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:

   o I-D.ietf-netconf-keystore

   o I-D.ietf-netconf-ssh-client-server

   o I-D.ietf-netconf-tls-client-server

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

   o "XXXX" --> the assigned RFC value for this draft

   o "YYYY" --> the assigned RFC value for I-D.ietf-netconf-ssh-client-
      server

   o "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

   This Internet-Draft is submitted in full conformance with the
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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-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
|     |        |         |     |        +--:(keystore)
|     |        |         |     |                {keystore-supporte\
d}?
|     |        |         |     |           +--rw reference?
|     |        |         |     |                 ks:asymmetric-ke\
y-ref
|     |        |         |     +--:(certificate)
|     |        |         |        +--rw certificate
|     |        |         |              {sshcmn:ssh-x509-certs}?
|     |        |         |           +--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-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.

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  authors of the code. All rights reserved.

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  (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.

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   authors of the code. All rights reserved.

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   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

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Appendix A. **Change Log**

A.1. **00 to 01**

   o Renamed "keychain" to "keystore".

A.2. **01 to 02**

   o Added to ietf-netconf-client ability to connected to a cluster of
      endpoints, including a reconnection-strategy.

   o Added to ietf-netconf-client the ability to configure connection-
      type and also keep-alive strategy.

   o Updated both modules to accomodate new groupings in the ssh/tls
      drafts.

A.3. **02 to 03**

   o Refined use of tls-client-grouping to add a must statement
      indicating that the TLS client must specify a client-certificate.

   o Changed 'netconf-client' to be a grouping (not a container).

A.4. **03 to 04**

   o Added RFC 8174 to Requirements Language Section.

   o Replaced refine statement in ietf-netconf-client to add a
      mandatory true.

   o Added refine statement in ietf-netconf-server to add a must
      statement.

   o Now there are containers and groupings, for both the client and
      server models.

A.5. **04 to 05**

   o Now tree diagrams reference ietf-netmod-yang-tree-diagrams

   o Updated examples to inline key and certificates (no longer a
      leafref to keystore)

A.6. 05 to 06

   o Fixed change log missing section issue.

   o Updated examples to match latest updates to the crypto-types,
      trust-anchors, and keystore drafts.

   o Reduced line length of the YANG modules to fit within 69 columns.

A.7. 06 to 07

   o Removed "idle-timeout" from "persistent" connection config.

   o Added "random-selection" for reconnection-strategy's "starts-with"
      enum.

   o Replaced "connection-type" choice default (persistent) with
      "mandatory true".

   o Reduced the periodic-connection's "idle-timeout" from 5 to 2
      minutes.

   o Replaced reconnect-timeout with period/anchor-time combo.

A.8. 07 to 08

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

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