                |  +--rw pinned-client-certs?
          |                |  |       ta:pinned-certificates-ref
          |                |  |       {ta:x509-certificates}?
          |                |  +--rw cert-maps
          |                |     +--rw cert-to-name* [id]
          |                |        +--rw id             uint32
          |                |        +--rw fingerprint
          |                |        |       x509c2n:tls-fingerprint
          |                |        +--rw map-type       identityref
          |                |        +--rw name           string
          |                +--rw hello-params
          |                         {tls-server-hello-params-config}?
          |                   +--rw tls-versions
          |                   |  +--rw tls-version*   identityref
          |                   +--rw cipher-suites
          |                      +--rw cipher-suite*   identityref
          |
        +--rw call-home! {call-home}?
           +--rw netconf-client* [name]
              +--rw name                  string
              +--rw endpoints
              |  +--rw endpoint* [name]
              |     +--rw name         string
              |     +--rw (transport)
              |        +--:(ssh) {ssh-call-home}?
              |           |  +--rw ssh
              |           |     +--rw address             inet:host
              |           |     +--rw port?               inet:port-number
              |           |     +--rw server-identity
              |           |     |  +--rw host-key* [name]
              |           |     |     +--rw name                  string
              |           |     |     +--rw (host-key-type)
              |           |     |        +--:(public-key)
              |           |     |           |  +--rw public-key
```

```
                |         |      |         |     +--rw (local-or-keystore)
                |         |      |         |        +--:(local)
                |         |      |         |           |        {local-keys-sup\
   ported}?
                |         |      |         |           |  +--rw algorithm?
                |         |      |         |           |  |       asymmetric-ke\
   y-encryption-algorithm-ref
                |         |      |         |           |  +--rw public-key?
                |         |      |         |           |  |       binary
                |         |      |         |           |  +--rw private-key?
                |         |      |         |           |  |       union
                |         |      |         |           |  +---x generate-hidden\
   -key
                |         |      |         |           |  |  +---w input
                |         |      |         |           |  |     +---w algorithm
                |         |      |         |           |  |              asymmet\
   ric-key-encryption-algorithm-ref
                |         |      |         |           |  +---x install-hidden-\
   key
                |         |      |         |           |     +---w input
                |         |      |         |           |        +---w algorithm
                |         |      |         |           |        |       asymmet\
   ric-key-encryption-algorithm-ref
                |         |      |         |           |        +---w public-ke\
   y?
                |         |      |         |           |        |       binary
                |         |      |         |           |        +---w private-k\
   ey?
                |         |      |         |           |                binary
                |         |      |         |           +--:(keystore)
                |         |      |         |                      {keystore-suppo\
   rted}?
                |         |      |         |              +--rw reference?
                |         |      |         |                      ks:asymmetric\
   -key-ref
                |         |      |       +--:(certificate)
                |         |      |          +--rw certificate
                |         |      |                  {sshcmn:ssh-x509-certs\
   }?
                |         |      |             +--rw (local-or-keystore)
                |         |      |                +--:(local)
                |         |      |                |        {local-keys-sup\
   ported}?
                |         |      |                |  +--rw algorithm?
                |         |      |                |  |       asymmetric-ke\
   y-encryption-algorithm-ref
                |         |      |                |  +--rw public-key?
                |         |      |                |  |       binary
```

```
                |         |     |                   |  +--rw private-key?
                |         |     |                   |  |       union
                |         |     |                   |  +---x generate-hidden\
   -key
                |         |     |                   |  |  +---w input
                |         |     |                   |  |     +---w algorithm
                |         |     |                   |  |             asymmet\
   ric-key-encryption-algorithm-ref
                |         |     |                   |  +---x install-hidden-\
   key
                |         |     |                   |  |  +---w input
                |         |     |                   |  |     +---w algorithm
                |         |     |                   |  |     |       asymmet\
   ric-key-encryption-algorithm-ref
                |         |     |                   |  |     +---w public-ke\
   y?
                |         |     |                   |  |     |       binary
                |         |     |                   |  |     +---w private-k\
   ey?
                |         |     |                   |  |             binary
                |         |     |                   |  +--rw cert?
                |         |     |                   |  |       end-entity-ce\
   rt-cms
                |         |     |                   |  +---n certificate-exp\
   iration
                |         |     |                   |     +-- expiration-date
                |         |     |                   |             yang:date-\
   and-time
                |         |     |                  +--:(keystore)
                |         |     |                         {keystore-suppo\
   rted}?
                |         |     |                     +--rw reference?
                |         |     |                           ks:asymmetric\
   -key-certificate-ref
                |         |     +--rw client-cert-auth
                |         |     |       {sshcmn:ssh-x509-certs}?
                |         |     |  +--rw pinned-ca-certs?
                |         |     |  |       ta:pinned-certificates-ref
                |         |     |  |       {ta:x509-certificates}?
                |         |     |  +--rw pinned-client-certs?
                |         |     |          ta:pinned-certificates-ref
                |         |     |          {ta:x509-certificates}?
                |         |     +--rw transport-params
                |         |             {ssh-server-transport-params-confi\
   g}?
                |         |        +--rw host-key
                |         |        |  +--rw host-key-alg*   identityref
                |         |        +--rw key-exchange
```

```
                |          |          |  +--rw key-exchange-alg*   identityref
                |          |          +--rw encryption
                |          |          |  +--rw encryption-alg*   identityref
                |          |          +--rw mac
                |          |             +--rw mac-alg*   identityref
                |          +--:(tls) {tls-call-home}?
                |             +--rw tls
                |                +--rw address            inet:host
                |                +--rw port?              inet:port-number
                |                +--rw server-identity
                |                |  +--rw (local-or-keystore)
                |                |     +--:(local) {local-keys-supported}?
                |                |     |  +--rw algorithm?
                |                |     |  |       asymmetric-key-encryption\
   -algorithm-ref
                |                |     |  +--rw public-key?
                |                |     |  |       binary
                |                |     |  +--rw private-key?
                |                |     |  |       union
                |                |     |  +---x generate-hidden-key
                |                |     |  |  +---w input
                |                |     |  |     +---w algorithm
                |                |     |  |             asymmetric-key-encr\
   yption-algorithm-ref
                |                |     |  +---x install-hidden-key
                |                |     |  |  +---w input
                |                |     |  |     +---w algorithm
                |                |     |  |     |       asymmetric-key-encr\
   yption-algorithm-ref
                |                |     |  |     +---w public-key?    binary
                |                |     |  |     +---w private-key?   binary
                |                |     |  +--rw cert?
                |                |     |  |       end-entity-cert-cms
                |                |     |  +---n certificate-expiration
                |                |     |     +-- expiration-date
                |                |     |                 yang:date-and-time
                |                |     +--:(keystore) {keystore-supported}?
                |                |        +--rw reference?
                |                |                ks:asymmetric-key-certifi\
   cate-ref
                |                +--rw client-auth
                |                |  +--rw pinned-ca-certs?
                |                |  |       ta:pinned-certificates-ref
                |                |  |       {ta:x509-certificates}?
                |                |  +--rw pinned-client-certs?
                |                |  |       ta:pinned-certificates-ref
                |                |  |       {ta:x509-certificates}?
                |                |  +--rw cert-maps
```

```
|              |     +--rw cert-to-name* [id]
|              |        +--rw id             uint32
|              |        +--rw fingerprint
|              |        |       x509c2n:tls-fingerprint
|              |        +--rw map-type       identityref
|              |        +--rw name           string
|              |     +--rw hello-params
|              |             {tls-server-hello-params-config}?
|              |        +--rw tls-versions
|              |        |  +--rw tls-version*   identityref
|              |        +--rw cipher-suites
|              |           +--rw cipher-suite*   identityref
|              +--rw connection-type
|              |  +--rw (connection-type)
|              |     +--:(persistent-connection)
|              |     |  +--rw persistent!
|              |     |     +--rw keep-alives
|              |     |        +--rw max-wait?       uint16
|              |     |        +--rw max-attempts?   uint8
|              |     +--:(periodic-connection)
|              |        +--rw periodic!
|              |           +--rw period?         uint16
|              |           +--rw anchor-time?    yang:date-and-time
|              |           +--rw idle-timeout?   uint16
|              +--rw reconnect-strategy
|                 +--rw start-with?     enumeration
|                 +--rw max-attempts?   uint8
```

4.2. Example Usage

The following example illustrates configuring a NETCONF server to listen for NETCONF client connections using both the SSH and TLS transport protocols, as well as configuring call-home to two NETCONF clients, one using SSH and the other using TLS.

This example is consistent with the examples presented in Section 3.2 of [I-D.ietf-netconf-keystore].

[Note: '\' line wrapping for formatting only]

```
<netconf-server
  xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-server"
  xmlns:x509c2n="urn:ietf:params:xml:ns:yang:ietf-x509-cert-to-name">

  <!-- endpoints to listen for NETCONF connections on -->
  <listen>
    <endpoint> <!-- listening for SSH connections -->
```

```
        <name>netconf/ssh</name>
        <ssh>
          <address>192.0.2.7</address>
          <server-identity>
            <host-key>
              <name>deployment-specific-certificate</name>
              <public-key>
                <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-\
  crypto-types">ct:rsa2048</algorithm>
                <private-key>base64encodedvalue==</private-key>
                <public-key>base64encodedvalue==</public-key>
              </public-key>
            </host-key>
          </server-identity>
          <client-cert-auth>
            <pinned-ca-certs>explicitly-trusted-client-ca-certs</pinne\
  d-ca-certs>
            <pinned-client-certs>explicitly-trusted-client-certs</pinn\
  ed-client-certs>
          </client-cert-auth>
        </ssh>
      </endpoint>
      <endpoint> <!-- listening for TLS sessions -->
        <name>netconf/tls</name>
        <tls>
          <address>192.0.2.7</address>
          <server-identity>
            <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-cryp\
  to-types">ct:rsa2048</algorithm>
            <private-key>base64encodedvalue==</private-key>
            <public-key>base64encodedvalue==</public-key>
            <cert>base64encodedvalue==</cert>
          </server-identity>
          <client-auth>
            <pinned-ca-certs>explicitly-trusted-client-ca-certs</pinne\
  d-ca-certs>
            <pinned-client-certs>explicitly-trusted-client-certs</pinn\
  ed-client-certs>
            <cert-maps>
              <cert-to-name>
                <id>1</id>
                <fingerprint>11:0A:05:11:00</fingerprint>
                <map-type>x509c2n:san-any</map-type>
              </cert-to-name>
              <cert-to-name>
                <id>2</id>
                <fingerprint>B3:4F:A1:8C:54</fingerprint>
                <map-type>x509c2n:specified</map-type>
```

```
                <name>scooby-doo</name>
              </cert-to-name>
            </cert-maps>
          </client-auth>
        </tls>
      </endpoint>
    </listen>

    <!-- calling home to SSH and TLS based NETCONF clients -->
    <call-home>
      <netconf-client> <!-- SSH-based client -->
        <name>config-mgr</name>
        <endpoints>
          <endpoint>
            <name>east-data-center</name>
            <ssh>
              <address>east.config-mgr.example.com</address>
              <server-identity>
                <host-key>
                  <name>deployment-specific-certificate</name>
                  <public-key>
                    <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:i\
etf-crypto-types">ct:rsa2048</algorithm>
                    <private-key>base64encodedvalue==</private-key>
                    <public-key>base64encodedvalue==</public-key>
                  </public-key>
                </host-key>
              </server-identity>
              <client-cert-auth>
                <pinned-ca-certs>explicitly-trusted-client-ca-certs</p\
inned-ca-certs>
                <pinned-client-certs>explicitly-trusted-client-certs</\
pinned-client-certs>
              </client-cert-auth>
            </ssh>
          </endpoint>
          <endpoint>
            <name>west-data-center</name>
            <ssh>
              <address>west.config-mgr.example.com</address>
              <server-identity>
                <host-key>
                  <name>deployment-specific-certificate</name>
                  <public-key>
                    <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:i\
etf-crypto-types">ct:rsa2048</algorithm>
                    <private-key>base64encodedvalue==</private-key>
                    <public-key>base64encodedvalue==</public-key>
```

```
                  </public-key>
                </host-key>
              </server-identity>
              <client-cert-auth>
                <pinned-ca-certs>explicitly-trusted-client-ca-certs</p\
   inned-ca-certs>
                <pinned-client-certs>explicitly-trusted-client-certs</\
   pinned-client-certs>
              </client-cert-auth>
            </ssh>
          </endpoint>
        </endpoints>
        <connection-type>
          <periodic>
            <idle-timeout>300</idle-timeout>
            <period>60</period>
          </periodic>
        </connection-type>
        <reconnect-strategy>
          <start-with>last-connected</start-with>
          <max-attempts>3</max-attempts>
        </reconnect-strategy>
      </netconf-client>
      <netconf-client> <!-- TLS-based client -->
        <name>data-collector</name>
        <endpoints>
          <endpoint>
            <name>east-data-center</name>
            <tls>
              <address>east.analytics.example.com</address>
              <server-identity>
                <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-\
   crypto-types">ct:rsa2048</algorithm>
                <private-key>base64encodedvalue==</private-key>
                <public-key>base64encodedvalue==</public-key>
                <cert>base64encodedvalue==</cert>
              </server-identity>
              <client-auth>
                <pinned-ca-certs>explicitly-trusted-client-ca-certs</p\
   inned-ca-certs>
                <pinned-client-certs>explicitly-trusted-client-certs</\
   pinned-client-certs>
                <cert-maps>
                  <cert-to-name>
                    <id>1</id>
                    <fingerprint>11:0A:05:11:00</fingerprint>
                    <map-type>x509c2n:san-any</map-type>
                  </cert-to-name>
```

```
                  <cert-to-name>
                    <id>2</id>
                    <fingerprint>B3:4F:A1:8C:54</fingerprint>
                    <map-type>x509c2n:specified</map-type>
                    <name>scooby-doo</name>
                  </cert-to-name>
                </cert-maps>
              </client-auth>
            </tls>
          </endpoint>
          <endpoint>
            <name>west-data-center</name>
            <tls>
              <address>west.analytics.example.com</address>
              <server-identity>
                <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-\
  crypto-types">ct:rsa2048</algorithm>
                <private-key>base64encodedvalue==</private-key>
                <public-key>base64encodedvalue==</public-key>
                <cert>base64encodedvalue==</cert>
              </server-identity>
              <client-auth>
                <pinned-ca-certs>explicitly-trusted-client-ca-certs</p\
  inned-ca-certs>
                <pinned-client-certs>explicitly-trusted-client-certs</\
  pinned-client-certs>
                <cert-maps>
                  <cert-to-name>
                    <id>1</id>
                    <fingerprint>11:0A:05:11:00</fingerprint>
                    <map-type>x509c2n:san-any</map-type>
                  </cert-to-name>
                  <cert-to-name>
                    <id>2</id>
                    <fingerprint>B3:4F:A1:8C:54</fingerprint>
                    <map-type>x509c2n:specified</map-type>
                    <name>scooby-doo</name>
                  </cert-to-name>
                </cert-maps>
              </client-auth>
            </tls>
          </endpoint>
        </endpoints>
        <connection-type>
          <persistent>
            <keep-alives>
              <max-wait>30</max-wait>
              <max-attempts>3</max-attempts>
```

```
            </keep-alives>
          </persistent>
        </connection-type>
        <reconnect-strategy>
          <start-with>first-listed</start-with>
          <max-attempts>3</max-attempts>
        </reconnect-strategy>
      </netconf-client>
    </call-home>
  </netconf-server>
```

4.3. YANG Module

This YANG module has normative references to [RFC6242], [RFC6991], [RFC7407], [RFC7589], [RFC8071], [I-D.ietf-netconf-ssh-client-server], and [I-D.ietf-netconf-tls-client-server].

This YANG module imports YANG types from [RFC6991], and YANG groupings from [RFC7407], [I-D.ietf-netconf-ssh-client-server] and [I-D.ietf-netconf-ssh-client-server].

```
<CODE BEGINS> file "ietf-netconf-server@2018-10-22.yang"
module ietf-netconf-server {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-netconf-server";
  prefix "ncs";

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

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

  import ietf-x509-cert-to-name {
    prefix x509c2n;
    reference
      "RFC 7407: A YANG Data Model for SNMP Configuration";
  }

  import ietf-ssh-server {
```

```
      prefix ss;
      revision-date 2018-10-22; // stable grouping definitions
      reference
        "RFC YYYY: YANG Groupings for SSH Clients and SSH Servers";
    }

    import ietf-tls-server {
      prefix ts;
      revision-date 2018-10-22; // stable grouping definitions
      reference
        "RFC ZZZZ: YANG Groupings for TLS Clients and TLS Servers";
    }

    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:kwatsen@juniper.net>

      Author:   Gary Wu
                <mailto:garywu@cisco.com>

      Author:   Juergen Schoenwaelder
                <mailto:j.schoenwaelder@jacobs-university.de>";


    description
     "This module contains a collection of YANG definitions for
      configuring NETCONF servers.

      Copyright (c) 2017 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 XXXX; see
      the RFC itself for full legal notices.";

    revision "2018-10-22" {
```

```
    description
     "Initial version";
    reference
     "RFC XXXX: NETCONF Client and Server Models";
  }


  // Features

  feature listen {
    description
     "The 'listen' feature indicates that the NETCONF server
      supports opening a port to accept NETCONF client connections
      using at least one transport (e.g., SSH, TLS, etc.).";
  }

  feature ssh-listen {
    description
     "The 'ssh-listen' feature indicates that the NETCONF server
      supports opening a port to accept NETCONF over SSH
      client connections.";
    reference
     "RFC 6242:
        Using the NETCONF Protocol over Secure Shell (SSH)";
  }

  feature tls-listen {
    description
     "The 'tls-listen' feature indicates that the NETCONF server
      supports opening a port to accept NETCONF over TLS
      client connections.";
    reference
     "RFC 7589: Using the NETCONF Protocol over Transport
                Layer Security (TLS) with Mutual X.509
                Authentication";
  }

  feature call-home {
    description
     "The 'call-home' feature indicates that the NETCONF server
      supports initiating NETCONF call home connections to
      NETCONF clients using at least one transport (e.g., SSH,
      TLS, etc.).";
    reference
     "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
  }

  feature ssh-call-home {
```

```
      description
       "The 'ssh-call-home' feature indicates that the NETCONF
        server supports initiating a NETCONF over SSH call
        home connection to NETCONF clients.";
      reference
       "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
    }

    feature tls-call-home {
      description
       "The 'tls-call-home' feature indicates that the NETCONF
        server supports initiating a NETCONF over TLS call
        home connection to NETCONF clients.";
      reference
       "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
    }


    // protocol accessible nodes

    container netconf-server {
      uses netconf-server-grouping;
      description
        "Top-level container for NETCONF server configuration.";
    }

    // reusable groupings

    grouping netconf-server-grouping {
      description
        "Top-level grouping for NETCONF server configuration.";
      container listen {
        if-feature listen;
        presence "Enables server to listen for TCP connections";
        description "Configures listen behavior";
        leaf idle-timeout {
          type uint16;
          units "seconds";
          default 3600; // one hour
          description
            "Specifies the maximum number of seconds that a NETCONF
             session may remain idle. A NETCONF session will be
             dropped if it is idle for an interval longer than this
             number of seconds.  If set to zero, then the server
             will never drop a session because it is idle.  Sessions
             that have a notification subscription active are never
             dropped.";
        }
```

```
        list endpoint {
          key name;
          min-elements 1;
          description
            "List of endpoints to listen for NETCONF connections.";
          leaf name {
            type string;
            description
              "An arbitrary name for the NETCONF listen endpoint.";
          }
          choice transport {
            mandatory true;
            description
              "Selects between available transports.";
            case ssh {
              if-feature ssh-listen;
              container ssh {
                description
                  "SSH-specific listening configuration for inbound
                   connections.";
                leaf address {
                  type inet:ip-address;
                  mandatory true;
                  description
                    "The IP address to listen on for incoming
                     connections.  The NETCONF server will listen
                     on all configured interfaces if no value is
                     specified.  INADDR_ANY (0.0.0.0) or INADDR6_ANY
                     (0:0:0:0:0:0:0:0 a.k.a. ::) MUST be used when
                     the server is to listen on all IPv4 or IPv6
                     addresses, respectively.";
                }
                leaf port {
                  type inet:port-number;
                  default 830;
                  description
                   "The local port number to listen on.  If no value
                    is specified, the IANA-assigned port value for
                    'netconf-ssh' (830) is used.";
                }
                uses ss:ssh-server-grouping;
              }
            }
            case tls {
              if-feature tls-listen;
              container tls {
                description
                  "TLS-specific listening configuration for inbound
```

```
           connections.";
        leaf address {
          type inet:ip-address;
          mandatory true;
          description
            "The IP address to listen on for incoming
             connections.  The NETCONF server will listen
             on all configured interfaces if no value is
             specified.  INADDR_ANY (0.0.0.0) or INADDR6_ANY
             (0:0:0:0:0:0:0:0 a.k.a. ::) MUST be used when
             the server is to listen on all IPv4 or IPv6
             addresses, respectively.";
        }
        leaf port {
          type inet:port-number;
          default 6513;
          description
           "The local port number to listen on.  If no value
            is specified, the IANA-assigned port value for
            'netconf-tls' (6513) is used.";
        }
        uses ts:tls-server-grouping {
          refine "client-auth" {
            must 'pinned-ca-certs or pinned-client-certs';
            description
              "NETCONF/TLS servers MUST validate client
               certiticates.";
          }
          augment "client-auth" {
            description
              "Augments in the cert-to-name structure.";
            container cert-maps {
              uses x509c2n:cert-to-name;
              description
               "The cert-maps container is used by a TLS-
                based NETCONF server to map the NETCONF
                client's presented X.509 certificate to a
                NETCONF username.  If no matching and valid
                cert-to-name list entry can be found, then
                the NETCONF server MUST close the connection,
                and MUST NOT accept NETCONF messages over
                it.";
              reference
                "RFC WWWW: NETCONF over TLS, Section 7";
            }
          }
        }
      }
```

```
          }
        }
      }
    }

    container call-home {
      if-feature call-home;
      presence "Enables server to initiate TCP connections";
      description "Configures call-home behavior";
      list netconf-client {
        key name;
        min-elements 1;
        description
          "List of NETCONF clients the NETCONF server is to
           initiate call-home connections to in parallel.";
        leaf name {
          type string;
          description
            "An arbitrary name for the remote NETCONF client.";
        }
        container endpoints {
          description
            "Container for the list of endpoints.";
          list endpoint {
            key name;
            min-elements 1;
            ordered-by user;
            description
              "A non-empty user-ordered list of endpoints for this
               NETCONF server to try to connect to in sequence.
               Defining more than one enables high-availability.";
            leaf name {
              type string;
              description
                "An arbitrary name for this endpoint.";
            }
            choice transport {
              mandatory true;
              description
                "Selects between available transports.";
              case ssh {
                if-feature ssh-call-home;
                container ssh {
                  description
                    "Specifies SSH-specific call-home transport
                     configuration.";
                  leaf address {
                    type inet:host;
```

```
            mandatory true;
            description
             "The IP address or hostname of the endpoint.
              If a domain name is configured, then the
              DNS resolution should happen on each usage
              attempt.  If the the DNS resolution results
              in multiple IP addresses, the IP addresses
              will be tried according to local preference
              order until a connection has been established
              or until all IP addresses have failed.";
          }
          leaf port {
            type inet:port-number;
            default 4334;
            description
             "The IP port for this endpoint. The NETCONF
              server will use the IANA-assigned well-known
              port for 'netconf-ch-ssh' (4334) if no value
              is specified.";
          }
          uses ss:ssh-server-grouping;
        }
      }
      case tls {
        if-feature tls-call-home;
        container tls {
          description
            "Specifies TLS-specific call-home transport
             configuration.";
          leaf address {
            type inet:host;
            mandatory true;
            description
             "The IP address or hostname of the endpoint.
              If a domain name is configured, then the
              DNS resolution should happen on each usage
              attempt.  If the the DNS resolution results
              in multiple IP addresses, the IP addresses
              will be tried according to local preference
              order until a connection has been established
              or until all IP addresses have failed.";
          }
          leaf port {
            type inet:port-number;
            default 4335;
            description
             "The IP port for this endpoint.  The NETCONF
              server will use the IANA-assigned well-known
```

```
                        port for 'netconf-ch-tls' (4335) if no value
                        is specified.";
                    }
                    uses ts:tls-server-grouping {
                      refine "client-auth" {
                       must 'pinned-ca-certs or pinned-client-certs';
                       description
                        "NETCONF/TLS servers MUST validate client
                         certiticates.";
                      }
                      augment "client-auth" {
                        description
                          "Augments in the cert-to-name structure.";
                        container cert-maps {
                          uses x509c2n:cert-to-name;
                          description
                           "The cert-maps container is used by a
                            TLS-based NETCONF server to map the
                            NETCONF client's presented X.509
                            certificate to a NETCONF username.  If
                            no matching and valid cert-to-name list
                            entry can be found, then the NETCONF
                            server MUST close the connection, and
                            MUST NOT accept NETCONF messages over
                            it.";
                          reference
                            "RFC WWWW: NETCONF over TLS, Section 7";
                        }
                      }
                    }
                  }
                } // end tls
              } // end choice
            } // end endpoint
          }
          container connection-type {
            description
             "Indicates the kind of connection to use.";
            choice connection-type {
              mandatory true;
              description
                "Selects between available connection types.";
              case persistent-connection {
                container persistent {
                  presence
                   "Indicates that a persistent connection is to be
                    maintained.";
                  description
```

```
                "Maintain a persistent connection to the NETCONF
                 client. If the connection goes down, immediately
                 start trying to reconnect to it, using the
                 reconnection strategy.

                 This connection type minimizes any NETCONF client
                 to NETCONF server data-transfer delay, albeit at
                 the expense of holding resources longer.";
               container keep-alives {
                 description
                   "Configures the keep-alive policy, to
                    proactively test the aliveness of the SSH/TLS
                    client.  An unresponsive SSH/TLS client will
                    be dropped after approximately max-attempts *
                    max-wait seconds.";
                 reference
                   "RFC 8071: NETCONF Call Home and RESTCONF
                              Call Home, Section 4.1, item S7";
                 leaf max-wait {
                   type uint16 {
                     range "1..max";
                   }
                   units seconds;
                   default 30;
                   description
                    "Sets the amount of time in seconds after
                     which if no data has been received from
                     the SSH/TLS client, a SSH/TLS-level message
                     will be sent to test the aliveness of the
                     SSH/TLS client.";
                 }
                 leaf max-attempts {
                   type uint8;
                   default 3;
                   description
                    "Sets the maximum number of sequential keep-
                     alive messages that can fail to obtain a
                     response from the SSH/TLS client before
                     assuming the SSH/TLS client is no longer
                     alive.";
                 }
               }
             }
           }

           case periodic-connection {
             container periodic {
               presence
```

```
                "Indicates that a periodic connection is to be
                 maintained.";
               description
                "Periodically connect to the NETCONF client.  The
                 NETCONF client should close the underlying TLS
                 connection upon completing planned activities.

                 This connection type increases resource
                 utilization, albeit with increased delay in
                 NETCONF client to NETCONF client interactions.";
               leaf period {
                 type uint16;
                 units "minutes";
                 default 60;
                 description
                   "Duration of time between periodic connections.";
               }
               leaf anchor-time {
                 type yang:date-and-time {
                   // constrained to minute-level granularity
                   pattern '\d{4}-\d{2}-\d{2}T\d{2}:\d{2}'
                           + '(Z|[\+\-]\d{2}:\d{2})';
                 }
                 description
                   "Designates a timestamp before or after which a
                    series of periodic connections are determined.
                    The periodic connections occur at a whole
                    multiple interval from the anchor time.  For
                    example, for an anchor time is 15 minutes past
                    midnight and a period interval of 24 hours, then
                    a periodic connection will occur 15 minutes past
                    midnight everyday.";
               }
               leaf idle-timeout {
                 type uint16;
                 units "seconds";
                 default 120; // two minutes
                 description
                   "Specifies the maximum number of seconds that
                    a NETCONF session may remain idle. A NETCONF
                    session will be dropped if it is idle for an
                    interval longer than this number of seconds.
                    If set to zero, then the server will never
                    drop a session because it is idle.";
               }
             }
           }
         }
```

```
          }
          container reconnect-strategy {
            description
             "The reconnection strategy directs how a NETCONF server
              reconnects to a NETCONF client, after discovering its
              connection to the client has dropped, even if due to a
              reboot.  The NETCONF server starts with the specified
              endpoint and tries to connect to it max-attempts times
              before trying the next endpoint in the list (round
              robin).";
            leaf start-with {
              type enumeration {
                enum first-listed {
                  description
                    "Indicates that reconnections should start with
                     the first endpoint listed.";
                }
                enum last-connected {
                  description
                    "Indicates that reconnections should start with
                     the endpoint last connected to.  If no previous
                     connection has ever been established, then the
                     first endpoint configured is used.   NETCONF
                     servers SHOULD be able to remember the last
                     endpoint connected to across reboots.";
                }
                enum random-selection {
                  description
                    "Indicates that reconnections should start with
                     a random endpoint.";
                }
              }
              default first-listed;
              description
               "Specifies which of the NETCONF client's endpoints
                the NETCONF server should start with when trying
                to connect to the NETCONF client.";
            }
            leaf max-attempts {
              type uint8 {
                range "1..max";
              }
              default 3;
              description
               "Specifies the number times the NETCONF server tries
                to connect to a specific endpoint before moving on
                to the next endpoint in the list (round robin).";
            }
```

```
          }
        }
      }
    }
  }
```

<CODE ENDS>

5. Design Considerations

Editorial: this section is a hold over from before, previously called "Objectives". It was only written two support the "server" (not the "client"). The question is if it's better to add the missing "client" parts, or remove this section altogether.

The primary purpose of the YANG modules defined herein is to enable the configuration of the NETCONF client and servers. This scope includes the following objectives:

5.1. Support all NETCONF transports

The YANG module should support all current NETCONF transports, namely NETCONF over SSH [RFC6242], NETCONF over TLS [RFC7589], and to be extensible to support future transports as necessary.

Because implementations may not support all transports, the modules should use YANG "feature" statements so that implementations can accurately advertise which transports are supported.

5.2. Enable each transport to select which keys to use

Servers may have a multiplicity of host-keys or server-certificates from which subsets may be selected for specific uses. For instance, a NETCONF server may want to use one set of SSH host-keys when listening on port 830, and a different set of SSH host-keys when calling home. The data models provided herein should enable configuration of which keys to use on a per-use basis.

5.3. Support authenticating NETCONF clients certificates

When a certificate is used to authenticate a NETCONF client, there is a need to configure the server to know how to authenticate the certificates. The server should be able to authenticate the client's certificate either by using path-validation to a configured trust anchor or by matching the client-certificate to one previously configured.

5.4. Support mapping authenticated NETCONF client certificates to usernames

When a client certificate is used for TLS client authentication, the NETCONF server must be able to derive a username from the authenticated certificate. Thus the modules defined herein should enable this mapping to be configured.

5.5. Support both listening for connections and call home

The NETCONF protocols were originally defined as having the server opening a port to listen for client connections. More recently the NETCONF working group defined support for call-home ([RFC8071]), enabling the server to initiate the connection to the client. Thus the modules defined herein should enable configuration for both listening for connections and calling home. Because implementations may not support both listening for connections and calling home, YANG "feature" statements should be used so that implementation can accurately advertise the connection types it supports.

5.6. For Call Home connections

The following objectives only pertain to call home connections.

5.6.1. Support more than one NETCONF client

A NETCONF server may be managed by more than one NETCONF client. For instance, a deployment may have one client for provisioning and another for fault monitoring. Therefore, when it is desired for a server to initiate call home connections, it should be able to do so to more than one client.

5.6.2. Support NETCONF clients having more than one endpoint

A NETCONF client managing a NETCONF server may implement a high-availability strategy employing a multiplicity of active and/or passive endpoint. Therefore, when it is desired for a server to initiate call home connections, it should be able to connect to any of the client's endpoints.

5.6.3. Support a reconnection strategy

Assuming a NETCONF client has more than one endpoint, then it becomes necessary to configure how a NETCONF server should reconnect to the client should it lose its connection to one the client's endpoints. For instance, the NETCONF server may start with first endpoint defined in a user-ordered list of endpoints or with the last endpoints it was connected to.

5.6.4. Support both persistent and periodic connections

NETCONF clients may vary greatly on how frequently they need to interact with a NETCONF server, how responsive interactions need to be, and how many simultaneous connections they can support. Some clients may need a persistent connection to servers to optimize real-time interactions, while others prefer periodic interactions in order to minimize resource requirements. Therefore, when it is necessary for server to initiate connections, it should be configurable if the connection is persistent or periodic.

5.6.5. Reconnection strategy for periodic connections

The reconnection strategy should apply to both persistent and periodic connections. How it applies to periodic connections becomes clear when considering that a periodic "connection" is a logical connection to a single server. That is, the periods of unconnectedness are intentional as opposed to due to external reasons. A periodic "connection" should always reconnect to the same server until it is no longer able to, at which time the reconnection strategy guides how to connect to another server.

5.6.6. Keep-alives for persistent connections

If a persistent connection is desired, it is the responsibility of the connection initiator to actively test the "aliveness" of the connection. The connection initiator must immediately work to reestablish a persistent connection as soon as the connection is lost. How often the connection should be tested is driven by NETCONF client requirements, and therefore keep-alive settings should be configurable on a per-client basis.

5.6.7. Customizations for periodic connections

If a periodic connection is desired, it is necessary for the NETCONF server to know how often it should connect. This frequency determines the maximum amount of time a NETCONF client may have to wait to send data to a server. A server may connect to a client before this interval expires if desired (e.g., to send data to a client).

6. Security Considerations

The YANG module defined in this document uses groupings defined in [I-D.ietf-netconf-ssh-client-server] and [I-D.ietf-netconf-tls-client-server]. Please see the Security Considerations section in those documents for concerns related those groupings.

The YANG module defined in this document is 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.

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes may be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. These are the subtrees and data nodes and their sensitivity/vulnerability:

/: The entire data trees defined by the modules defined in this draft are sensitive to write operations. For instance, the addition or removal of references to keys, certificates, trusted anchors, etc., can dramatically alter the implemented security policy. However, no NACM annotations are applied as the data SHOULD be editable by users other than a designated 'recovery session'.

Some of the readable data nodes 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:

NONE

Some of the RPC 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:

NONE

7. IANA Considerations

7.1. The IETF XML Registry

This document registers two URIs in the "ns" subregistry of the IETF XML Registry [RFC3688]. Following the format in [RFC3688], the following registrations are requested:

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

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

7.2. The YANG Module Names Registry

This document registers two YANG modules in the YANG Module Names registry [RFC6020]. Following the format in [RFC6020], the the following registrations are requested:

```
name:         ietf-netconf-client
namespace:    urn:ietf:params:xml:ns:yang:ietf-netconf-client
prefix:       ncc
reference:    RFC XXXX

name:         ietf-netconf-server
namespace:    urn:ietf:params:xml:ns:yang:ietf-netconf-server
prefix:       ncs
reference:    RFC XXXX
```

8. References

8.1. Normative References

[I-D.ietf-netconf-keystore]
Watsen, K., "YANG Data Model for a Centralized Keystore Mechanism", draft-ietf-netconf-keystore-06 (work in progress), September 2018.

[I-D.ietf-netconf-ssh-client-server]
Watsen, K. and G. Wu, "YANG Groupings for SSH Clients and SSH Servers", draft-ietf-netconf-ssh-client-server-07 (work in progress), September 2018.

[I-D.ietf-netconf-tls-client-server]
Watsen, K. and G. Wu, "YANG Groupings for TLS Clients and TLS Servers", draft-ietf-netconf-tls-client-server-07 (work in progress), September 2018.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <https://www.rfc-editor.org/info/rfc6020>.

[RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <https://www.rfc-editor.org/info/rfc6241>.

[RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", RFC 6242, DOI 10.17487/RFC6242, June 2011, <https://www.rfc-editor.org/info/rfc6242>.

[RFC6991] Schoenwaelder, J., Ed., "Common YANG Data Types", RFC 6991, DOI 10.17487/RFC6991, July 2013, <https://www.rfc-editor.org/info/rfc6991>.

[RFC7407] Bjorklund, M. and J. Schoenwaelder, "A YANG Data Model for SNMP Configuration", RFC 7407, DOI 10.17487/RFC7407, December 2014, <https://www.rfc-editor.org/info/rfc7407>.

[RFC7589] Badra, M., Luchuk, A., and J. Schoenwaelder, "Using the NETCONF Protocol over Transport Layer Security (TLS) with Mutual X.509 Authentication", RFC 7589, DOI 10.17487/RFC7589, June 2015, <https://www.rfc-editor.org/info/rfc7589>.

[RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, DOI 10.17487/RFC7950, August 2016, <https://www.rfc-editor.org/info/rfc7950>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

8.2. Informative References

[RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <https://www.rfc-editor.org/info/rfc3688>.

[RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <https://www.rfc-editor.org/info/rfc8040>.

[RFC8071] Watsen, K., "NETCONF Call Home and RESTCONF Call Home", RFC 8071, DOI 10.17487/RFC8071, February 2017, <https://www.rfc-editor.org/info/rfc8071>.

[RFC8340] Bjorklund, M. and L. Berger, Ed., "YANG Tree Diagrams", BCP 215, RFC 8340, DOI 10.17487/RFC8340, March 2018, <https://www.rfc-editor.org/info/rfc8340>.

[RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", STD 91, RFC 8341, DOI 10.17487/RFC8341, March 2018, <https://www.rfc-editor.org/info/rfc8341>.

Appendix A. Change Log

A.1. 00 to 01

- Renamed "keychain" to "keystore".

A.2. 01 to 02

- Added to ietf-netconf-client ability to connected to a cluster of endpoints, including a reconnection-strategy.
- Added to ietf-netconf-client the ability to configure connection-type and also keep-alive strategy.
- Updated both modules to accomodate new groupings in the ssh/tls drafts.

A.3. 02 to 03

- Refined use of tls-client-grouping to add a must statement indicating that the TLS client must specify a client-certificate.
- Changed 'netconf-client' to be a grouping (not a container).

A.4. 03 to 04

- Added RFC 8174 to Requirements Language Section.
- Replaced refine statement in ietf-netconf-client to add a mandatory true.
- Added refine statement in ietf-netconf-server to add a must statement.
- Now there are containers and groupings, for both the client and server models.

A.5. 04 to 05

- Now tree diagrams reference ietf-netmod-yang-tree-diagrams
- Updated examples to inline key and certificates (no longer a leafref to keystore)

A.6. 05 to 06

- Fixed change log missing section issue.
- Updated examples to match latest updates to the crypto-types, trust-anchors, and keystore drafts.
- Reduced line length of the YANG modules to fit within 69 columns.

A.7. 06 to 07

- Removed "idle-timeout" from "persistent" connection config.
- Added "random-selection" for reconnection-strategy's "starts-with" enum.
- Replaced "connection-type" choice default (persistent) with "mandatory true".
- Reduced the periodic-connection's "idle-timeout" from 5 to 2 minutes.
- Replaced reconnect-timeout with period/anchor-time combo.

A.8. 07 to 08

- Modified examples to be compatible with new crypto-types algs

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