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RESTCONF Client and Server Models
draft-ietf-netconf-restconf-client-server-15

Abstract

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

Editorial Note (To be removed by RFC Editor)

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

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

- I-D.ietf-netconf-keystore
- I-D.ietf-netconf-tcp-client-server
- I-D.ietf-netconf-tls-client-server
- I-D.ietf-netconf-http-client-server

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

- "XXXX" --> the assigned RFC value for this draft
- "AAAA" --> the assigned RFC value for I-D.ietf-netconf-tcp-client-server
- "BBBB" --> the assigned RFC value for I-D.ietf-netconf-tls-client-server

- "CCCC" --> the assigned RFC value for I-D.ietf-netconf-http-client-server

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

- "2019-10-18" --> the publication date of this draft

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

- Appendix B. Change Log

Status of This Memo

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

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on April 20, 2020.

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Table of Contents

1. Introduction

This document defines two YANG [RFC7950] modules, one module to configure a RESTCONF client and the other module to configure a RESTCONF server [RFC8040]. Both modules support the TLS [RFC8446] transport protocol with both standard RESTCONF and RESTCONF Call Home connections [RFC8071].

1.1. 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.

2. The RESTCONF Client Model

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

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

2.1. Tree Diagram

The following tree diagram [RFC8340] provides an overview of the data model for the "ietf-restconf-client" module.

This tree diagram only shows the nodes defined in this module; it does show the nodes defined by "grouping" statements used by this module.

Please see Appendix A.1 for a tree diagram that illustrates what the module looks like with all the "grouping" statements expanded.

```
module: ietf-restconf-client
  +--rw restconf-client
     +---u restconf-client-app-grouping

  grouping restconf-client-grouping
  grouping restconf-client-initiate-stack-grouping
    +-- (transport)
       +--:(https) {https-initiate}?
          +-- https
             +-- tcp-client-parameters
             |  +---u tcpc:tcp-client-grouping
             +-- tls-client-parameters
             |  +---u tlsc:tls-client-grouping
             +-- http-client-parameters
             |  +---u httpc:http-client-grouping
             +-- restconf-client-parameters
  grouping restconf-client-listen-stack-grouping
    +-- (transport)
```

```
         +--:(http) {http-listen}?
         |  +-- FIXME
         +--:(https) {https-listen}?
            +-- https
               +-- tcp-server-parameters
               |  +---u tcps:tcp-server-grouping
               +-- tls-client-parameters
               |  +---u tlsc:tls-client-grouping
               +-- http-client-parameters
               |  +---u httpc:http-client-grouping
               +-- restconf-client-parameters
   grouping restconf-client-app-grouping
     +-- initiate! {https-initiate}?
     |  +-- restconf-server* [name]
     |     +-- name?                string
     |     +-- endpoints
     |     |  +-- endpoint* [name]
     |     |     +-- name?                                        string
     |     |     +---u restconf-client-initiate-stack-grouping
     |     +-- connection-type
     |     |  +-- (connection-type)
     |     |     +--:(persistent-connection)
     |     |     |  +-- persistent!
     |     |     +--:(periodic-connection)
     |     |        +-- periodic!
     |     |           +-- period?         uint16
     |     |           +-- anchor-time?    yang:date-and-time
     |     |           +-- idle-timeout?   uint16
     |     +-- reconnect-strategy
     |        +-- start-with?     enumeration
     |        +-- max-attempts?   uint8
     +-- listen! {http-listen or https-listen}?
        +-- idle-timeout?   uint16
        +-- endpoint* [name]
           +-- name?                                    string
           +---u restconf-client-listen-stack-grouping
```

2.2. Example Usage

The following example illustrates configuring a RESTCONF client to initiate connections, as well as listening for call-home connections.

This example is consistent with the examples presented in Section 2 of [I-D.ietf-netconf-trust-anchors] and Section 3.2 of [I-D.ietf-netconf-keystore].

========== NOTE: '\' line wrapping per BCP XXX (RFC XXXX) ==========

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

     <!-- RESTCONF servers to initiate connections to -->
     <initiate>
       <restconf-server>
         <name>corp-fw1</name>
         <endpoints>
           <endpoint>
             <name>corp-fw1.example.com</name>
             <https>
               <tcp-client-parameters>
                 <remote-address>corp-fw1.example.com</remote-address>
                 <keepalives>
                   <idle-time>15</idle-time>
                   <max-probes>3</max-probes>
                   <probe-interval>30</probe-interval>
                 </keepalives>
               </tcp-client-parameters>
               <tls-client-parameters>
                 <client-identity>
                   <local-definition>
                     <algorithm>rsa2048</algorithm>
                     <private-key>base64encodedvalue==</private-key>
                     <public-key>base64encodedvalue==</public-key>
                     <cert>base64encodedvalue==</cert>
                   </local-definition>
                 </client-identity>
                 <server-authentication>
                   <ca-certs>
                     <truststore-reference>explicitly-trusted-server-ca\
   -certs</truststore-reference>
                   </ca-certs>
                   <server-certs>
                     <truststore-reference>explicitly-trusted-server-ce\
   rts</truststore-reference>
                   </server-certs>
                 </server-authentication>
                 <keepalives>
                   <max-wait>30</max-wait>
                   <max-attempts>3</max-attempts>
                 </keepalives>
               </tls-client-parameters>
               <http-client-parameters>
                 <protocol-version>HTTP/1.1</protocol-version>
                 <client-identity>
                   <basic>
                     <user-id>bob</user-id>
```

```
                    <password>secret</password>
                  </basic>
                </client-identity>
              </http-client-parameters>
            </https>
          </endpoint>
          <endpoint>
            <name>corp-fw2.example.com</name>
            <https>
              <tcp-client-parameters>
                <remote-address>corp-fw2.example.com</remote-address>
                <keepalives>
                  <idle-time>15</idle-time>
                  <max-probes>3</max-probes>
                  <probe-interval>30</probe-interval>
                </keepalives>
              </tcp-client-parameters>
              <tls-client-parameters>
                <client-identity>
                  <local-definition>
                    <algorithm>rsa2048</algorithm>
                    <private-key>base64encodedvalue==</private-key>
                    <public-key>base64encodedvalue==</public-key>
                    <cert>base64encodedvalue==</cert>
                  </local-definition>
                </client-identity>
                <server-authentication>
                  <ca-certs>
                    <truststore-reference>explicitly-trusted-server-ca\
-certs</truststore-reference>
                  </ca-certs>
                  <server-certs>
                    <truststore-reference>explicitly-trusted-server-ce\
rts</truststore-reference>
                  </server-certs>
                </server-authentication>
                <keepalives>
                  <max-wait>30</max-wait>
                  <max-attempts>3</max-attempts>
                </keepalives>
              </tls-client-parameters>
              <http-client-parameters>
                <protocol-version>HTTP/1.1</protocol-version>
                <client-identity>
                  <basic>
                    <user-id>bob</user-id>
                    <password>secret</password>
                  </basic>
```

```
              </client-identity>
            </http-client-parameters>
          </https>
        </endpoint>
      </endpoints>
      <connection-type>
        <persistent/>
      </connection-type>
    </restconf-server>
  </initiate>

  <!-- endpoints to listen for RESTCONF Call Home connections on -->
  <listen>
    <endpoint>
      <name>Intranet-facing listener</name>
      <https>
        <tcp-server-parameters>
          <local-address>11.22.33.44</local-address>
        </tcp-server-parameters>
        <tls-client-parameters>
          <client-identity>
            <local-definition>
              <algorithm>rsa2048</algorithm>
              <private-key>base64encodedvalue==</private-key>
              <public-key>base64encodedvalue==</public-key>
              <cert>base64encodedvalue==</cert>
            </local-definition>
          </client-identity>
          <server-authentication>
            <ca-certs>
              <truststore-reference>explicitly-trusted-server-ca-cer\
ts</truststore-reference>
            </ca-certs>
            <server-certs>
              <truststore-reference>explicitly-trusted-server-certs<\
/truststore-reference>
            </server-certs>
          </server-authentication>
        </tls-client-parameters>
        <http-client-parameters>
          <protocol-version>HTTP/1.1</protocol-version>
          <client-identity>
            <basic>
              <user-id>bob</user-id>
              <password>secret</password>
            </basic>
          </client-identity>
        </http-client-parameters>
```

```
        </https>
      </endpoint>
    </listen>
  </restconf-client>
```

2.3. YANG Module

This YANG module has normative references to [RFC6991], [RFC8040], and [RFC8071], [I-D.kwatsen-netconf-tcp-client-server], [I-D.ietf-netconf-tls-client-server], and [I-D.kwatsen-netconf-http-client-server].

<CODE BEGINS> file "ietf-restconf-client@2019-10-18.yang"

```
module ietf-restconf-client {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-restconf-client";
  prefix rcc;

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

  import ietf-tcp-client {
    prefix tcpc;
    reference
      "RFC AAAA: YANG Groupings for TCP Clients and TCP Servers";
  }

  import ietf-tcp-server {
    prefix tcps;
    reference
      "RFC AAAA: YANG Groupings for TCP Clients and TCP Servers";
  }

  import ietf-tls-client {
    prefix tlsc;
    reference
      "RFC BBBB: YANG Groupings for TLS Clients and TLS Servers";
  }

  import ietf-http-client {
    prefix httpc;
    reference
      "RFC CCCC: YANG Groupings for HTTP Clients and HTTP 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:kent+ietf@watsen.net>
       Author:   Gary Wu <mailto:garywu@cisco.com>";

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

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       as authors of the code. All rights reserved.

       Redistribution and use in source and binary forms, with
       or without modification, is permitted pursuant to, and
       subject to the license terms contained in, the Simplified
       BSD License set forth in Section 4.c of the IETF Trust's
       Legal Provisions Relating to IETF Documents
       (https://trustee.ietf.org/license-info).

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

       The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL',
       'SHALL NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED',
       'NOT RECOMMENDED', 'MAY', and 'OPTIONAL' in this document
       are to be interpreted as described in BCP 14 (RFC 2119)
       (RFC 8174) when, and only when, they appear in all
       capitals, as shown here.";

    revision 2019-10-18 {
      description
        "Initial version";
      reference
        "RFC XXXX: RESTCONF Client and Server Models";
    }

    // Features

    feature https-initiate {
      description
        "The 'https-initiate' feature indicates that the RESTCONF
         client supports initiating HTTPS connections to RESTCONF
         servers. This feature exists as HTTPS might not be a
```

```
          mandatory to implement transport in the future.";
      reference
        "RFC 8040: RESTCONF Protocol";
    }

    feature http-listen {
      description
        "The 'https-listen' feature indicates that the RESTCONF client
         supports opening a port to listen for incoming RESTCONF
         server call-home connections.  This feature exists as not
         all RESTCONF clients may support RESTCONF call home.";
      reference
        "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
    }

    feature https-listen {
      description
        "The 'https-listen' feature indicates that the RESTCONF client
         supports opening a port to listen for incoming RESTCONF
         server call-home connections.  This feature exists as not
         all RESTCONF clients may support RESTCONF call home.";
      reference
        "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
    }

    // Groupings

    grouping restconf-client-grouping {
      description
        "A reusable grouping for configuring a RESTCONF client
         without any consideration for how underlying transport
         sessions are established.

         This grouping currently doesn't define any nodes.";
    }

    grouping restconf-client-initiate-stack-grouping {
      description
        "A reusable grouping for configuring a RESTCONF client
         'initiate' protocol stack for a single connection.";

      choice transport {
        mandatory true;
        description
          "Selects between available transports. This is a
           'choice' statement so as to support additional
           transport options to be augmented in.";
        case https {
```

```
          if-feature "https-initiate";
          container https {
            description
              "Specifies HTTPS-specific transport
               configuration.";
            container tcp-client-parameters {
              description
                "A wrapper around the TCP client parameters
                 to avoid name collisions.";
              uses tcpc:tcp-client-grouping {
                refine "remote-port" {
                  default "443";
                  description
                    "The RESTCONF client will attempt to
                     connect to the IANA-assigned well-known
                     port value for 'https' (443) if no value
                     is specified.";
                }
              }
            }
            container tls-client-parameters {
              must "client-identity" {
                description
                  "NETCONF/TLS clients MUST pass some
                   authentication credentials.";
              }
              description
                "A wrapper around the TLS client parameters
                 to avoid name collisions.";
              uses tlsc:tls-client-grouping;
            }
            container http-client-parameters {
              description
                "A wrapper around the HTTP client parameters
                 to avoid name collisions.";
              uses httpc:http-client-grouping;
            }
            container restconf-client-parameters {
              description
                "A wrapper around the HTTP client parameters
                 to avoid name collisions.";
              uses rcc:restconf-client-grouping;
            }
          }
        }
      }
    } // restconf-client-initiate-stack-grouping
```

```
     grouping restconf-client-listen-stack-grouping {
       description
         "A reusable grouping for configuring a RESTCONF client
          'listen' protocol stack for a single connection.";
       choice transport {
         mandatory true;
         description
           "Selects between available transports. This is a
            'choice' statement so as to support additional
            transport options to be augmented in.";
         case http {
           if-feature "http-listen";
           container FIXME {
             description "FIXME";
           }
         }
         case https {
           if-feature "https-listen";
           container https {
             description
               "HTTPS-specific listening configuration for inbound
                connections.";
             container tcp-server-parameters {
               description
                 "A wrapper around the TCP client parameters
                  to avoid name collisions.";
               uses tcps:tcp-server-grouping {
                 refine "local-port" {
                   default "4336";
                   description
                     "The RESTCONF client will listen on the IANA-
                      assigned well-known port for 'restconf-ch-tls'
                      (4336) if no value is specified.";
                 }
               }
             }
             container tls-client-parameters {
               must "client-identity" {
                 description
                   "NETCONF/TLS clients MUST pass some
                    authentication credentials.";
               }
               description
                 "A wrapper around the TLS client parameters
                  to avoid name collisions.";
               uses tlsc:tls-client-grouping;
             }
             container http-client-parameters {
```

```
              description
                "A wrapper around the HTTP client parameters
                 to avoid name collisions.";
              uses httpc:http-client-grouping;
            }
            container restconf-client-parameters {
              description
                "A wrapper around the RESTCONF client parameters
                 to avoid name collisions.";
              uses rcc:restconf-client-grouping;
            }
          }
        }
      }
    } // restconf-client-listen-stack-grouping

    grouping restconf-client-app-grouping {
      description
        "A reusable grouping for configuring a RESTCONF client
         application that supports both 'initiate' and 'listen'
         protocol stacks for a multiplicity of connections.";
      container initiate {
        if-feature "https-initiate";
        presence "Enables client to initiate TCP connections";
        description
          "Configures client initiating underlying TCP connections.";
        list restconf-server {
          key "name";
          min-elements 1;
          description
            "List of RESTCONF servers the RESTCONF client is to
             maintain simultaneous connections with.";
          leaf name {
            type string;
            description
              "An arbitrary name for the RESTCONF server.";
          }
          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
                 RESTCONF client 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.";
            }
            uses restconf-client-initiate-stack-grouping;
          }
        }
        container connection-type {
          description
            "Indicates the RESTCONF client's preference for how
             the RESTCONF connection is maintained.";
          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
                   RESTCONF server. If the connection goes down,
                   immediately start trying to reconnect to the
                   RESTCONF server, using the reconnection strategy.

                   This connection type minimizes any RESTCONF server
                   to RESTCONF client data-transfer delay, albeit
                   at the expense of holding resources longer.";
              }
            }
            case periodic-connection {
              container periodic {
                presence "Indicates that a periodic connection is
                          to be maintained.";
                description
                  "Periodically connect to the RESTCONF server.

                   This connection type increases resource
                   utilization, albeit with increased delay
                   in RESTCONF server to RESTCONF client
                   interactions.

                   The RESTCONF client SHOULD gracefully close
                   the underlying TLS connection upon completing
                   planned activities.

                   In the case that the previous connection is
```

```
                   still active, establishing a new connection
                   is NOT RECOMMENDED.";

                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 the underlying TCP session may remain
                     idle. A TCP session will be dropped if it
                     is idle for an interval longer than this
                     number of seconds If set to zero, then the
                     RESTCONF client will never drop a session
                     because it is idle.";
                }
              }
            } // periodic-connection
          } // connection-type
        } // connection-type
        container reconnect-strategy {
          description
            "The reconnection strategy directs how a RESTCONF
             client reconnects to a RESTCONF server, after
```

```
            discovering its connection to the server has
            dropped, even if due to a reboot.  The RESTCONF
            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.   RESTCONF 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 RESTCONF server's
               endpoints the RESTCONF client should start
               with when trying to connect to the RESTCONF
               server.";
          }
          leaf max-attempts {
            type uint8 {
              range "1..max";
            }
            default "3";
            description
              "Specifies the number times the RESTCONF client
               tries to connect to a specific endpoint before
               moving on to the next endpoint in the list
               (round robin).";
          }
        }
```

```
        }
      } // initiate
      container listen {
        if-feature "http-listen or https-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 an
             underlying TCP session may remain idle. A TCP session
             will be dropped if it is idle for an interval longer
             then 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 RESTCONF connections.";
          leaf name {
            type string;
            description
              "An arbitrary name for the RESTCONF listen endpoint.";
          }
          uses restconf-client-listen-stack-grouping;
        }
      }
    } // restconf-client-app-grouping

    // Protocol accessible node, for servers that implement this
    // module.

    container restconf-client {
      uses restconf-client-app-grouping;
      description
        "Top-level container for RESTCONF client configuration.";
    }
  }

  <CODE ENDS>
```

3. The RESTCONF Server Model

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

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

3.1. Tree Diagram

The following tree diagram [RFC8340] provides an overview of the data model for the "ietf-restconf-server" module.

This tree diagram only shows the nodes defined in this module; it does show the nodes defined by "grouping" statements used by this module.

Please see Appendix A.2 for a tree diagram that illustrates what the module looks like with all the "grouping" statements expanded.

```
module: ietf-restconf-server
  +--rw restconf-server
     +---u restconf-server-app-grouping

  grouping restconf-server-grouping
    +-- client-identification
       +-- cert-maps
          +---u x509c2n:cert-to-name
  grouping restconf-server-listen-stack-grouping
    +-- (transport)
       +--:(http) {http-listen}?
       |  +-- http
       |     +-- external-endpoint!
       |     |  +-- address    inet:ip-address
       |     |  +-- port?      inet:port-number
       |     +-- tcp-server-parameters
       |     |  +---u tcps:tcp-server-grouping
       |     +-- http-server-parameters
       |     |  +---u https:http-server-grouping
       |     +-- restconf-server-parameters
       |        +---u rcs:restconf-server-grouping
       +--:(https) {https-listen}?
          +-- https
             +-- tcp-server-parameters
             |  +---u tcps:tcp-server-grouping
             +-- tls-server-parameters
```

```
               |  +---u tlss:tls-server-grouping
               +-- http-server-parameters
               |  +---u https:http-server-grouping
               +-- restconf-server-parameters
                  +---u rcs:restconf-server-grouping
     grouping restconf-server-callhome-stack-grouping
       +-- (transport)
          +--:(https) {https-listen}?
             +-- https
                +-- tcp-client-parameters
                |  +---u tcpc:tcp-client-grouping
                +-- tls-server-parameters
                |  +---u tlss:tls-server-grouping
                +-- http-server-parameters
                |  +---u https:http-server-grouping
                +-- restconf-server-parameters
                   +---u rcs:restconf-server-grouping
     grouping restconf-server-app-grouping
       +-- listen! {http-listen or https-listen}?
       |  +-- endpoint* [name]
       |     +-- name?                                    string
       |     +---u restconf-server-listen-stack-grouping
       +-- call-home! {https-call-home}?
          +-- restconf-client* [name]
             +-- name?                string
             +-- endpoints
             |  +-- endpoint* [name]
             |     +-- name?                                        string
             |     +---u restconf-server-callhome-stack-grouping
             +-- connection-type
             |  +-- (connection-type)
             |     +--:(persistent-connection)
             |     |  +-- persistent!
             |     +--:(periodic-connection)
             |        +-- periodic!
             |           +-- period?         uint16
             |           +-- anchor-time?    yang:date-and-time
             |           +-- idle-timeout?   uint16
             +-- reconnect-strategy
                +-- start-with?     enumeration
                +-- max-attempts?   uint8
```

3.2. Example Usage

The following example illustrates configuring a RESTCONF server to listen for RESTCONF client connections, as well as configuring call-home to one RESTCONF client.

This example is consistent with the examples presented in Section 2 of [I-D.ietf-netconf-trust-anchors] and Section 3.2 of [I-D.ietf-netconf-keystore].

```
========== NOTE: '\' line wrapping per BCP XXX (RFC XXXX) ==========

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

  <!-- endpoints to listen for RESTCONF connections on -->
  <listen>
    <endpoint>
      <name>netconf/tls</name>
      <https>
        <tcp-server-parameters>
          <local-address>11.22.33.44</local-address>
        </tcp-server-parameters>
        <tls-server-parameters>
          <server-identity>
            <local-definition>
              <algorithm>rsa2048</algorithm>
              <private-key>base64encodedvalue==</private-key>
              <public-key>base64encodedvalue==</public-key>
              <cert>base64encodedvalue==</cert>
            </local-definition>
          </server-identity>
          <client-authentication>
            <required/>
            <ca-certs>
              <truststore-reference>explicitly-trusted-client-ca-cer\
ts</truststore-reference>
            </ca-certs>
            <client-certs>
              <truststore-reference>explicitly-trusted-client-certs<\
/truststore-reference>
            </client-certs>
          </client-authentication>
        </tls-server-parameters>
        <http-server-parameters>
          <server-name>foo.example.com</server-name>
          <protocol-versions>
            <protocol-version>HTTP/1.1</protocol-version>
            <protocol-version>HTTP/2.0</protocol-version>
          </protocol-versions>
        </http-server-parameters>
        <restconf-server-parameters>
          <client-identification>
```

```
              <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-identification>
          </restconf-server-parameters>
        </https>
      </endpoint>
    </listen>

    <!-- call home to a RESTCONF client with two endpoints -->
    <call-home>
      <restconf-client>
        <name>config-manager</name>
        <endpoints>
          <endpoint>
            <name>east-data-center</name>
            <https>
              <tcp-client-parameters>
                <remote-address>east.example.com</remote-address>
              </tcp-client-parameters>
              <tls-server-parameters>
                <server-identity>
                  <local-definition>
                    <algorithm>rsa2048</algorithm>
                    <private-key>base64encodedvalue==</private-key>
                    <public-key>base64encodedvalue==</public-key>
                    <cert>base64encodedvalue==</cert>
                  </local-definition>
                </server-identity>
                <client-authentication>
                  <required/>
                  <ca-certs>
                    <truststore-reference>explicitly-trusted-client-ca\
  -certs</truststore-reference>
                  </ca-certs>
                  <client-certs>
                    <truststore-reference>explicitly-trusted-client-ce\
  rts</truststore-reference>
```

```
                </client-certs>
              </client-authentication>
            </tls-server-parameters>
            <http-server-parameters>
              <server-name>foo.example.com</server-name>
              <protocol-versions>
                <protocol-version>HTTP/1.1</protocol-version>
                <protocol-version>HTTP/2.0</protocol-version>
              </protocol-versions>
            </http-server-parameters>
            <restconf-server-parameters>
              <client-identification>
                <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-identification>
            </restconf-server-parameters>
          </https>
        </endpoint>
        <endpoint>
          <name>west-data-center</name>
          <https>
            <tcp-client-parameters>
              <remote-address>west.example.com</remote-address>
            </tcp-client-parameters>
            <tls-server-parameters>
              <server-identity>
                <local-definition>
                  <algorithm>rsa2048</algorithm>
                  <private-key>base64encodedvalue==</private-key>
                  <public-key>base64encodedvalue==</public-key>
                  <cert>base64encodedvalue==</cert>
                </local-definition>
              </server-identity>
              <client-authentication>
                <required/>
                <ca-certs>
                  <truststore-reference>explicitly-trusted-client-ca\
```

```
   -certs</truststore-reference>
                  </ca-certs>
                  <client-certs>
                    <truststore-reference>explicitly-trusted-client-ce\
   rts</truststore-reference>
                  </client-certs>
                </client-authentication>
              </tls-server-parameters>
              <http-server-parameters>
                <server-name>foo.example.com</server-name>
                <protocol-versions>
                  <protocol-version>HTTP/1.1</protocol-version>
                  <protocol-version>HTTP/2.0</protocol-version>
                </protocol-versions>
              </http-server-parameters>
              <restconf-server-parameters>
                <client-identification>
                  <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-identification>
              </restconf-server-parameters>
            </https>
          </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>
      </restconf-client>
    </call-home>
   </restconf-server>
```

3.3. YANG Module

This YANG module has normative references to [RFC6991], [RFC7407], [RFC8040], [RFC8071], [I-D.kwatsen-netconf-tcp-client-server], [I-D.ietf-netconf-tls-client-server], and [I-D.kwatsen-netconf-http-client-server].

<CODE BEGINS> file "ietf-restconf-server@2019-10-18.yang"

```
module ietf-restconf-server {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-restconf-server";
  prefix rcs;

  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-tcp-client {
    prefix tcpc;
    reference
      "RFC AAAA: YANG Groupings for TCP Clients and TCP Servers";
  }

  import ietf-tcp-server {
    prefix tcps;
    reference
      "RFC AAAA: YANG Groupings for TCP Clients and TCP Servers";
  }

  import ietf-tls-server {
    prefix tlss;
    reference
      "RFC BBBB: YANG Groupings for TLS Clients and TLS Servers";
```

```
    }

    import ietf-http-server {
      prefix https;
      reference
        "RFC CCCC: YANG Groupings for HTTP Clients and HTTP 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:kent+ietf@watsen.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 RESTCONF servers.

       Copyright (c) 2019 IETF Trust and the persons identified
       as authors of the code. All rights reserved.

       Redistribution and use in source and binary forms, with
       or without modification, is permitted pursuant to, and
       subject to the license terms contained in, the Simplified
       BSD License set forth in Section 4.c of the IETF Trust's
       Legal Provisions Relating to IETF Documents
       (https://trustee.ietf.org/license-info).

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

       The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL',
       'SHALL NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED',
       'NOT RECOMMENDED', 'MAY', and 'OPTIONAL' in this document
       are to be interpreted as described in BCP 14 (RFC 2119)
       (RFC 8174) when, and only when, they appear in all
       capitals, as shown here.";

    revision 2019-10-18 {
      description
        "Initial version";
      reference
```

```
        "RFC XXXX: RESTCONF Client and Server Models";
    }

    // Features

    feature http-listen {
      description
        "The 'http-listen' feature indicates that the RESTCONF server
         supports opening a port to listen for incoming RESTCONF over
         TPC client connections, whereby the TLS connections are
         terminated by an external system.";
      reference
        "RFC 8040: RESTCONF Protocol";
    }

    feature https-listen {
      description
        "The 'https-listen' feature indicates that the RESTCONF server
         supports opening a port to listen for incoming RESTCONF over
         TLS client connections, whereby the TLS connections are
         terminated by the server itself.";
      reference
        "RFC 8040: RESTCONF Protocol";
    }

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


    // Groupings

    grouping restconf-server-grouping {
      description
        "A reusable grouping for configuring a RESTCONF server
         without any consideration for how underlying transport
         sessions are established.

         Note that this grouping uses a fairly typical descendent
         node name such that a stack of 'uses' statements will
         have name conflicts.  It is intended that the consuming
         data model will resolve the issue by wrapping the 'uses'
         statement in a container called, e.g.,
         'restconf-server-parameters'.  This model purposely does
```

```
          not do this itself so as to provide maximum flexibility
          to consuming models.";

        container client-identification {  // FIXME: if-feature?
          description
            "Specifies a mapping through which clients MAY be identified
             (i.e., the RESTCONF username) from a supplied certificate.
             Note that a client MAY alternatively be identified via an
             HTTP-level authentication schema.  This configuration does
             not necessitate clients send a certificate (that can be
             controlled via the ietf-restconf-server module).";
          container cert-maps {
            uses x509c2n:cert-to-name;
            description
              "The cert-maps container is used by TLS-based RESTCONF
               servers (even if the TLS sessions are terminated
               externally) to map the RESTCONF client's presented
               X.509 certificate to a RESTCONF username.  If no
               matching and valid cert-to-name list entry can be
               found, then the RESTCONF server MUST close the
               connection, and MUST NOT accept RESTCONF messages
               over it.";
            reference
              "RFC 7407: A YANG Data Model for SNMP Configuration.";
          }
        }
      }


      grouping restconf-server-listen-stack-grouping {
        description
          "A reusable grouping for configuring a RESTCONF server
           'listen' protocol stack for a single connection.";
        choice transport {
          mandatory true;
          description
            "Selects between available transports. This is a
             'choice' statement so as to support additional
             transport options to be augmented in.";
          case http {
            if-feature "http-listen";
            container http {
              description
                "Configures RESTCONF server stack assuming that
                 TLS-termination is handled externally.";
              container external-endpoint {
                presence
                  "Specifies configuration for an external endpoint.";
```

```
        description
          "Identifies contact information for the external
           system that terminates connections before passing
           them thru to this server (e.g., a network address
           translator or a load balancer).  These values have
           no effect on the local operation of this server, but
           may be used by the application when needing to
           inform other systems how to contact this server.";
        leaf address {
          type inet:ip-address;
          mandatory true;
          description
            "The IP address or hostname of the external system
             that terminates incoming RESTCONF client
             connections before forwarding them to this
             server.";
        }
        leaf port {
          type inet:port-number;
          default "443";
          description
            "The port number that the external system listens
             on for incoming RESTCONF client connections that
             are forwarded to this server.  The default HTTPS
             port (443) is used, as expected for a RESTCONF
             connection.";
        }
      }
      container tcp-server-parameters {
        description
          "A wrapper around the TCP server parameters
           to avoid name collisions.";
        uses tcps:tcp-server-grouping {
          refine "local-port" {
            default "80";
            description
              "The RESTCONF server will listen on the IANA-
               assigned well-known port value for 'http'
               (80) if no value is specified.";
          }
        }
      }
      container http-server-parameters {
        description
          "A wrapper around the HTTP server parameters
           to avoid name collisions.";
        uses https:http-server-grouping;
      }
```

```
            container restconf-server-parameters {
              description
                "A wrapper around the RESTCONF server parameters
                 to avoid name collisions.";
              uses rcs:restconf-server-grouping;
            }
          }
        }
        case https {
          if-feature "https-listen";
          container https {
            description
              "Configures RESTCONF server stack assuming that
               TLS-termination is handled internally.";
            container tcp-server-parameters {
              description
                "A wrapper around the TCP server parameters
                 to avoid name collisions.";
              uses tcps:tcp-server-grouping {
                refine "local-port" {
                  default "443";
                  description
                    "The RESTCONF server will listen on the IANA-
                     assigned well-known port value for 'https'
                     (443) if no value is specified.";
                }
              }
            }
            container tls-server-parameters {
              description
                "A wrapper around the TLS server parameters
                 to avoid name collisions.";
              uses tlss:tls-server-grouping;
            }
            container http-server-parameters {
              description
                "A wrapper around the HTTP server parameters
                 to avoid name collisions.";
              uses https:http-server-grouping;
            }
            container restconf-server-parameters {
              description
                "A wrapper around the RESTCONF server parameters
                 to avoid name collisions.";
              uses rcs:restconf-server-grouping;
            }
          }
        }
```

```
      }
    }

    grouping restconf-server-callhome-stack-grouping {
      description
        "A reusable grouping for configuring a RESTCONF server
         'call-home' protocol stack, for a single connection.";
      choice transport {
        mandatory true;
        description
          "Selects between available transports. This is a
           'choice' statement so as to support additional
           transport options to be augmented in.";
        case https {
          if-feature "https-listen";
          container https {
            description
              "Configures RESTCONF server stack assuming that
               TLS-termination is handled internally.";
            container tcp-client-parameters {
              description
                "A wrapper around the TCP client parameters
                 to avoid name collisions.";
              uses tcpc:tcp-client-grouping {
                refine "remote-port" {
                  default "4336";
                  description
                    "The RESTCONF server will attempt to
                     connect to the IANA-assigned well-known
                     port for 'restconf-ch-tls' (4336) if no
                     value is specified.";
                }
              }
            }
            container tls-server-parameters {
              description
                "A wrapper around the TLS server parameters
                 to avoid name collisions.";
              uses tlss:tls-server-grouping;
            }
            container http-server-parameters {
              description
                "A wrapper around the HTTP server parameters
                 to avoid name collisions.";
              uses https:http-server-grouping;
            }
            container restconf-server-parameters {
              description
```

```
                "A wrapper around the RESTCONF server parameters
                 to avoid name collisions.";
              uses rcs:restconf-server-grouping;
            }
          }
        }
      }
    }


    grouping restconf-server-app-grouping {
      description
        "A reusable grouping for configuring a RESTCONF server
         application that supports both 'listen' and 'call-home'
         protocol stacks for a multiplicity of connections.";
      container listen {
        if-feature "http-listen or https-listen";
        presence
          "Enables the RESTCONF server to listen for RESTCONF
           client connections.";
        description "Configures listen behavior";
        list endpoint {
          key "name";
          min-elements 1;
          description
            "List of endpoints to listen for RESTCONF connections.";
          leaf name {
            type string;
            description
              "An arbitrary name for the RESTCONF listen endpoint.";
          }
          uses restconf-server-listen-stack-grouping;
        }
      }
      container call-home {
        if-feature "https-call-home";
        presence
          "Enables the RESTCONF server to initiate the underlying
           transport connection to RESTCONF clients.";
        description "Configures call-home behavior";
        list restconf-client {
          key "name";
          min-elements 1;
          description
            "List of RESTCONF clients the RESTCONF server is to
             maintain simultaneous call-home connections with.";
          leaf name {
            type string;
```

```
            description
              "An arbitrary name for the remote RESTCONF client.";
          }
          container endpoints {
            description
              "Container for the list of endpoints.";
            list endpoint {
              key "name";
              min-elements 1;
              ordered-by user;
              description
                "User-ordered list of endpoints for this RESTCONF
                 client.  Defining more than one enables high-
                 availability.";
              leaf name {
                type string;
                description
                  "An arbitrary name for this endpoint.";
              }
              uses restconf-server-callhome-stack-grouping;
            }
          }
          container connection-type {
            description
              "Indicates the RESTCONF server's preference for how the
               RESTCONF connection is maintained.";
            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 RESTCONF
                     client. If the connection goes down, immediately
                     start trying to reconnect to the RESTCONF server,
                     using the reconnection strategy.

                     This connection type minimizes any RESTCONF
                     client to RESTCONF server data-transfer delay,
                     albeit at the expense of holding resources
                     longer.";
                }
              }
              case periodic-connection {
                container periodic {
```

```
                presence "Indicates that a periodic connection is
                          to be maintained.";
                description
                  "Periodically connect to the RESTCONF client.

                   This connection type increases resource
                   utilization, albeit with increased delay in
                   RESTCONF client to RESTCONF client interactions.

                   The RESTCONF client SHOULD gracefully close
                   the underlying TLS connection upon completing
                   planned activities.  If the underlying TLS
                   connection is not closed gracefully, the
                   RESTCONF server MUST immediately attempt
                   to reestablish the connection.

                   In the case that the previous connection is
                   still active (i.e., the RESTCONF client has not
                   closed it yet), establishing a new connection
                   is NOT RECOMMENDED.";

                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
                       the underlying TCP session may remain idle.
                       A TCP 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 RESTCONF server
               reconnects to a RESTCONF client after discovering its
               connection to the client has dropped, even if due to a
               reboot.  The RESTCONF 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.   RESTCONF
                     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 RESTCONF client's endpoints
                 the RESTCONF server should start with when trying
                 to connect to the RESTCONF client.";
```

```
            }
            leaf max-attempts {
              type uint8 {
                range "1..max";
              }
              default "3";
              description
                "Specifies the number times the RESTCONF server tries
                 to connect to a specific endpoint before moving on to
                 the next endpoint in the list (round robin).";
            }
          }
        } // restconf-client
      } // call-home
    } // restconf-server-app-grouping



    // Protocol accessible node, for servers that implement this
    // module.

    container restconf-server {
      uses restconf-server-app-grouping;
      description
        "Top-level container for RESTCONF server configuration.";
    }

  }

  <CODE ENDS>
```

4. Security Considerations

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

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

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

There are a number of data nodes defined in the YANG modules that are writable/creatable/deletable (i.e., config true, which is the default). Some of 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:

None of the subtrees or data nodes in the modules defined in this document need to be protected from write operations.

Some of the readable data nodes in the YANG modules 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 of the subtrees or data nodes in the modules defined in this document need to be protected from read operations.

Some of the RPC operations in the YANG modules 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:

The modules defined in this document do not define any 'RPC' or 'action' statements.

5. IANA Considerations

5.1. 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-restconf-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-restconf-server
Registrant Contact: The NETCONF WG of the IETF.
XML: N/A, the requested URI is an XML namespace.

5.2. The YANG Module Names Registry

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

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

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

6. References

6.1. Normative References

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6.2. Informative References

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Appendix A. Expanded Tree Diagrams

A.1. Expanded Tree Diagram for 'ietf-restconf-client'

The following tree diagram [RFC8340] provides an overview of the data model for the "ietf-restconf-client" module.

This tree diagram shows all the nodes defined in this module, including those defined by "grouping" statements used by this module.

Please see Section 2.1 for a tree diagram that illustrates what the module looks like without all the "grouping" statements expanded.

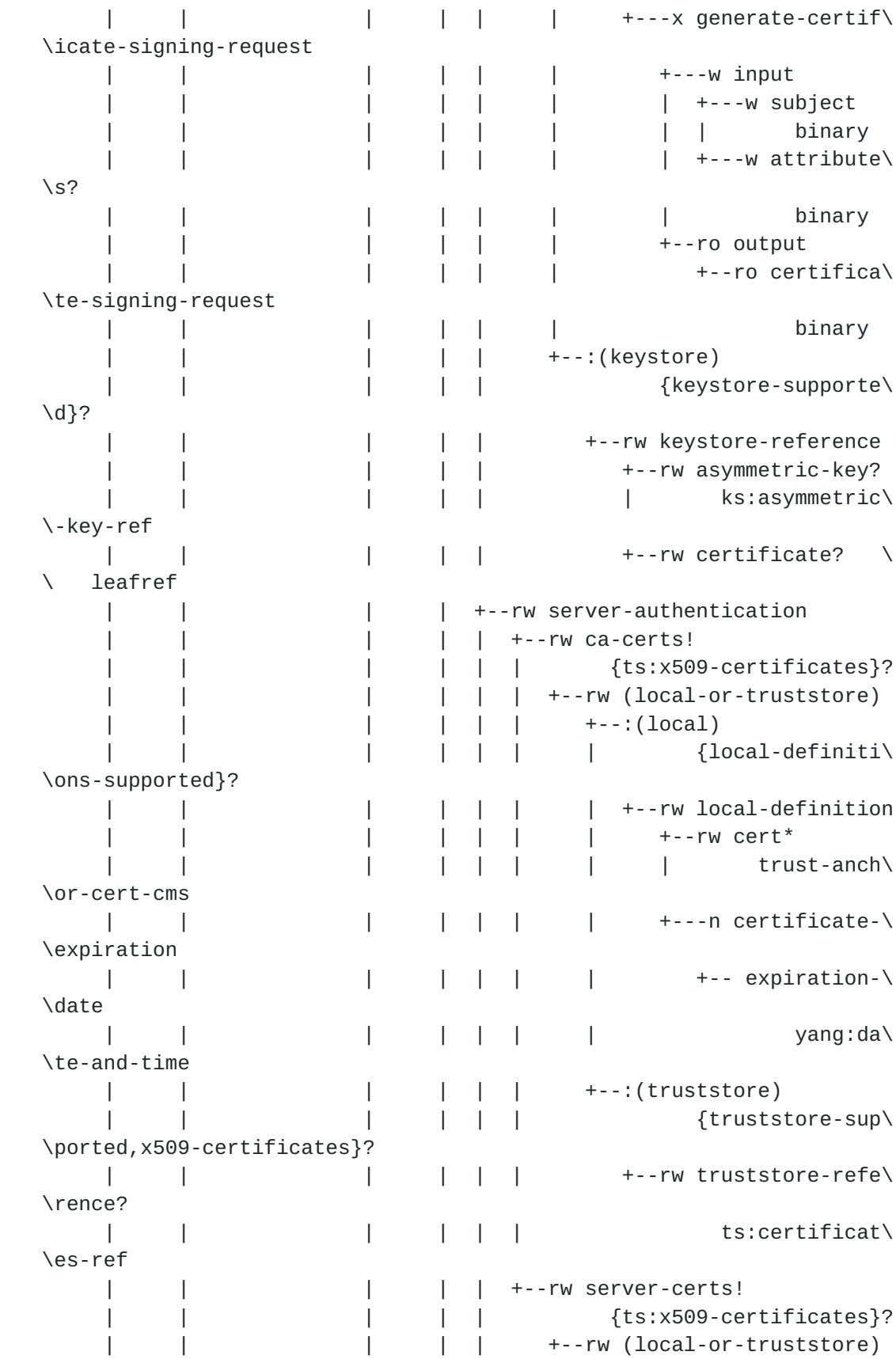
```
========== NOTE: '\\' line wrapping per BCP XXX (RFC XXXX) ==========

module: ietf-restconf-client
  +--rw restconf-client
     +--rw initiate! {https-initiate}?
     |  +--rw restconf-server* [name]
     |     +--rw name                  string
     |     +--rw endpoints
     |     |  +--rw endpoint* [name]
     |     |     +--rw name           string
     |     |     +--rw (transport)
     |     |        +--:(https) {https-initiate}?
     |     |           +--rw https
     |     |              +--rw tcp-client-parameters
     |     |              |  +--rw remote-address    inet:host
     |     |              |  +--rw remote-port?      inet:port-number
     |     |              |  +--rw local-address?    inet:ip-address
     |     |              |  |       {local-binding-supported}?
     |     |              |  +--rw local-port?       inet:port-number
     |     |              |  |       {local-binding-supported}?
     |     |              |  +--rw keepalives!
     |     |              |          {keepalives-supported}?
     |     |              |     +--rw idle-time         uint16
     |     |              |     +--rw max-probes        uint16
     |     |              |     +--rw probe-interval    uint16
     |     |              +--rw tls-client-parameters
     |     |              |  +--rw client-identity
     |     |              |  |  +--rw (local-or-keystore)
     |     |              |  |     +--:(local)
     |     |              |  |     |        {local-definitions-suppo\
\rted}?
     |     |              |  |     |  +--rw local-definition
     |     |              |  |     |     +--rw algorithm
     |     |              |  |     |     |       asymmetric-key-algo\
\rithm-t
```

```
        |     |              |  |     |     +--rw public-key-format?
        |     |              |  |     |     |       identityref
        |     |              |  |     |     +--rw public-key
        |     |              |  |     |     |       binary
        |     |              |  |     |     +--rw private-key-format?
        |     |              |  |     |     |       identityref
        |     |              |  |     |     +--rw (private-key-type)
        |     |              |  |     |     |  +--:(private-key)
        |     |              |  |     |     |  |  +--rw private-key?
        |     |              |  |     |     |  |          binary
        |     |              |  |     |     |  +--:(hidden-private-key)
        |     |              |  |     |     |  |  +--rw hidden-private-\
   \key?
        |     |              |  |     |     |  |          empty
        |     |              |  |     |     |  +--:(encrypted-private-k\
   \ey)
        |     |              |  |     |     |     +--rw encrypted-priva\
   \te-key
        |     |              |  |     |     |        +--rw (key-type)
        |     |              |  |     |     |        |  +--:(symmetric-\
   \key-ref)
        |     |              |  |     |     |        |  |  +--rw symmet\
   \ric-key-ref?    leafref
        |     |              |  |     |     |        |  |          {key\
   \store-supported}?
        |     |              |  |     |     |        |  +--:(asymmetric\
   \-key-ref)
        |     |              |  |     |     |        |     +--rw asymme\
   \tric-key-ref?   leafref
        |     |              |  |     |     |        |             {key\
   \store-supported}?
        |     |              |  |     |     |        +--rw value?
        |     |              |  |     |     |                 binary
        |     |              |  |     |     +--rw cert?
        |     |              |  |     |     |       end-entity-cert-cms
        |     |              |  |     |     +---n certificate-expiration
        |     |              |  |     |     |  +-- expiration-date
        |     |              |  |     |     |          yang:date-and-ti\
   \me
        |     |              |  |     |     +---x generate-certificate-\
   \signing-request
        |     |              |  |     |        +---w input
        |     |              |  |     |        |  +---w subject
        |     |              |  |     |        |  |       binary
        |     |              |  |     |        |  +---w attributes?
        |     |              |  |     |        |          binary
        |     |              |  |     |        +--ro output
        |     |              |  |     |           +--ro certificate-sig\
```

```
   \ning-request
        |     |              |  |     |                   binary
        |     |              |  |     +--:(keystore)
        |     |              |  |              {keystore-supported}?
        |     |              |  |        +--rw keystore-reference
        |     |              |  |           +--rw asymmetric-key?
        |     |              |  |           |       ks:asymmetric-key-r\
   \ef
        |     |              |  |           +--rw certificate?      lea\
   \fref
        |     |              |  +--rw server-authentication
        |     |              |  |  +--rw ca-certs!
        |     |              |  |  |       {ts:x509-certificates}?
        |     |              |  |  |  +--rw (local-or-truststore)
        |     |              |  |  |     +--:(local)
        |     |              |  |  |     |        {local-definitions-su\
   \pported}?
        |     |              |  |  |     |  +--rw local-definition
        |     |              |  |  |     |     +--rw cert*
        |     |              |  |  |     |     |       trust-anchor-cer\
   \t-cms
        |     |              |  |  |     |     +---n certificate-expira\
   \tion
        |     |              |  |  |     |        +-- expiration-date
        |     |              |  |  |     |                 yang:date-and\
   \-time
        |     |              |  |  |     +--:(truststore)
        |     |              |  |  |              {truststore-supported\
   \,x509-certificates}?
        |     |              |  |  |        +--rw truststore-reference?
        |     |              |  |  |                 ts:certificates-ref
        |     |              |  |  +--rw server-certs!
        |     |              |  |           {ts:x509-certificates}?
        |     |              |  |     +--rw (local-or-truststore)
        |     |              |  |        +--:(local)
        |     |              |  |        |        {local-definitions-su\
   \pported}?
        |     |              |  |        |  +--rw local-definition
        |     |              |  |        |     +--rw cert*
        |     |              |  |        |     |       trust-anchor-cer\
   \t-cms
        |     |              |  |        |     +---n certificate-expira\
   \tion
        |     |              |  |        |        +-- expiration-date
        |     |              |  |        |                 yang:date-and\
   \-time
        |     |              |  |        +--:(truststore)
        |     |              |  |                 {truststore-supported\
```

```
   \,x509-certificates}?
        |     |              |  |          +--rw truststore-reference?
        |     |              |  |                  ts:certificates-ref
        |     |              |  +--rw hello-params
        |     |              |  |       {tls-client-hello-params-config\
   \}?
        |     |              |  |  +--rw tls-versions
        |     |              |  |  |  +--rw tls-version*   identityref
        |     |              |  |  +--rw cipher-suites
        |     |              |  |     +--rw cipher-suite*   identityref
        |     |              |  +--rw keepalives!
        |     |              |          {tls-client-keepalives}?
        |     |              |     +--rw max-wait?       uint16
        |     |              |     +--rw max-attempts?   uint8
        |     |              +--rw http-client-parameters
        |     |              |  +--rw protocol-version?   enumeration
        |     |              |  +--rw client-identity
        |     |              |  |  +--rw (auth-type)
        |     |              |  |     +--:(basic)
        |     |              |  |        +--rw basic {basic-auth}?
        |     |              |  |           +--rw user-id     string
        |     |              |  |           +--rw password    string
        |     |              |  +--rw proxy-server! {proxy-connect}?
        |     |              |     +--rw tcp-client-parameters
        |     |              |     |  +--rw remote-address    inet:host
        |     |              |     |  +--rw remote-port?
        |     |              |     |  |       inet:port-number
        |     |              |     |  +--rw local-address?
        |     |              |     |  |       inet:ip-address
        |     |              |     |  |       {local-binding-supported}?
        |     |              |     |  +--rw local-port?
        |     |              |     |  |       inet:port-number
        |     |              |     |  |       {local-binding-supported}?
        |     |              |     |  +--rw keepalives!
        |     |              |     |          {keepalives-supported}?
        |     |              |     |     +--rw idle-time         uint16
        |     |              |     |     +--rw max-probes        uint16
        |     |              |     |     +--rw probe-interval    uint16
        |     |              |     +--rw tls-client-parameters
        |     |              |     |  +--rw client-identity
        |     |              |     |  |  +--rw (local-or-keystore)
        |     |              |     |  |     +--:(local)
        |     |              |     |  |     |        {local-definitions\
   \-supported}?
        |     |              |     |  |     |  +--rw local-definition
        |     |              |     |  |     |     +--rw algorithm
        |     |              |     |  |     |     |       asymmetric-ke\
   \y-algorithm-t
```

```
     |     |              |     |  |     |     +--rw public-key-form\
\at?
     |     |              |     |  |     |     |       identityref
     |     |              |     |  |     |     +--rw public-key
     |     |              |     |  |     |     |       binary
     |     |              |     |  |     |     +--rw private-key-for\
\mat?
     |     |              |     |  |     |     |       identityref
     |     |              |     |  |     |     +--rw (private-key-ty\
\pe)
     |     |              |     |  |     |     |  +--:(private-key)
     |     |              |     |  |     |     |  |  +--rw private-k\
\ey?
     |     |              |     |  |     |     |  |          binary
     |     |              |     |  |     |     |  +--:(hidden-privat\
\e-key)
     |     |              |     |  |     |     |  |  +--rw hidden-pr\
\ivate-key?
     |     |              |     |  |     |     |  |          empty
     |     |              |     |  |     |     |  +--:(encrypted-pri\
\vate-key)
     |     |              |     |  |     |     |     +--rw encrypted\
\-private-key
     |     |              |     |  |     |     |        +--rw (key-t\
\ype)
     |     |              |     |  |     |     |        |  +--:(symm\
\etric-key-ref)
     |     |              |     |  |     |     |        |  |  +--rw \
\symmetric-key-ref?    leafref
     |     |              |     |  |     |     |        |  |        \
\  {keystore-supported}?
     |     |              |     |  |     |     |        |  +--:(asym\
\metric-key-ref)
     |     |              |     |  |     |     |        |     +--rw \
\asymmetric-key-ref?   leafref
     |     |              |     |  |     |     |        |           \
\  {keystore-supported}?
     |     |              |     |  |     |     |        +--rw value?
     |     |              |     |  |     |     |                 bina\
\ry
     |     |              |     |  |     |     +--rw cert?
     |     |              |     |  |     |     |       end-entity-ce\
\rt-cms
     |     |              |     |  |     |     +---n certificate-exp\
\iration
     |     |              |     |  |     |     |  +-- expiration-date
     |     |              |     |  |     |     |          yang:date-\
\and-time
```


+---x generate-certif\
\icate-signing-request
+---w input
+---w subject
| binary
+---w attribute\
\s?
binary
+--ro output
+--ro certifica\
\te-signing-request
binary
+--:(keystore)
{keystore-supporte\
\d}?
+--rw keystore-reference
+--rw asymmetric-key?
ks:asymmetric\
\-key-ref
+--rw certificate? \
\ leafref
+--rw server-authentication
+--rw ca-certs!
{ts:x509-certificates}?
+--rw (local-or-truststore)
+--:(local)
{local-definiti\
\ons-supported}?
+--rw local-definition
+--rw cert*
trust-anch\
\or-cert-cms
+---n certificate-\
\expiration
+-- expiration-\
\date
yang:da\
\te-and-time
+--:(truststore)
{truststore-sup\
\ported,x509-certificates}?
+--rw truststore-refe\
\rence?
ts:certificat\
\es-ref
+--rw server-certs!
{ts:x509-certificates}?
+--rw (local-or-truststore)

```
        |     |              |     |  |        +--:(local)
        |     |              |     |  |        |       {local-definiti\
   \ons-supported}?
        |     |              |     |  |        |  +--rw local-definition
        |     |              |     |  |        |     +--rw cert*
        |     |              |     |  |        |     |       trust-anch\
   \or-cert-cms
        |     |              |     |  |        |     +---n certificate-\
   \expiration
        |     |              |     |  |        |        +-- expiration-\
   \date
        |     |              |     |  |        |                yang:da\
   \te-and-time
        |     |              |     |  |        +--:(truststore)
        |     |              |     |  |                 {truststore-sup\
   \ported,x509-certificates}?
        |     |              |     |  |           +--rw truststore-refe\
   \rence?
        |     |              |     |  |                   ts:certificat\
   \es-ref
        |     |              |     |  +--rw hello-params
        |     |              |     |  |       {tls-client-hello-params-\
   \config}?
        |     |              |     |  |  +--rw tls-versions
        |     |              |     |  |  |  +--rw tls-version*
        |     |              |     |  |  |          identityref
        |     |              |     |  |  +--rw cipher-suites
        |     |              |     |  |     +--rw cipher-suite*
        |     |              |     |  |             identityref
        |     |              |     |  +--rw keepalives!
        |     |              |     |          {tls-client-keepalives}?
        |     |              |     |     +--rw max-wait?       uint16
        |     |              |     |     +--rw max-attempts?   uint8
        |     |              |     +--rw proxy-client-identity
        |     |              |        +--rw (auth-type)
        |     |              |           +--:(basic)
        |     |              |              +--rw basic {basic-auth}?
        |     |              |                 +--rw user-id     string
        |     |              |                 +--rw password    string
        |     |             +--rw restconf-client-parameters
        |     +--rw connection-type
        |     |  +--rw (connection-type)
        |     |     +--:(persistent-connection)
        |     |     |  +--rw persistent!
        |     |     +--:(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! {http-listen or https-listen}?
           +--rw idle-timeout?   uint16
           +--rw endpoint* [name]
              +--rw name           string
              +--rw (transport)
                 +--:(http) {http-listen}?
                 |  +--rw FIXME
                 +--:(https) {https-listen}?
                    +--rw https
                       +--rw tcp-server-parameters
                       |  +--rw local-address    inet:ip-address
                       |  +--rw local-port?      inet:port-number
                       |  +--rw keepalives! {keepalives-supported}?
                       |     +--rw idle-time         uint16
                       |     +--rw max-probes        uint16
                       |     +--rw probe-interval    uint16
                       +--rw tls-client-parameters
                       |  +--rw client-identity
                       |  |  +--rw (local-or-keystore)
                       |  |     +--:(local)
                       |  |     |        {local-definitions-supported}?
                       |  |     |  +--rw local-definition
                       |  |     |     +--rw algorithm
                       |  |     |     |       asymmetric-key-algorithm-t
                       |  |     |     +--rw public-key-format?
                       |  |     |     |       identityref
                       |  |     |     +--rw public-key
                       |  |     |     |       binary
                       |  |     |     +--rw private-key-format?
                       |  |     |     |       identityref
                       |  |     |     +--rw (private-key-type)
                       |  |     |     |  +--:(private-key)
                       |  |     |     |  |  +--rw private-key?
                       |  |     |     |  |          binary
                       |  |     |     |  +--:(hidden-private-key)
                       |  |     |     |  |  +--rw hidden-private-key?
                       |  |     |     |  |          empty
                       |  |     |     |  +--:(encrypted-private-key)
                       |  |     |     |     +--rw encrypted-private-key
                       |  |     |     |        +--rw (key-type)
                       |  |     |     |        |  +--:(symmetric-key-re\
   \f)
                       |  |     |     |        |  |  +--rw symmetric-ke\
   \y-ref?    leafref
```

```
                     |  |     |     |        |  |          {keystore-\
   \supported}?
                     |  |     |     |        |  +--:(asymmetric-key-r\
   \ef)
                     |  |     |     |        |     +--rw asymmetric-k\
   \ey-ref?   leafref
                     |  |     |     |        |             {keystore-\
   \supported}?
                     |  |     |     |        +--rw value?
                     |  |     |     |                 binary
                     |  |     |     +--rw cert?
                     |  |     |     |       end-entity-cert-cms
                     |  |     |     +---n certificate-expiration
                     |  |     |     |  +-- expiration-date
                     |  |     |     |          yang:date-and-time
                     |  |     |     +---x generate-certificate-signin\
   \g-request
                     |  |     |        +---w input
                     |  |     |        |  +---w subject       binary
                     |  |     |        |  +---w attributes?   binary
                     |  |     |        +--ro output
                     |  |     |           +--ro certificate-signing-r\
   \equest
                     |  |     |                  binary
                     |  |     +--:(keystore) {keystore-supported}?
                     |  |        +--rw keystore-reference
                     |  |           +--rw asymmetric-key?
                     |  |           |       ks:asymmetric-key-ref
                     |  |           +--rw certificate?      leafref
                     |  +--rw server-authentication
                     |  |  +--rw ca-certs! {ts:x509-certificates}?
                     |  |  |  +--rw (local-or-truststore)
                     |  |  |     +--:(local)
                     |  |  |     |        {local-definitions-supporte\
   \d}?
                     |  |  |     |  +--rw local-definition
                     |  |  |     |     +--rw cert*
                     |  |  |     |     |       trust-anchor-cert-cms
                     |  |  |     |     +---n certificate-expiration
                     |  |  |     |        +-- expiration-date
                     |  |  |     |                yang:date-and-time
                     |  |  |     +--:(truststore)
                     |  |  |              {truststore-supported,x509-\
   \certificates}?
                     |  |  |        +--rw truststore-reference?
                     |  |  |                 ts:certificates-ref
                     |  |  +--rw server-certs! {ts:x509-certificates}?
                     |  |     +--rw (local-or-truststore)
```

```
                        |  |        +--:(local)
                        |  |        |        {local-definitions-supporte\
   \d}?
                        |  |        |  +--rw local-definition
                        |  |        |     +--rw cert*
                        |  |        |     |       trust-anchor-cert-cms
                        |  |        |     +---n certificate-expiration
                        |  |        |        +-- expiration-date
                        |  |        |                yang:date-and-time
                        |  |        +--:(truststore)
                        |  |                 {truststore-supported,x509-\
   \certificates}?
                        |  |           +--rw truststore-reference?
                        |  |                   ts:certificates-ref
                        |  +--rw hello-params
                        |  |       {tls-client-hello-params-config}?
                        |  |  +--rw tls-versions
                        |  |  |  +--rw tls-version*   identityref
                        |  |  +--rw cipher-suites
                        |  |     +--rw cipher-suite*   identityref
                        |  +--rw keepalives! {tls-client-keepalives}?
                        |     +--rw max-wait?       uint16
                        |     +--rw max-attempts?   uint8
                        +--rw http-client-parameters
                        |  +--rw protocol-version?   enumeration
                        |  +--rw client-identity
                        |  |  +--rw (auth-type)
                        |  |     +--:(basic)
                        |  |        +--rw basic {basic-auth}?
                        |  |           +--rw user-id     string
                        |  |           +--rw password    string
                        |  +--rw proxy-server! {proxy-connect}?
                        |     +--rw tcp-client-parameters
                        |     |  +--rw remote-address    inet:host
                        |     |  +--rw remote-port?      inet:port-number
                        |     |  +--rw local-address?    inet:ip-address
                        |     |  |       {local-binding-supported}?
                        |     |  +--rw local-port?       inet:port-number
                        |     |  |       {local-binding-supported}?
                        |     |  +--rw keepalives!
                        |     |          {keepalives-supported}?
                        |     |     +--rw idle-time         uint16
                        |     |     +--rw max-probes        uint16
                        |     |     +--rw probe-interval    uint16
                        |     +--rw tls-client-parameters
                        |     |  +--rw client-identity
                        |     |  |  +--rw (local-or-keystore)
                        |     |  |     +--:(local)
```

```
                     |     |  |     |        {local-definitions-suppo\
   \rted}?
                     |     |  |     |  +--rw local-definition
                     |     |  |     |     +--rw algorithm
                     |     |  |     |     |       asymmetric-key-algo\
   \rithm-t
                     |     |  |     |     +--rw public-key-format?
                     |     |  |     |     |       identityref
                     |     |  |     |     +--rw public-key
                     |     |  |     |     |       binary
                     |     |  |     |     +--rw private-key-format?
                     |     |  |     |     |       identityref
                     |     |  |     |     +--rw (private-key-type)
                     |     |  |     |     |  +--:(private-key)
                     |     |  |     |     |  |  +--rw private-key?
                     |     |  |     |     |  |          binary
                     |     |  |     |     |  +--:(hidden-private-key)
                     |     |  |     |     |  |  +--rw hidden-private-\
   \key?
                     |     |  |     |     |  |          empty
                     |     |  |     |     |  +--:(encrypted-private-k\
   \ey)
                     |     |  |     |     |     +--rw encrypted-priva\
   \te-key
                     |     |  |     |     |        +--rw (key-type)
                     |     |  |     |     |        |  +--:(symmetric-\
   \key-ref)
                     |     |  |     |     |        |  |  +--rw symmet\
   \ric-key-ref?    leafref
                     |     |  |     |     |        |  |          {key\
   \store-supported}?
                     |     |  |     |     |        |  +--:(asymmetric\
   \-key-ref)
                     |     |  |     |     |        |     +--rw asymme\
   \tric-key-ref?   leafref
                     |     |  |     |     |        |             {key\
   \store-supported}?
                     |     |  |     |     |        +--rw value?
                     |     |  |     |     |                 binary
                     |     |  |     |     +--rw cert?
                     |     |  |     |     |       end-entity-cert-cms
                     |     |  |     |     +---n certificate-expiration
                     |     |  |     |     |  +-- expiration-date
                     |     |  |     |     |          yang:date-and-ti\
   \me
                     |     |  |     |     +---x generate-certificate-\
   \signing-request
                     |     |  |     |        +---w input
```

```
                       |     |  |     |        |  +---w subject
                       |     |  |     |        |  |       binary
                       |     |  |     |        |  +---w attributes?
                       |     |  |     |        |          binary
                       |     |  |     |        +--ro output
                       |     |  |     |           +--ro certificate-sig\
   \ning-request
                       |     |  |     |                  binary
                       |     |  |     +--:(keystore)
                       |     |  |              {keystore-supported}?
                       |     |  |        +--rw keystore-reference
                       |     |  |           +--rw asymmetric-key?
                       |     |  |           |       ks:asymmetric-key-r\
   \ef
                       |     |  |           +--rw certificate?      lea\
   \fref
                       |     |  +--rw server-authentication
                       |     |  |  +--rw ca-certs!
                       |     |  |  |       {ts:x509-certificates}?
                       |     |  |  |  +--rw (local-or-truststore)
                       |     |  |  |     +--:(local)
                       |     |  |  |     |        {local-definitions-su\
   \pported}?
                       |     |  |  |     |  +--rw local-definition
                       |     |  |  |     |     +--rw cert*
                       |     |  |  |     |     |       trust-anchor-cer\
   \t-cms
                       |     |  |  |     |     +---n certificate-expira\
   \tion
                       |     |  |  |     |        +-- expiration-date
                       |     |  |  |     |                yang:date-and\
   \-time
                       |     |  |  |     +--:(truststore)
                       |     |  |  |              {truststore-supported\
   \,x509-certificates}?
                       |     |  |  |        +--rw truststore-reference?
                       |     |  |  |                 ts:certificates-ref
                       |     |  |  +--rw server-certs!
                       |     |  |           {ts:x509-certificates}?
                       |     |  |     +--rw (local-or-truststore)
                       |     |  |        +--:(local)
                       |     |  |        |        {local-definitions-su\
   \pported}?
                       |     |  |        |  +--rw local-definition
                       |     |  |        |     +--rw cert*
                       |     |  |        |     |       trust-anchor-cer\
   \t-cms
                       |     |  |        |     +---n certificate-expira\
```

```
   \tion
                       |     |  |        |       +-- expiration-date
                       |     |  |        |               yang:date-and\
   \-time
                       |     |  |        +--:(truststore)
                       |     |  |                 {truststore-supported\
   \,x509-certificates}?
                       |     |  |           +--rw truststore-reference?
                       |     |  |                ts:certificates-ref
                       |     |  +--rw hello-params
                       |     |  |       {tls-client-hello-params-config\
   \}?
                       |     |  |  +--rw tls-versions
                       |     |  |  |  +--rw tls-version*   identityref
                       |     |  |  +--rw cipher-suites
                       |     |  |     +--rw cipher-suite*   identityref
                       |     |  +--rw keepalives!
                       |     |         {tls-client-keepalives}?
                       |     |     +--rw max-wait?       uint16
                       |     |     +--rw max-attempts?   uint8
                       |     +--rw proxy-client-identity
                       |        +--rw (auth-type)
                       |           +--:(basic)
                       |              +--rw basic {basic-auth}?
                       |                 +--rw user-id     string
                       |                 +--rw password    string
                       +--rw restconf-client-parameters
```

A.2. Expanded Tree Diagram for 'ietf-restconf-server'

The following tree diagram [RFC8340] provides an overview of the data model for the "ietf-restconf-server" module.

This tree diagram shows all the nodes defined in this module, including those defined by "grouping" statements used by this module.

Please see Section 3.1 for a tree diagram that illustrates what the module looks like without all the "grouping" statements expanded.

========== NOTE: '\' line wrapping per BCP XXX (RFC XXXX) ==========

```
module: ietf-restconf-server
  +--rw restconf-server
     +--rw listen! {http-listen or https-listen}?
     |  +--rw endpoint* [name]
     |     +--rw name           string
     |     +--rw (transport)
     |        +--:(http) {http-listen}?
```

```
        |        |  +--rw http
        |        |     +--rw external-endpoint!
        |        |     |  +--rw address    inet:ip-address
        |        |     |  +--rw port?      inet:port-number
        |        |     +--rw tcp-server-parameters
        |        |     |  +--rw local-address    inet:ip-address
        |        |     |  +--rw local-port?      inet:port-number
        |        |     |  +--rw keepalives! {keepalives-supported}?
        |        |     |     +--rw idle-time         uint16
        |        |     |     +--rw max-probes        uint16
        |        |     |     +--rw probe-interval    uint16
        |        |     +--rw http-server-parameters
        |        |     |  +--rw server-name?             string
        |        |     |  +--rw protocol-versions
        |        |     |  |  +--rw protocol-version*   enumeration
        |        |     |  +--rw client-authentication!
        |        |     |     +--rw (required-or-optional)
        |        |     |     |  +--:(required)
        |        |     |     |  |  +--rw required?
        |        |     |     |  |          empty
        |        |     |     |  +--:(optional)
        |        |     |     |     +--rw optional?
        |        |     |     |             empty
        |        |     |     +--rw (local-or-external)
        |        |     |        +--:(local)
        |        |     |        |        {local-client-auth-supported}?
        |        |     |        |  +--rw users
        |        |     |        |     +--rw user* [user-id]
        |        |     |        |        +--rw user-id        string
        |        |     |        |        +--rw (auth-type)?
        |        |     |        |           +--:(basic)
        |        |     |        |              +--rw basic {basic-auth}?
        |        |     |        |                 +--rw user-id?
        |        |     |        |                 |       string
        |        |     |        |                 +--rw password?
        |        |     |        |                         ianach:crypt-\
  hash
        |        |     |        +--:(external)
        |        |     |                 {external-client-auth-supporte\
  d}?
        |        |     |           +--rw client-auth-defined-elsewhere?
        |        |     |                   empty
        |        |     +--rw restconf-server-parameters
        |        |        +--rw client-identification
        |        |           +--rw cert-maps
        |        |              +--rw cert-to-name* [id]
        |        |                 +--rw id             uint32
        |        |                 +--rw fingerprint
```

```
        |       |                |       x509c2n:tls-fingerprint
        |       |                +--rw map-type       identityref
        |       |                +--rw name           string
        |       +--:(https) {https-listen}?
        |          +--rw https
        |             +--rw tcp-server-parameters
        |             |  +--rw local-address    inet:ip-address
        |             |  +--rw local-port?      inet:port-number
        |             |  +--rw keepalives! {keepalives-supported}?
        |             |     +--rw idle-time         uint16
        |             |     +--rw max-probes        uint16
        |             |     +--rw probe-interval    uint16
        |             +--rw tls-server-parameters
        |             |  +--rw server-identity
        |             |  |  +--rw (local-or-keystore)
        |             |  |     +--:(local)
        |             |  |     |        {local-definitions-supported}?
        |             |  |     |  +--rw local-definition
        |             |  |     |     +--rw algorithm
        |             |  |     |     |       asymmetric-key-algorithm-t
        |             |  |     |     +--rw public-key-format?
        |             |  |     |     |       identityref
        |             |  |     |     +--rw public-key
        |             |  |     |     |       binary
        |             |  |     |     +--rw private-key-format?
        |             |  |     |     |       identityref
        |             |  |     |     +--rw (private-key-type)
        |             |  |     |     |  +--:(private-key)
        |             |  |     |     |  |  +--rw private-key?
        |             |  |     |     |  |          binary
        |             |  |     |     |  +--:(hidden-private-key)
        |             |  |     |     |  |  +--rw hidden-private-key?
        |             |  |     |     |  |          empty
        |             |  |     |     |  +--:(encrypted-private-key)
        |             |  |     |     |     +--rw encrypted-private-key
        |             |  |     |     |        +--rw (key-type)
        |             |  |     |     |        |  +--:(symmetric-key-re\
f)
        |             |  |     |     |        |  |  +--rw symmetric-ke\
y-ref?    leafref
        |             |  |     |     |        |  |          {keystore-\
supported}?
        |             |  |     |     |        |  +--:(asymmetric-key-r\
ef)
        |             |  |     |     |        |     +--rw asymmetric-k\
ey-ref?   leafref
        |             |  |     |     |        |             {keystore-\
supported}?
```

```
       |              |  |     |     |       +--rw value?
       |              |  |     |     |               binary
       |              |  |     |     +--rw cert?
       |              |  |     |     |       end-entity-cert-cms
       |              |  |     |     +---n certificate-expiration
       |              |  |     |     |  +-- expiration-date
       |              |  |     |     |          yang:date-and-time
       |              |  |     |     +---x generate-certificate-signin\
  g-request
       |              |  |     |        +---w input
       |              |  |     |        |  +---w subject       binary
       |              |  |     |        |  +---w attributes?   binary
       |              |  |     |        +--ro output
       |              |  |     |           +--ro certificate-signing-r\
  equest
       |              |  |     |                  binary
       |              |  |     +--:(keystore) {keystore-supported}?
       |              |  |        +--rw keystore-reference
       |              |  |           +--rw asymmetric-key?
       |              |  |           |       ks:asymmetric-key-ref
       |              |  |           +--rw certificate?      leafref
       |              |  +--rw client-authentication!
       |              |  |  +--rw (required-or-optional)
       |              |  |  |  +--:(required)
       |              |  |  |  |  +--rw required?
       |              |  |  |  |          empty
       |              |  |  |  +--:(optional)
       |              |  |  |     +--rw optional?
       |              |  |  |             empty
       |              |  |  +--rw (local-or-external)
       |              |  |     +--:(local)
       |              |  |     |        {local-client-auth-supported}?
       |              |  |     |  +--rw ca-certs!
       |              |  |     |  |       {ts:x509-certificates}?
       |              |  |     |  |  +--rw (local-or-truststore)
       |              |  |     |  |     +--:(local)
       |              |  |     |  |     |        {local-definitions-su\
  pported}?
       |              |  |     |  |     |  +--rw local-definition
       |              |  |     |  |     |     +--rw cert*
       |              |  |     |  |     |     |       trust-anchor-cer\
  t-cms
       |              |  |     |  |     |     +---n certificate-expira\
  tion
       |              |  |     |  |     |        +-- expiration-date
       |              |  |     |  |     |                yang:date-and\
  -time
       |              |  |     |  |     +--:(truststore)
```

```
      |              |  |     |  |             {truststore-supported\
   ,x509-certificates}?
      |              |  |     |  |       +--rw truststore-reference?
      |              |  |     |  |               ts:certificates-ref
      |              |  |     |  +--rw client-certs!
      |              |  |     |         {ts:x509-certificates}?
      |              |  |     |    +--rw (local-or-truststore)
      |              |  |     |       +--:(local)
      |              |  |     |       |       {local-definitions-su\
   pported}?
      |              |  |     |       |  +--rw local-definition
      |              |  |     |       |     +--rw cert*
      |              |  |     |       |     |       trust-anchor-cer\
   t-cms
      |              |  |     |       |     +---n certificate-expira\
   tion
      |              |  |     |       |       +-- expiration-date
      |              |  |     |       |               yang:date-and\
   -time
      |              |  |     |       +--:(truststore)
      |              |  |     |               {truststore-supported\
   ,x509-certificates}?
      |              |  |     |          +--rw truststore-reference?
      |              |  |     |                  ts:certificates-ref
      |              |  |     +--:(external)
      |              |  |             {external-client-auth-supporte\
   d}?
      |              |  |       +--rw client-auth-defined-elsewhere?
      |              |  |               empty
      |              |  +--rw hello-params
      |              |  |      {tls-server-hello-params-config}?
      |              |  |  +--rw tls-versions
      |              |  |  |  +--rw tls-version*   identityref
      |              |  |  +--rw cipher-suites
      |              |  |     +--rw cipher-suite*   identityref
      |              |  +--rw keepalives! {tls-server-keepalives}?
      |              |     +--rw max-wait?       uint16
      |              |     +--rw max-attempts?   uint8
      |              +--rw http-server-parameters
      |              |  +--rw server-name?            string
      |              |  +--rw protocol-versions
      |              |  |  +--rw protocol-version*   enumeration
      |              |  +--rw client-authentication!
      |              |     +--rw (required-or-optional)
      |              |     |  +--:(required)
      |              |     |  |  +--rw required?
      |              |     |  |         empty
      |              |     |  +--:(optional)
```

```
        |              |     |     +--rw optional?
        |              |     |             empty
        |              |     +--rw (local-or-external)
        |              |        +--:(local)
        |              |        |        {local-client-auth-supported}?
        |              |        |  +--rw users
        |              |        |     +--rw user* [user-id]
        |              |        |        +--rw user-id        string
        |              |        |        +--rw (auth-type)?
        |              |        |           +--:(basic)
        |              |        |              +--rw basic {basic-auth}?
        |              |        |                 +--rw user-id?
        |              |        |                 |       string
        |              |        |                 +--rw password?
        |              |        |                         ianach:crypt-\
   hash
        |              |        +--:(external)
        |              |                 {external-client-auth-supporte\
   d}?
        |              |           +--rw client-auth-defined-elsewhere?
        |              |                   empty
        |              +--rw restconf-server-parameters
        |                 +--rw client-identification
        |                    +--rw cert-maps
        |                       +--rw cert-to-name* [id]
        |                          +--rw id             uint32
        |                          +--rw fingerprint
        |                          |       x509c2n:tls-fingerprint
        |                          +--rw map-type       identityref
        |                          +--rw name           string
        +--rw call-home! {https-call-home}?
           +--rw restconf-client* [name]
              +--rw name                 string
              +--rw endpoints
              |  +--rw endpoint* [name]
              |     +--rw name           string
              |     +--rw (transport)
              |        +--:(https) {https-listen}?
              |           +--rw https
              |              +--rw tcp-client-parameters
              |              |  +--rw remote-address    inet:host
              |              |  +--rw remote-port?      inet:port-number
              |              |  +--rw local-address?    inet:ip-address
              |              |  |       {local-binding-supported}?
              |              |  +--rw local-port?       inet:port-number
              |              |  |       {local-binding-supported}?
              |              |  +--rw keepalives!
              |              |          {keepalives-supported}?
```

```
              |              |     +--rw idle-time         uint16
              |              |     +--rw max-probes        uint16
              |              |     +--rw probe-interval    uint16
              |              +--rw tls-server-parameters
              |              |  +--rw server-identity
              |              |  |  +--rw (local-or-keystore)
              |              |  |     +--:(local)
              |              |  |     |        {local-definitions-suppo\
   rted}?
              |              |  |     |  +--rw local-definition
              |              |  |     |     +--rw algorithm
              |              |  |     |     |       asymmetric-key-algo\
   rithm-t
              |              |  |     |     +--rw public-key-format?
              |              |  |     |     |       identityref
              |              |  |     |     +--rw public-key
              |              |  |     |     |       binary
              |              |  |     |     +--rw private-key-format?
              |              |  |     |     |       identityref
              |              |  |     |     +--rw (private-key-type)
              |              |  |     |     |  +--:(private-key)
              |              |  |     |     |  |  +--rw private-key?
              |              |  |     |     |  |          binary
              |              |  |     |     |  +--:(hidden-private-key)
              |              |  |     |     |  |  +--rw hidden-private-\
   key?
              |              |  |     |     |  |          empty
              |              |  |     |     |  +--:(encrypted-private-k\
   ey)
              |              |  |     |     |     +--rw encrypted-priva\
   te-key
              |              |  |     |     |        +--rw (key-type)
              |              |  |     |     |        |  +--:(symmetric-\
   key-ref)
              |              |  |     |     |        |  |  +--rw symmet\
   ric-key-ref?    leafref
              |              |  |     |     |        |  |          {key\
   store-supported}?
              |              |  |     |     |        |  +--:(asymmetric\
   -key-ref)
              |              |  |     |     |        |     +--rw asymme\
   tric-key-ref?   leafref
              |              |  |     |     |        |             {key\
   store-supported}?
              |              |  |     |     |        +--rw value?
              |              |  |     |     |                 binary
              |              |  |     |     +--rw cert?
              |              |  |     |     |       end-entity-cert-cms
```

```
             |              |  |     |     +---n certificate-expiration
             |              |  |     |     |  +-- expiration-date
             |              |  |     |     |          yang:date-and-ti\
   me
             |              |  |     |     +---x generate-certificate-\
   signing-request
             |              |  |     |        +---w input
             |              |  |     |        |  +---w subject
             |              |  |     |        |  |       binary
             |              |  |     |        |  +---w attributes?
             |              |  |     |        |          binary
             |              |  |     |        +--ro output
             |              |  |     |           +--ro certificate-sig\
   ning-request
             |              |  |     |                  binary
             |              |  |     +--:(keystore)
             |              |  |              {keystore-supported}?
             |              |  |        +--rw keystore-reference
             |              |  |           +--rw asymmetric-key?
             |              |  |           |       ks:asymmetric-key-r\
   ef
             |              |  |           +--rw certificate?      lea\
   fref
             |              |  +--rw client-authentication!
             |              |  |  +--rw (required-or-optional)
             |              |  |  |  +--:(required)
             |              |  |  |  |  +--rw required?
             |              |  |  |  |          empty
             |              |  |  |  +--:(optional)
             |              |  |  |     +--rw optional?
             |              |  |  |             empty
             |              |  |  +--rw (local-or-external)
             |              |  |     +--:(local)
             |              |  |     |        {local-client-auth-suppo\
   rted}?
             |              |  |     |  +--rw ca-certs!
             |              |  |     |  |       {ts:x509-certificates}?
             |              |  |     |  |  +--rw (local-or-truststore)
             |              |  |     |  |     +--:(local)
             |              |  |     |  |     |        {local-definiti\
   ons-supported}?
             |              |  |     |  |     |  +--rw local-definition
             |              |  |     |  |     |     +--rw cert*
             |              |  |     |  |     |     |       trust-anch\
   or-cert-cms
             |              |  |     |  |     |     +---n certificate-\
   expiration
             |              |  |     |  |     |        +-- expiration-\
```

```
   date
              |              |  |     |  |     |               yang:da\
   te-and-time
              |              |  |     |  |     +--:(truststore)
              |              |  |     |  |              {truststore-sup\
   ported,x509-certificates}?
              |              |  |     |  |        +--rw truststore-refe\
   rence?
              |              |  |     |  |                ts:certificat\
   es-ref
              |              |  |     |  +--rw client-certs!
              |              |  |     |           {ts:x509-certificates}?
              |              |  |     |     +--rw (local-or-truststore)
              |              |  |     |        +--:(local)
              |              |  |     |        |        {local-definiti\
   ons-supported}?
              |              |  |     |        |  +--rw local-definition
              |              |  |     |        |     +--rw cert*
              |              |  |     |        |     |       trust-anch\
   or-cert-cms
              |              |  |     |        |     +---n certificate-\
   expiration
              |              |  |     |        |       +-- expiration-\
   date
              |              |  |     |        |               yang:da\
   te-and-time
              |              |  |     |        +--:(truststore)
              |              |  |     |                 {truststore-sup\
   ported,x509-certificates}?
              |              |  |     |           +--rw truststore-refe\
   rence?
              |              |  |     |                   ts:certificat\
   es-ref
              |              |  |     +--:(external)
              |              |  |              {external-client-auth-su\
   pported}?
              |              |  |        +--rw client-auth-defined-else\
   where?
              |              |  |                empty
              |              |  +--rw hello-params
              |              |  |       {tls-server-hello-params-config\
   }?
              |              |  |  +--rw tls-versions
              |              |  |  |  +--rw tls-version*   identityref
              |              |  |  +--rw cipher-suites
              |              |  |     +--rw cipher-suite*   identityref
              |              |  +--rw keepalives!
              |              |           {tls-server-keepalives}?
```

```
               |              |     +--rw max-wait?       uint16
               |              |     +--rw max-attempts?   uint8
               |              +--rw http-server-parameters
               |              |  +--rw server-name?            string
               |              |  +--rw protocol-versions
               |              |  |  +--rw protocol-version*   enumeration
               |              |  +--rw client-authentication!
               |              |     +--rw (required-or-optional)
               |              |     |  +--:(required)
               |              |     |  |  +--rw required?
               |              |     |  |          empty
               |              |     |  +--:(optional)
               |              |     |     +--rw optional?
               |              |     |             empty
               |              |     +--rw (local-or-external)
               |              |        +--:(local)
               |              |        |        {local-client-auth-suppo\
   rted}?
               |              |        |  +--rw users
               |              |        |     +--rw user* [user-id]
               |              |        |        +--rw user-id
               |              |        |        |       string
               |              |        |        +--rw (auth-type)?
               |              |        |           +--:(basic)
               |              |        |              +--rw basic
               |              |        |                      {basic-aut\
   h}?
               |              |        |                 +--rw user-id?
               |              |        |                 |       string
               |              |        |                 +--rw password?
               |              |        |                         ianach:\
   crypt-hash
               |              |        +--:(external)
               |              |                 {external-client-auth-su\
   pported}?
               |              |           +--rw client-auth-defined-else\
   where?
               |              |                   empty
               |              +--rw restconf-server-parameters
               |                 +--rw client-identification
               |                    +--rw cert-maps
               |                       +--rw cert-to-name* [id]
               |                          +--rw id             uint32
               |                          +--rw fingerprint
               |                          |       x509c2n:tls-fingerprint
               |                          +--rw map-type
               |                          |       identityref
               |                          +--rw name           string
```

```
            +--rw connection-type
            |  +--rw (connection-type)
            |     +--:(persistent-connection)
            |     |  +--rw persistent!
            |     +--:(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
```

Appendix B. Change Log

B.1. 00 to 01

- Renamed "keychain" to "keystore".

B.2. 01 to 02

- Filled in previously missing 'ietf-restconf-client' module.
- Updated the ietf-restconf-server module to accommodate new grouping 'ietf-tls-server-grouping'.

B.3. 02 to 03

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

B.4. 03 to 04

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

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

B.5. 04 to 05

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

B.6. 05 to 06

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

B.7. 06 to 07

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

B.8. 07 to 08

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

B.9. 08 to 09

- Corrected use of "mandatory true" for "address" leafs.
- Updated examples to reflect update to groupings defined in the keystore draft.
- Updated to use groupings defined in new TCP and HTTP drafts.

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

B.10. 09 to 10

- Reformatted YANG modules.

B.11. 10 to 11

- Adjusted for the top-level "demux container" added to groupings imported from other modules.

- Added "must" expressions to ensure that keepalives are not configured for "periodic" connections.

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

- Moved "expanded" tree diagrams to the Appendix.

B.12. 11 to 12

- Removed the 'must' statement limiting keepalives in periodic connections.

- Updated models and examples to reflect removal of the "demux" containers in the imported models.

- Updated the "periodic-connnection" description statements to better describe behavior when connections are not closed gracefully.

- Updated text to better reference where certain examples come from (e.g., which Section in which draft).

- In the server model, commented out the "must 'pinned-ca-certs or pinned-client-certs'" statement to reflect change made in the TLS draft whereby the trust anchors MAY be defined externally.

- Replaced the 'listen', 'initiate', and 'call-home' features with boolean expressions.

B.13. 12 to 13

- Updated to reflect changes in trust-anchors drafts (e.g., s/trust-anchors/truststore/g + s/pinned.//)

- In ietf-restconf-server, Added 'http-listen' (not https-listen) choice, to support case when server is behind a TLS-terminator.

- Refactored server module to be more like other 'server' models. If folks like it, will also apply to the client model, as well as to both the netconf client/server models. Now the 'restconf-server-grouping' is just the RC-specific bits (i.e., the "demux" container minus the container), 'restconf-server-[listen|callhome]-stack-grouping' is the protocol stack for a single connection, and 'restconf-server-app-grouping' is effectively what was before (both listen+callhome for many inbound/outbound endpoints).

B.14. 13 to 14

- Updated examples to reflect ietf-crypto-types change (e.g., identities --> enumerations)

- Adjusting from change in TLS client model (removing the top-level 'certificate' container).

- Added "external-endpoint" to the "http-listen" choice in ietf-restconf-server.

B.15. 14 to 15

- Added missing "or https-listen" clause in a "must" expression.

- Refactored the client module similar to how the server module was refactored in -13. Now the 'restconf-client-grouping' is just the RC-specific bits, the 'restconf-client-[initiate|listen]-stack-grouping' is the protocol stack for a single connection, and 'restconf-client-app-grouping' is effectively what was before (both listen+callhome for many inbound/outbound endpoints).

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