

A YANG Data Model for NETCONF Clients and Servers
draft-ietf-netconf-netconf-client-server-39

Abstract

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

Editorial Note (To be removed by RFC Editor)

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

Artwork in this document contains shorthand references to drafts in progress. Please apply the following replacements (note: not all may be present):

- * GGGG --> the assigned RFC value for draft-ietf-netconf-http-client-server
- * HHHH --> the assigned RFC value for this draft
- * IIII --> the assigned RFC value for draft-ietf-netconf-restconf-client-server

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

- * 2025-04-24 --> the publication date of this draft

The "Relation to other RFCs" section Section 1.1 contains the text "one or more YANG modules" and, later, "modules". This text is sourced from a file in a context where it is unknown how many modules a draft defines. The text is not wrong as is, but it may be improved by stating more directly how many modules are defined.

The "Relation to other RFCs" section Section 1.1 contains a self-reference to this draft, along with a corresponding reference in the Appendix. Please replace the self-reference in this section with "This RFC" (or similar) and remove the self-reference in the "Normative/Informative References" section, whichever it is in.

Tree-diagrams in this draft may use the '\ ' line-folding mode defined in RFC 8792. However, nicer-to-the-eye is when the '\\ ' line-folding mode is used. The AD suggested suggested putting a request here for the RFC Editor to help convert "ugly" '\ ' folded examples to use the '\\ ' folding mode. "Help convert" may be interpreted as, identify what looks ugly and ask the authors to make the adjustment.

Due to a bug in the pyang tool used to create tree diagrams, some "key" nodes appear as optional (i.e., have a '?' postfix). Ideally the '?' character is removed in the tree diagrams for "key" nodes. Recipe: search for lists using the string "* [", then note the nodes appearing in the square brackets (e.g., "* [name]"), then look for matching child nodes and remove the '?' characters (e.g., "name?" becomes "name").

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

- * Appendix A. Change Log

Status of This Memo

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

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 26 October 2025.

Copyright Notice

Copyright (c) 2025 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Revised BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Revised BSD License.

Table of Contents

1. Introduction	4
1.1. Relation to other RFCs	4
1.2. Specification Language	6
1.3. Adherence to the NMDA	6
2. The "ietf-netconf-client" Module	6
2.1. Data Model Overview	7
2.2. Example Usage	11
2.3. YANG Module	15
3. The "ietf-netconf-server" Module	27
3.1. Data Model Overview	27
3.2. Example Usage	32
3.3. YANG Module	38
4. Security Considerations	53
4.1. Considerations for the "ietf-netconf-client" YANG Module	53
4.2. Considerations for the "ietf-netconf-server" YANG Module	53
5. IANA Considerations	54
5.1. The "IETF XML" Registry	54
5.2. The "YANG Module Names" Registry	55
6. References	55
6.1. Normative References	55
6.2. Informative References	56
Appendix A. Change Log	58
A.1. 00 to 01	58
A.2. 01 to 02	58
A.3. 02 to 03	58
A.4. 03 to 04	59
A.5. 04 to 05	59
A.6. 05 to 06	59
A.7. 06 to 07	59
A.8. 07 to 08	60
A.9. 08 to 09	60
A.10. 09 to 10	60
A.11. 10 to 11	60
A.12. 11 to 12	60
A.13. 12 to 13	61

A.14. 13 to 14	61
A.15. 14 to 15	61
A.16. 15 to 16	61
A.17. 16 to 17	61
A.18. 17 to 18	62
A.19. 18 to 19	62
A.20. 19 to 20	62
A.21. 20 to 21	62
A.22. 21 to 22	62
A.23. 22 to 23	62
A.24. 23 to 24	63
A.25. 24 to 25	63
A.26. 25 to 26	63
A.27. 26 to 27	63
A.28. 27 to 28	63
A.29. 28 to 29	63
A.30. 29 to 30	63
A.31. 30 to 31	64
A.32. 31 to 32	64
A.33. 32 to 34	64
A.34. 34 to 36	64
A.35. 37 to 38	64
A.36. 38 to 39	65
Acknowledgements	65
Author's Address	65

1. Introduction

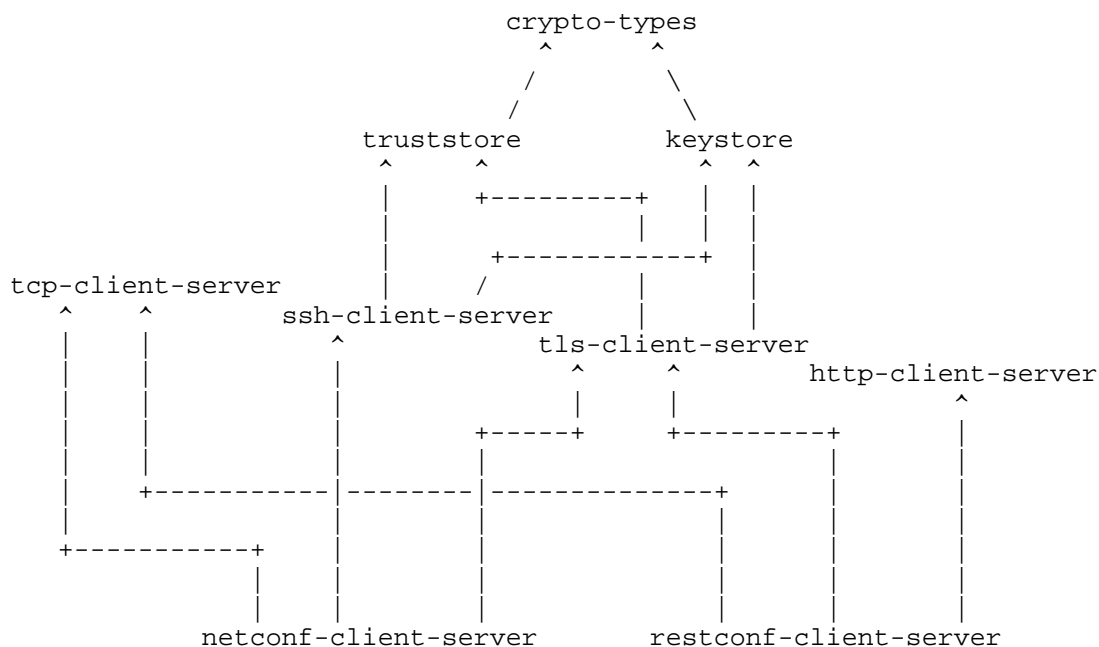
This document presents two YANG [RFC7950] modules, one module to configure a NETCONF [RFC6241] client and the other module to configure a NETCONF server. Both modules support both NETCONF over SSH [RFC6242] and NETCONF over TLS [RFC7589] and NETCONF Call Home connections [RFC8071].

1.1. Relation to other RFCs

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

Primary dependency relationships between the YANG groupings defined in the various RFCs is presented in the below diagram. In some cases, a draft may define secondary groupings that introduce dependencies not illustrated in the diagram. The labels in the diagram are a shorthand name for the defining RFC. The citation reference for shorthand name is provided below the diagram.

Please note that the arrows in the diagram point from referencer to referenced. For example, the "crypto-types" RFC does not have any dependencies, whilst the "keystore" RFC depends on the "crypto-types" RFC.



Label in Diagram	Originating RFC
crypto-types	[RFC9640]
truststore	[RFC9641]
keystore	[RFC9642]
tcp-client-server	[RFC9643]
ssh-client-server	[RFC9644]
tls-client-server	[RFC9645]
http-client-server	[I-D.ietf-netconf-http-client-server]
netconf-client-server	[I-D.ietf-netconf-netconf-client-server]
restconf-client-server	[I-D.ietf-netconf-restconf-client-server]

Table 1: Label in Diagram to RFC Mapping

1.2. Specification Language

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

1.3. Adherence to the NMDA

This document is compliant with the Network Management Datastore Architecture (NMDA) [RFC8342]. For instance, as described in [RFC9641] and [RFC9642], trust anchors and keys installed during manufacturing are expected to appear in <operational> (Section 5.3 of [RFC8342]), and <system> [I-D.ietf-netmod-system-config], if implemented.

2. The "ietf-netconf-client" Module

The NETCONF client data model presented in this section supports both clients initiating connections to servers, as well as clients listening for connections from servers calling home, using either the SSH and TLS transport protocols.

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

2.1. Data Model Overview

This section provides an overview of the "ietf-netconf-client" module in terms of its features and groupings.

2.1.1. Features

The following diagram lists all the "feature" statements defined in the "ietf-netconf-client" module:

Features:

```
+-- ssh-initiate
+-- tls-initiate
+-- ssh-listen
+-- tls-listen
+-- central-netconf-client-supported
```

The diagram above uses syntax that is similar to but not defined in [RFC8340].

2.1.2. Groupings

The "ietf-netconf-client" module defines the following "grouping" statements:

```
* netconf-client-initiate-stack-grouping
* netconf-client-listen-stack-grouping
* netconf-client-app-grouping
```

Each of these groupings are presented in the following subsections.

2.1.2.1. The "netconf-client-initiate-stack-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "netconf-client-initiate-stack-grouping" grouping:

```

grouping netconf-client-initiate-stack-grouping:
  +-- (transport)
    +---:(ssh) {ssh-initiate}?
      |   +-- ssh
      |     +-- tcp-client-parameters
      |       |   +---u tcpc:tcp-client-grouping
      |     +-- ssh-client-parameters
      |       |   +---u sshc:ssh-client-grouping
      |     +-- netconf-client-parameters
      |       |   +---u ncc:netconf-client-grouping
    +---:(tls) {tls-initiate}?
      +-- tls
        +-- tcp-client-parameters
          |   +---u tcpc:tcp-client-grouping
        +-- tls-client-parameters
          |   +---u tlsc:tls-client-grouping
        +-- netconf-client-parameters
          |   +---u ncc:netconf-client-grouping

```

Comments:

- * The "netconf-client-initiate-stack-grouping" defines the configuration for a full NETCONF protocol stack, for NETCONF clients that initiate connections to NETCONF servers, as opposed to receiving call-home [RFC8071] connections.
- * The "transport" choice node enables either the SSH or TLS transports to be configured, with each option enabled by a "feature" statement.
- * For the referenced grouping statement(s):
 - The "tcp-client-grouping" grouping is discussed in Section 3.1.2.1 of [RFC9643].
 - The "ssh-client-grouping" grouping is discussed in Section 3.1.2.1 of [RFC9644].
 - The "tls-client-grouping" grouping is discussed in Section 3.1.2.1 of [RFC9645].

2.1.2.2. The "netconf-client-listen-stack-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "netconf-client-listen-stack-grouping" grouping:


```

grouping netconf-client-listen-stack-grouping:
  +-- (transport)
    +---:(ssh) {ssh-listen}?
      |   +-- ssh
      |     +-- tcp-server-parameters
      |       |   +---u tcps:tcp-server-grouping
      |     +-- ssh-client-parameters
      |       |   +---u sshc:ssh-client-grouping
      |     +-- netconf-client-parameters
      |       |   +---u ncc:netconf-client-grouping
    +---:(tls) {tls-listen}?
      +-- tls
        +-- tcp-server-parameters
          |   +---u tcps:tcp-server-grouping
        +-- tls-client-parameters
          |   +---u tlsc:tls-client-grouping
        +-- netconf-client-parameters
          |   +---u ncc:netconf-client-grouping

```

Comments:

- * The "netconf-client-listen-stack-grouping" defines the configuration for a full NETCONF protocol stack, for NETCONF clients that receive call-home [RFC8071] connections from NETCONF servers.
- * The "transport" choice node enables either the SSH or TLS transports to be configured, with each option enabled by a "feature" statement.
- * For the referenced grouping statement(s):
 - The "tcp-server-grouping" grouping is discussed in Section 4.1.2.1 of [RFC9643].
 - The "ssh-client-grouping" grouping is discussed in Section 3.1.2.1 of [RFC9644].
 - The "tls-client-grouping" grouping is discussed in Section 3.1.2.1 of [RFC9645].

2.1.2.3. The "netconf-client-app-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "netconf-client-app-grouping" grouping:

```

grouping netconf-client-app-grouping:
  +-- initiate! {ssh-initiate or tls-initiate}?
    |   +-- netconf-server* [name]
    |   |   +-- name?                string
    |   |   +-- endpoints
    |   |   |   +-- endpoint* [name]
    |   |   |   |   +-- name?                string
    |   |   |   |   +---u netconf-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-wait?            uint16
    |   |   |   +-- max-attempts?        uint8
    |   +-- listen! {ssh-listen or tls-listen}?
    |   |   +-- idle-timeout?          uint16
    |   |   +-- endpoints
    |   |   |   +-- endpoint* [name]
    |   |   |   |   +-- name?                string
    |   |   |   |   +---u netconf-client-listen-stack-grouping

```

Comments:

- * The "netconf-client-app-grouping" defines the configuration for a NETCONF client that supports both initiating connections to NETCONF servers as well as receiving call-home connections from NETCONF servers.
- * Both the "initiate" and "listen" subtrees are predicated by "feature" statements.
- * For the referenced grouping statement(s):
 - The "netconf-client-initiate-stack-grouping" grouping is discussed in Section 2.1.2.1 in this document.
 - The "netconf-client-listen-stack-grouping" grouping is discussed in Section 2.1.2.2 in this document.

2.1.3. Protocol-accessible Nodes

The following tree diagram [RFC8340] lists all the protocol-accessible nodes defined in the "ietf-netconf-client" module:

```
module: ietf-netconf-client
  +--rw netconf-client {central-netconf-client-supported}?
    +---u netconf-client-app-grouping
```

Comments:

- * Protocol-accessible nodes are those nodes that are accessible when the module is "implemented", as described in Section 5.6.5 of [RFC7950].
- * The top-level node "netconf-client" is additionally constrained by the feature "central-netconf-client-supported".
- * The "netconf-client-app-grouping" grouping is discussed in Section 2.1.2.3 in this document.
- * The reason for why "netconf-client-app-grouping" exists separate from the protocol-accessible nodes definition is so as to enable instances of netconf-client-app-grouping to be instantiated in other locations, as may be needed or desired by some modules.

2.2. Example Usage

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

This example is consistent with the examples presented in Section 2.2.1 of [RFC9641] and Section 2.2.1 of [RFC9642].

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

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

```
  <!-- NETCONF servers to initiate connections to -->
  <initiate>
    <netconf-server>
      <name>corp-fw1</name>
      <endpoints>
        <endpoint>
          <name>corp-fw1.example.com</name>
```

```

    <ssh>
      <tcp-client-parameters>
        <remote-address>corp-fw1.example.com</remote-address>
        <keepalives>
          <idle-time>7200</idle-time>
          <max-probes>9</max-probes>
          <probe-interval>75</probe-interval>
        </keepalives>
      </tcp-client-parameters>
      <ssh-client-parameters>
        <client-identity>
          <username>foobar</username>
          <public-key>
            <central-keystore-reference>ssh-rsa-key</central-k\
eystore-reference>
          </public-key>
        </client-identity>
        <server-authentication>
          <ca-certs>
            <central-truststore-reference>trusted-server-ca-ce\
rts</central-truststore-reference>
          </ca-certs>
          <ee-certs>
            <central-truststore-reference>trusted-server-ee-ce\
rts</central-truststore-reference>
          </ee-certs>
        </server-authentication>
        <keepalives>
          <max-wait>30</max-wait>
          <max-attempts>3</max-attempts>
        </keepalives>
      </ssh-client-parameters>
    </ssh>
  </endpoint>
</endpoint>
<name>corp-fw2.example.com</name>
<tls>
  <tcp-client-parameters>
    <remote-address>corp-fw2.example.com</remote-address>
    <keepalives>
      <idle-time>7200</idle-time>
      <max-probes>9</max-probes>
      <probe-interval>75</probe-interval>
    </keepalives>
  </tcp-client-parameters>
  <tls-client-parameters>
    <client-identity>
      <certificate>

```

```

        <central-keystore-reference>
          <asymmetric-key>rsa-asymmetric-key</asymmetric-k\
ey>
          <certificate>ex-rsa-cert</certificate>
        </central-keystore-reference>
      </certificate>
    </client-identity>
    <server-authentication>
      <ca-certs>
        <central-truststore-reference>trusted-server-ca-ce\
rts</central-truststore-reference>
      </ca-certs>
      <ee-certs>
        <central-truststore-reference>trusted-server-ee-ce\
rts</central-truststore-reference>
      </ee-certs>
    </server-authentication>
    <keepalives>
      <test-peer-aliveness>
        <max-wait>30</max-wait>
        <max-attempts>3</max-attempts>
      </test-peer-aliveness>
    </keepalives>
  </tls-client-parameters>
</tls>
</endpoint>
</endpoints>
<connection-type>
  <persistent/>
</connection-type>
<reconnect-strategy>
  <start-with>last-connected</start-with>
</reconnect-strategy>
</netconf-server>
</initiate>

<!-- endpoints to listen for NETCONF Call Home connections on -->
<listen>
  <endpoints>
    <endpoint>
      <name>Intranet-facing SSH listener</name>
      <ssh>
        <tcp-server-parameters>
          <local-bind>
            <local-address>192.0.2.7</local-address>
          </local-bind>
        </tcp-server-parameters>
        <ssh-client-parameters>

```

```

        <client-identity>
          <username>foobar</username>
          <public-key>
            <central-keystore-reference>ssh-rsa-key</central-key\
store-reference>
          </public-key>
        </client-identity>
        <server-authentication>
          <ca-certs>
            <central-truststore-reference>trusted-server-ca-cert\
s</central-truststore-reference>
          </ca-certs>
          <ee-certs>
            <central-truststore-reference>trusted-server-ee-cert\
s</central-truststore-reference>
          </ee-certs>
          <ssh-host-keys>
            <central-truststore-reference>trusted-ssh-public-key\
s</central-truststore-reference>
          </ssh-host-keys>
        </server-authentication>
      </ssh-client-parameters>
    </ssh>
  </endpoint>
<endpoint>
  <name>Intranet-facing TLS listener</name>
  <tls>
    <tcp-server-parameters>
      <local-bind>
        <local-address>192.0.2.7</local-address>
      </local-bind>
    </tcp-server-parameters>
    <tls-client-parameters>
      <client-identity>
        <certificate>
          <central-keystore-reference>
            <asymmetric-key>rsa-asymmetric-key</asymmetric-key>
            <certificate>ex-rsa-cert</certificate>
          </central-keystore-reference>
        </certificate>
      </client-identity>
      <server-authentication>
        <ca-certs>
          <central-truststore-reference>trusted-server-ca-cert\
s</central-truststore-reference>
        </ca-certs>
        <ee-certs>
          <central-truststore-reference>trusted-server-ee-cert\

```

```
s</central-truststore-reference>
    </ee-certs>
  </server-authentication>
  <keepalives>
    <peer-allowed-to-send/>
  </keepalives>
</tls-client-parameters>
</tls>
</endpoint>
</endpoints>
</listen>
</netconf-client>
```

2.3. YANG Module

This YANG module has normative references to [RFC6242], [RFC6991], [RFC7589], [RFC8071], [RFC9643], [RFC9644], and [RFC9643].

<CODE BEGINS> file "ietf-netconf-client@2025-04-24.yang"

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

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

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

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

  import ietf-ssh-client {
    prefix sshc;
    reference
      "RFC EEEE: YANG Groupings for SSH Clients and SSH Servers";
  }
}
```

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

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

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

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

  Copyright (c) 2025 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 Revised
  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 HHHH
  (https://www.rfc-editor.org/info/rfcHHHH); 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 2025-04-24 {
  description
    "Initial version";
  reference
    "RFC HHHH: A YANG Data Model for NETCONF Clients and Server";
}

// Features
```



```
feature ssh-initiate {
  description
    "The 'ssh-initiate' feature indicates that the NETCONF client
    supports initiating SSH connections to NETCONF servers.";
  reference
    "RFC 6242:
    Using the NETCONF Protocol over Secure Shell (SSH)";
}

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

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

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

feature central-netconf-client-supported {
  description
    "The 'central-netconf-client-supported' feature indicates
    that the server that implements this module supports
    the top-level 'netconf-client' node.

    This feature is needed as some servers may want to use
    features defined in this module, which requires this
    module to be implemented, without having to support
    the top-level 'netconf-client' node.";
}
```

```
// Groupings

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

    As no NETCONF-specific client configuration needs to be
    set, this node is empty, but retained for clarity and for
    consistency with other 'client-server' models.";
}

grouping netconf-client-initiate-stack-grouping {
  description
    "A grouping for configuring a NETCONF client
    'initiate' protocol stack for a single outbound connection.";
  choice transport {
    mandatory true;
    description
      "Selects between available transports.";
    case ssh {
      if-feature "ssh-initiate";
      container ssh {
        description
          "Specifies TCP, SSH, and NETCONF configuration
          for the connection.";
        container tcp-client-parameters {
          description
            "TCP-level client parameters to initiate
            a NETCONF over SSH connection.";
          uses tcp:tcp-client-grouping {
            refine "remote-port" {
              default "830";
              description
                "The NETCONF client will attempt to connect
                to the IANA-assigned well-known port value
                for 'netconf-ssh' (830) if no value is
                specified.";
            }
          }
        }
      }
    }
    container ssh-client-parameters {
      description
        "SSH-level client parameters to initiate
        a NETCONF over SSH connection.";
      uses sshc:ssh-client-grouping;
    }
  }
}
```

```
        container netconf-client-parameters {
            description
                "NETCONF-level client parameters to initiate
                 a NETCONF over SSH connection.";
            uses ncc:netconf-client-grouping;
        }
    }
}
case tls {
    if-feature "tls-initiate";
    container tls {
        description
            "Specifies TCP, TLS, and NETCONF configuration
             for the connection.";
        container tcp-client-parameters {
            description
                "TCP-level client parameters to initiate
                 a NETCONF over TLS connection.";
            uses tcpc:tcp-client-grouping {
                refine "remote-port" {
                    default "6513";
                    description
                        "The NETCONF client will attempt to connect
                         to the IANA-assigned well-known port value
                         for 'netconf-tls' (6513) if no value is
                         specified.";
                }
            }
        }
    }
}
container tls-client-parameters {
    must client-identity {
        description
            "NETCONF/TLS clients MUST pass some
             authentication credentials.";
    }
    description
        "TLS-level client parameters to initiate
         a NETCONF over TLS connection.";
    uses tlsc:tls-client-grouping;
}
container netconf-client-parameters {
    description
        "NETCONF-level client parameters to initiate
         a NETCONF over TLS connection.";
    uses ncc:netconf-client-grouping;
}
}
```

```
    }
  } // netconf-client-initiate-stack-grouping

  grouping netconf-client-listen-stack-grouping {
    description
      "A grouping for configuring a NETCONF client
       'listen' protocol stack for listening on a single port. The
       'listen' stack supports call home connections, as
       described in RFC 8071";
    reference
      "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
    choice transport {
      mandatory true;
      description
        "Selects between available transports.";
      case ssh {
        if-feature "ssh-listen";
        container ssh {
          description
            "TCP, SSH, and NETCONF configuration to listen
             for NETCONF over SSH Call Home connections.";
          container tcp-server-parameters {
            description
              "TCP-level server parameters to listen for
               NETCONF over SSH Call Home connections.";
            uses tcps:tcp-server-grouping {
              refine "local-bind/local-port" {
                default "4334";
                description
                  "The NETCONF client will listen on the IANA-
                   assigned well-known port for 'netconf-ch-ssh'
                   (4334) if no value is specified.";
              }
            }
          }
        }
      }
      container ssh-client-parameters {
        description
          "SSH-level client parameters to listen for
           NETCONF over SSH Call Home connections.";
        uses sshc:ssh-client-grouping;
      }
      container netconf-client-parameters {
        description
          "NETCONF-level client parameters to listen for
           NETCONF over SSH Call Home connections.";
        uses ncc:netconf-client-grouping;
      }
    }
  }
```

```
}
case tls {
  if-feature "tls-listen";
  container tls {
    description
      "TCP, TLS, and NETCONF configuration to listen
       for NETCONF over TLS Call Home connections.";
    container tcp-server-parameters {
      description
        "TCP-level server parameters to listen for
         NETCONF over TLS Call Home connections.";
      uses tcps:tcp-server-grouping {
        refine "local-bind/local-port" {
          default "4335";
          description
            "The NETCONF client will listen on the IANA-
             assigned well-known port for 'netconf-ch-tls'
             (4335) if no value is specified.";
        }
      }
    }
  }
  container tls-client-parameters {
    must client-identity {
      description
        "NETCONF/TLS clients MUST pass some
         authentication credentials.";
    }
    description
      "TLS-level client parameters to listen for
       NETCONF over TLS Call Home connections.";
    uses tlsc:tls-client-grouping;
  }
  container netconf-client-parameters {
    description
      "NETCONF-level client parameters to listen for
       NETCONF over TLS Call Home connections.";
    uses ncc:netconf-client-grouping;
  }
}
}
} // netconf-client-listen-stack-grouping

grouping netconf-client-app-grouping {
  description
    "A grouping for configuring a NETCONF client
     application that supports both 'initiate' and 'listen'
     protocol stacks for a multiplicity of connections.";
```

```
container initiate {
  if-feature "ssh-initiate or tls-initiate";
  presence
    "Indicates that client-initiated connections have been
    configured. This statement is present so the mandatory
    descendant nodes do not imply that this node must be
    configured.";
  description
    "Configures client initiating underlying TCP connections.";
  list netconf-server {
    key "name";
    min-elements 1;
    description
      "List of NETCONF servers the NETCONF client is to
      maintain simultaneous connections with.";
    leaf name {
      type string;
      description
        "An arbitrary name for the NETCONF server.";
    }
  }
  container endpoints {
    description
      "Container for the list of endpoints.";
    list endpoint {
      key "name";
      min-elements 1;
      ordered-by user;
      description
        "A user-ordered list of endpoints that the NETCONF
        client will attempt to connect to in the specified
        sequence. Defining more than one enables
        high-availability.";
      leaf name {
        type string;
        description
          "An arbitrary name for the endpoint.";
      }
      uses netconf-client-initiate-stack-grouping;
    } // list endpoint
  } // container endpoints

  container connection-type {
    description
      "Indicates the NETCONF client's preference for how the
      NETCONF 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 NETCONF
       server. If the connection goes down, immediately
       start trying to reconnect to the NETCONF server,
       using the reconnection strategy.

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

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

       The NETCONF client SHOULD close the underlying
       TCP connection upon completing planned activities.

       Connections are established at the same start
       time regardless how long the previous connection
       stayed open.

       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 '[0-9]{4}-(1[0-2]|0[1-9])-(0[1-9]|[1-2]'
+ '[0-9]|3[0-1])T(0[0-9]|1[0-9]|2[0-3]):['
+ '0-5][0-9]:00(Z|[\+\-]((1[0-3]|0[0-9]):'
+ '([0-5][0-9])|14:00))?'';
}
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.

      If an 'anchor-time' is not provided, then the
      server may implicitly set it to the time when
      this configuraton is applied (e.g., on boot).

      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 180; // three minutes
    description
        "Specifies the maximum number of seconds that
          a NETCONF session may remain idle. A NETCONF
          session will be dropped if it is idle for an
          interval longer then this number of seconds.
          If set to zero, then the NETCONF client will
          never drop a session because it is idle.";
}
}
}
}
}
container reconnect-strategy {
    description
        "The reconnection strategy directs how a NETCONF client
          reconnects to a NETCONF server, after discovering its
          connection to the server has dropped, even if due to a
          reboot. The NETCONF client starts with the specified
          endpoint and tries to connect to it max-attempts times
          before trying the next endpoint in the list (round
          robin).";
    leaf start-with {
        type enumeration {
            enum first-listed {

```



```
        description
            "Indicates that reconnections SHOULD start with
            the first endpoint listed.";
    }
    enum last-connected {
        description
            "Indicates that reconnections SHOULD start with
            the endpoint last connected to, if known.  If
            no previous connection is known, then the
            first endpoint configured is used.";
    }
    enum random-selection {
        description
            "Indicates that reconnections SHOULD start with
            a random endpoint.";
    }
    }
    default "first-listed";
    description
        "Specifies which of the NETCONF server's endpoints
        the NETCONF client SHOULD start with when trying
        to connect to the NETCONF server.";
    }
    leaf max-wait {
        type uint16 {
            range "1..max";
        }
        units "seconds";
        default "5";
        description
            "Specifies the amount of time in seconds after which,
            if the connection is not established, an endpoint
            connection attempt is considered unsuccessful.";
    }
    leaf max-attempts {
        type uint8 {
            range "1..max";
        }
        default "3";
        description
            "Specifies the number times the NETCONF client tries
            to connect to a specific endpoint before moving on
            to the next endpoint in the list (round robin).";
    }
    }
    } // netconf-server
} // initiate
```

```
container listen {
  if-feature "ssh-listen or tls-listen";
  presence
    "Indicates that client-listening ports have been configured.
    This statement is present so the mandatory descendant nodes
    do not imply that this node must be configured.";
  description
    "Configures the client to accept call-home TCP connections.";
  leaf idle-timeout {
    type uint16;
    units "seconds";
    default "180"; // three minutes
    description
      "Specifies the maximum number of seconds that a NETCONF
      session may remain idle. A NETCONF session will be
      dropped if it is idle for an interval longer than this
      number of seconds. If set to zero, then the server
      will never drop a session because it is idle.";
  }
  container endpoints {
    description
      "Container for a list of endpoints.";
    list endpoint {
      key "name";
      min-elements 1;
      description
        "List of endpoints to listen for NETCONF connections.";
      leaf name {
        type string;
        description
          "An arbitrary name for the NETCONF listen endpoint.";
      }
      uses netconf-client-listen-stack-grouping;
    }
  }
} // listen
} // netconf-client-app-grouping

// Protocol accessible node for clients that implement this module.
container netconf-client {
  if-feature central-netconf-client-supported;
  uses netconf-client-app-grouping;
  description
    "Top-level container for NETCONF client configuration.";
}
}
```

<CODE ENDS>

3. The "ietf-netconf-server" Module

The NETCONF server data model presented in this section supports both listening for connections as well as initiating call-home connections, using either the SSH and TLS transport protocols.

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

3.1. Data Model Overview

This section provides an overview of the "ietf-netconf-server" module in terms of its features and groupings.

3.1.1. Features

The following diagram lists all the "feature" statements defined in the "ietf-netconf-server" module:

Features:

```
+++ ssh-listen
+++ tls-listen
+++ ssh-call-home
+++ tls-call-home
+++ central-netconf-server-supported
```

The diagram above uses syntax that is similar to but not defined in [RFC8340].

3.1.2. Groupings

The "ietf-netconf-server" module defines the following "grouping" statements:

```
* netconf-server-grouping
* netconf-server-listen-stack-grouping
* netconf-server-callhome-stack-grouping
* netconf-server-app-grouping
```

Each of these groupings are presented in the following subsections.

3.1.2.1. The "netconf-server-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "netconf-server-grouping" grouping:

```

grouping netconf-server-grouping:
  +-- client-identity-mappings
    +---u x509c2n:cert-to-name

```

Comments:

- * The "netconf-server-grouping" defines the configuration for the "NETCONF" part of a protocol stack. It does not, for instance, define any configuration for the "TCP", "SSH" or "TLS" protocol layers (for that, see Section 3.1.2.2 and Section 3.1.2.3).
- * The "client-identity-mappings" node defines a mapping from certificate fields to NETCONF user names.
- * For the referenced grouping statement(s):
 - The "cert-to-name" grouping is discussed in Section 4.1 of [RFC7407].

3.1.2.2. The "netconf-server-listen-stack-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "netconf-server-listen-stack-grouping" grouping:

```

grouping netconf-server-listen-stack-grouping:
  +-- (transport)
    +--:(ssh) {ssh-listen}?
      |   +-- ssh
      |     +-- tcp-server-parameters
      |       |   +---u tcps:tcp-server-grouping
      |     +-- ssh-server-parameters
      |       |   +---u sshs:ssh-server-grouping
      |     +-- netconf-server-parameters
      |       |   +---u ncs:netconf-server-grouping
    +--:(tls) {tls-listen}?
      +-- tls
        +-- tcp-server-parameters
          |   +---u tcps:tcp-server-grouping
        +-- tls-server-parameters
          |   +---u tlss:tls-server-grouping
        +-- netconf-server-parameters
          |   +---u ncs:netconf-server-grouping

```

Comments:

- * The "netconf-server-listen-stack-grouping" defines the configuration for a full NETCONF protocol stack for NETCONF servers that listen for connections from NETCONF clients, as opposed to initiating call-home [RFC8071] connections.
- * The "transport" choice node enables either the SSH or TLS transports to be configured, with each option enabled by a "feature" statement.
- * For the referenced grouping statement(s):
 - The "tcp-server-grouping" grouping is discussed in Section 4.1.2.1 of [RFC9643].
 - The "ssh-server-grouping" grouping is discussed in Section 4.1.2.1 of [RFC9644].
 - The "tls-server-grouping" grouping is discussed in Section 4.1.2.1 of [RFC9645].
 - The "netconf-server-grouping" is discussed in Section 3.1.2.1 of this document.

3.1.2.3. The "netconf-server-callhome-stack-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "netconf-server-callhome-stack-grouping" grouping:

```
grouping netconf-server-callhome-stack-grouping:
  +-- (transport)
    +--:(ssh) {ssh-call-home}?
      |   +-- ssh
      |   |   +-- tcp-client-parameters
      |   |   |   +---u tcpc:tcp-client-grouping
      |   |   +-- ssh-server-parameters
      |   |   |   +---u sshs:ssh-server-grouping
      |   |   +-- netconf-server-parameters
      |   |   |   +---u ncs:netconf-server-grouping
    +--:(tls) {tls-call-home}?
      +-- tls
        +-- tcp-client-parameters
        |   +---u tcpc:tcp-client-grouping
        +-- tls-server-parameters
        |   +---u tlss:tls-server-grouping
        +-- netconf-server-parameters
        |   +---u ncs:netconf-server-grouping
```

Comments:

- * The "netconf-server-callhome-stack-grouping" defines the configuration for a full NETCONF protocol stack, for NETCONF servers that initiate call-home [RFC8071] connections to NETCONF clients.
- * The "transport" choice node enables either the SSH or TLS transports to be configured, with each option enabled by a "feature" statement.
- * For the referenced grouping statement(s):
 - The "tcp-client-grouping" grouping is discussed in Section 3.1.2.1 of [RFC9643].
 - The "ssh-server-grouping" grouping is discussed in Section 4.1.2.1 of [RFC9644].
 - The "tls-server-grouping" grouping is discussed in Section 4.1.2.1 of [RFC9645].
 - The "netconf-server-grouping" is discussed in Section 3.1.2.1 of this document.

3.1.2.4. The "netconf-server-app-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "netconf-server-app-grouping" grouping:

```

grouping netconf-server-app-grouping:
  +-- listen! {ssh-listen or tls-listen}?
  |   +-- idle-timeout?   uint16
  |   +-- endpoints
  |       +-- endpoint* [name]
  |           +-- name?                                     string
  |           +---u netconf-server-listen-stack-grouping
  +-- call-home! {ssh-call-home or tls-call-home}?
  |   +-- netconf-client* [name]
  |       +-- name?                                     string
  |       +-- endpoints
  |           +-- endpoint* [name]
  |               +-- name?                                     string
  |               +---u netconf-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-wait?     uint16
  |   +-- max-attempts? uint8

```

Comments:

- * The "netconf-server-app-grouping" defines the configuration for a NETCONF server that supports both listening for connections from NETCONF clients as well as initiating call-home connections to NETCONF clients.
- * Both the "listen" and "call-home" subtrees must be enabled by "feature" statements.
- * For the referenced grouping statement(s):
 - The "netconf-server-listen-stack-grouping" grouping is discussed in Section 3.1.2.2 in this document.
 - The "netconf-server-callhome-stack-grouping" grouping is discussed in Section 3.1.2.3 in this document.

3.1.3. Protocol-accessible Nodes

The following tree diagram [RFC8340] lists all the protocol-accessible nodes defined in the "ietf-netconf-server" module:

```
module: ietf-netconf-server
  +--rw netconf-server {central-netconf-server-supported}?
    +---u netconf-server-app-grouping
```

Comments:

- * Protocol-accessible nodes are those nodes that are accessible when the module is "implemented", as described in Section 5.6.5 of [RFC7950].
- * The top-level node "netconf-server" is additionally constrained by the feature "central-netconf-server-supported".
- * The "netconf-server-app-grouping" grouping is discussed in Section 3.1.2.4 in this document.
- * The reason for why "netconf-server-app-grouping" exists separate from the protocol-accessible nodes definition is so as to enable instances of netconf-server-app-grouping to be instantiated in other locations, as may be needed or desired by some modules.

3.2. Example Usage

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

This example is consistent with the examples presented in Section 2.2.1 of [RFC9641] and Section 2.2.1 of [RFC9642].

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

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

  <!-- endpoints to listen for NETCONF connections on -->
  <listen>
    <endpoints>
      <endpoint> <!-- listening for SSH connections -->
        <name>netconf/ssh</name>
        <ssh>
```



```

    <tcp-server-parameters>
      <local-bind>
        <local-address>192.0.2.7</local-address>
      </local-bind>
    </tcp-server-parameters>
    <ssh-server-parameters>
      <server-identity>
        <host-key>
          <name>deployment-specific-certificate</name>
          <public-key>
            <central-keystore-reference>ssh-rsa-key</central-k\
eystore-reference>
          </public-key>
        </host-key>
      </server-identity>
      <client-authentication>
      </client-authentication>
    </ssh-server-parameters>
    <netconf-server-parameters>
      <!-- nothing to configure -->
    </netconf-server-parameters>
  </ssh>
</endpoint>
<endpoint> <!-- listening for TLS sessions -->
  <name>netconf/tls</name>
  <tls>
    <tcp-server-parameters>
      <local-bind>
        <local-address>192.0.2.7</local-address>
      </local-bind>
    </tcp-server-parameters>
    <tls-server-parameters>
      <server-identity>
        <certificate>
          <central-keystore-reference>
            <asymmetric-key>rsa-asymmetric-key</asymmetric-key>
            <certificate>ex-rsa-cert</certificate>
          </central-keystore-reference>
        </certificate>
      </server-identity>
      <client-authentication>
        <ca-certs>
          <central-truststore-reference>trusted-client-ca-cert\
s</central-truststore-reference>
        </ca-certs>
        <ee-certs>
          <central-truststore-reference>trusted-client-ee-cert\
s</central-truststore-reference>

```

```

        </ee-certs>
      </client-authentication>
    <keepalives>
      <peer-allowed-to-send/>
    </keepalives>
  </tls-server-parameters>
</netconf-server-parameters>
  <client-identity-mappings>
    <cert-to-name>
      <id>1</id>
      <fingerprint>11:0A:05:11:00</fingerprint>
      <map-type>x509c2n:specified</map-type>
      <name>scooby-doo</name>
    </cert-to-name>
    <cert-to-name>
      <id>2</id>
      <map-type>x509c2n:san-any</map-type>
    </cert-to-name>
  </client-identity-mappings>
</netconf-server-parameters>
</tls>
</endpoint>
</endpoints>
</listen>

<!-- calling home to SSH and TLS based NETCONF clients -->
<call-home>
  <netconf-client> <!-- SSH-based client -->
    <name>config-mgr</name>
    <endpoints>
      <endpoint>
        <name>east-data-center</name>
        <ssh>
          <tcp-client-parameters>
            <remote-address>east.config-mgr.example.com</remote-ad\
dress>
          <keepalives>
            <idle-time>7200</idle-time>
            <max-probes>9</max-probes>
            <probe-interval>75</probe-interval>
          </keepalives>
        </tcp-client-parameters>
      </ssh-server-parameters>
      <server-identity>
        <host-key>
          <name>deployment-specific-certificate</name>
          <public-key>
            <central-keystore-reference>ssh-rsa-key</central\

```

```

-keystore-reference>
    </public-key>
    </host-key>
    </server-identity>
    </ssh-server-parameters>
    <netconf-server-parameters>
        <!-- nothing to configure -->
    </netconf-server-parameters>
    </ssh>
</endpoint>
<endpoint>
    <name>west-data-center</name>
    <ssh>
        <tcp-client-parameters>
            <remote-address>west.config-mgr.example.com</remote-ad\
dress>
        </tcp-client-parameters>
        <ssh-server-parameters>
            <server-identity>
                <host-key>
                    <name>deployment-specific-certificate</name>
                <public-key>
                    <central-keystore-reference>ssh-rsa-key</central\
-keystore-reference>
                </public-key>
                </host-key>
            </server-identity>
            </ssh-server-parameters>
            <netconf-server-parameters>
                <!-- nothing to configure -->
            </netconf-server-parameters>
        </ssh>
    </endpoint>
</endpoints>
<connection-type>
    <periodic>
        <idle-timeout>300</idle-timeout>
        <period>60</period>
    </periodic>
</connection-type>
<reconnect-strategy>
    <start-with>last-connected</start-with>
    <max-wait>3</max-wait>
    <max-attempts>3</max-attempts>
</reconnect-strategy>
</netconf-client>
<netconf-client> <!-- TLS-based client -->
    <name>data-collector</name>

```

```

    <endpoints>
      <endpoint>
        <name>east-data-center</name>
        <tls>
          <tcp-client-parameters>
            <remote-address>east.analytics.example.com</remote-add\
ress>
            <keepalives>
              <idle-time>7200</idle-time>
              <max-probes>9</max-probes>
              <probe-interval>75</probe-interval>
            </keepalives>
          </tcp-client-parameters>
          <tls-server-parameters>
            <server-identity>
              <certificate>
                <central-keystore-reference>
                  <asymmetric-key>rsa-asymmetric-key</asymmetric-k\
ey>
                  <certificate>ex-rsa-cert</certificate>
                </central-keystore-reference>
              </certificate>
            </server-identity>
            <client-authentication>
              <ca-certs>
                <central-truststore-reference>trusted-client-ca-ce\
rts</central-truststore-reference>
              </ca-certs>
              <ee-certs>
                <central-truststore-reference>trusted-client-ee-ce\
rts</central-truststore-reference>
              </ee-certs>
            </client-authentication>
            <keepalives>
              <test-peer-aliveness>
                <max-wait>30</max-wait>
                <max-attempts>3</max-attempts>
              </test-peer-aliveness>
            </keepalives>
          </tls-server-parameters>
          <netconf-server-parameters>
            <client-identity-mappings>
              <cert-to-name>
                <id>1</id>
                <fingerprint>11:0A:05:11:00</fingerprint>
                <map-type>x509c2n:specified</map-type>
                <name>scooby-doo</name>
              </cert-to-name>
            </client-identity-mappings>
          </netconf-server-parameters>
        </tls>
      </endpoint>
    </endpoints>

```

```

        <cert-to-name>
          <id>2</id>
          <map-type>x509c2n:san-any</map-type>
        </cert-to-name>
      </client-identity-mappings>
    </netconf-server-parameters>
  </tls>
</endpoint>
<endpoint>
  <name>west-data-center</name>
  <tls>
    <tcp-client-parameters>
      <remote-address>west.analytics.example.com</remote-add\
ress>
      <keepalives>
        <idle-time>7200</idle-time>
        <max-probes>9</max-probes>
        <probe-interval>75</probe-interval>
      </keepalives>
    </tcp-client-parameters>
    <tls-server-parameters>
      <server-identity>
        <certificate>
          <central-keystore-reference>
            <asymmetric-key>rsa-asymmetric-key</asymmetric-k\
ey>
            <certificate>ex-rsa-cert</certificate>
          </central-keystore-reference>
        </certificate>
      </server-identity>
      <client-authentication>
        <ca-certs>
          <central-truststore-reference>trusted-client-ca-ce\
rts</central-truststore-reference>
        </ca-certs>
        <ee-certs>
          <central-truststore-reference>trusted-client-ee-ce\
rts</central-truststore-reference>
        </ee-certs>
      </client-authentication>
    </keepalives>
    <test-peer-aliveness>
      <max-wait>30</max-wait>
      <max-attempts>3</max-attempts>
    </test-peer-aliveness>
  </keepalives>
</tls-server-parameters>
</netconf-server-parameters>

```

```
<client-identity-mappings>
  <cert-to-name>
    <id>1</id>
    <fingerprint>11:0A:05:11:00</fingerprint>
    <map-type>x509c2n:specified</map-type>
    <name>scooby-doo</name>
  </cert-to-name>
  <cert-to-name>
    <id>2</id>
    <map-type>x509c2n:san-any</map-type>
  </cert-to-name>
</client-identity-mappings>
</netconf-server-parameters>
</tls>
</endpoint>
</endpoints>
<connection-type>
  <persistent/>
</connection-type>
<reconnect-strategy>
  <start-with>first-listed</start-with>
  <max-wait>3</max-wait>
  <max-attempts>3</max-attempts>
</reconnect-strategy>
</netconf-client>
</call-home>
</netconf-server>
```

3.3. YANG Module

This YANG module has normative references to [RFC6242], [RFC6991], [RFC7407], [RFC7589], [RFC8071], [RFC9643], [RFC9644], and [RFC9645].

<CODE BEGINS> file "ietf-netconf-server@2025-04-24.yang"

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

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

  import ietf-x509-cert-to-name {
    prefix x509c2n;
```

```
reference
  "RFC 7407: A YANG Data Model for SNMP Configuration";
}

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

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

import ietf-ssh-common {
  prefix sshcmn;
  reference
    "RFC EEEE: YANG Groupings for SSH Clients and SSH Servers";
}

import ietf-ssh-server {
  prefix sshs;
  reference
    "RFC EEEE: YANG Groupings for SSH Clients and SSH Servers";
}

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

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

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

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

  Copyright (c) 2025 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 Revised 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 HHHH (<https://www.rfc-editor.org/info/rfcHHHH>); 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 2025-04-24 {
  description
    "Initial version";
  reference
    "RFC HHHH: A YANG Data Model for NETCONF Clients and Server";
}

// Features

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

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



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

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

feature central-netconf-server-supported {
  description
    "The 'central-netconf-server-supported' feature indicates
    that the server supports the top-level 'netconf-server'
    node.

    This feature is needed as some servers may want to use
    features defined in this module, which requires this
    module to be implemented, without having to support
    the top-level 'netconf-server' node.";
}

// Groupings

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

    Note that this grouping uses a fairly typical descendant
    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.,
    'netconf-server-parameters'. This model purposely does
    not do this itself so as to provide maximum flexibility
    to consuming models.";

  container client-identity-mappings {
```

```
description
  "Specifies mappings through which NETCONF client X.509
  certificates are used to determine a NETCONF username,
  per RFC 7407.

  For TLS-based transports, if no matching and valid
  cert-to-name list entry can be found, then the NETCONF
  server MUST close the connection, and MUST NOT accept
  NETCONF messages over it, per Section 7 in RFC 7589.

  For SSH-based transports, a matching cert-to-name
  entry overrides the username provided by the SSH
  implementation, consistent with the second paragraph
  of Section 3 in RFC 6242.";
reference
  "RFC 6242:
    Using the NETCONF Protocol over Secure Shell (SSH)
  RFC 7589:
    Using the NETCONF Protocol over Transport Layer
    Security (TLS) with Mutual X.509 Authentication";
uses x509c2n:cert-to-name {
  refine "cert-to-name/fingerprint" {
    mandatory false;
    description
      "A 'fingerprint' value does not need to be specified
      when the 'cert-to-name' mapping is independent of
      fingerprint matching. A 'cert-to-name' having no
      fingerprint value will match any client certificate
      and therefore SHOULD only be present at the end of
      the user-ordered 'cert-to-name' list.";
  }
}
}
}

grouping netconf-server-listen-stack-grouping {
  description
    "A grouping for configuring a NETCONF server
    'listen' protocol stack for listening on a single port.";
  choice transport {
    mandatory true;
    description
      "Selects between available transports.";
    case ssh {
      if-feature "ssh-listen";
      container ssh {
        description
          "TCP, SSH, and NETCONF configuration to listen
```

```
    for NETCONF over SSH connections.";
  container tcp-server-parameters {
    description
      "TCP-level server parameters to listen
       for NETCONF over SSH connections.";
    uses tcps:tcp-server-grouping {
      refine "local-bind/local-port" {
        default "830";
        description
          "The NETCONF server will listen on the
           IANA-assigned well-known port value
           for 'netconf-ssh' (830) if no value
           is specified.";
      }
    }
  }
}
container ssh-server-parameters {
  description
    "SSH-level server parameters to listen
     for NETCONF over SSH connections.";
  uses sshs:ssh-server-grouping;
}
container netconf-server-parameters {
  description
    "NETCONF-level server parameters to listen
     for NETCONF over SSH connections.";
  uses ncs:netconf-server-grouping {
    refine "client-identity-mappings" {
      if-feature "sshcmn:ssh-x509-certs";
      description
        "Adds in an 'if-feature' statement
         ensuring the 'client-identity-mappings'
         descendant is enabled only when SSH
         supports X.509 certificates.";
    }
    augment "client-identity-mappings" {
      description
        "Adds a flag indicating if a cert-to-name
         is required.";
      leaf mapping-required {
        type boolean;
        description
          "Indicates that the cert-to-name mapping
           is required (i.e., the SSH-level username
           is ignored).";
      }
    }
  }
}
```

```
    }  
  }  
}  
case tls {  
  if-feature "tls-listen";  
  container tls {  
    description  
      "TCP, TLS, and NETCONF configuration to listen  
      for NETCONF over TLS connections.";  
    container tcp-server-parameters {  
      description  
        "TCP-level server parameters to listen  
        for NETCONF over TLS connections.";  
      uses tcps:tcp-server-grouping {  
        refine "local-bind/local-port" {  
          default "6513";  
          description  
            "The NETCONF server will listen on the  
            IANA-assigned well-known port value  
            for 'netconf-tls' (6513) if no value  
            is specified.";  
        }  
      }  
    }  
  }  
  container tls-server-parameters {  
    description  
      "TLS-level server parameters to listen  
      for NETCONF over TLS connections.";  
    uses tlss:tls-server-grouping {  
      refine "client-authentication" {  
        must 'ca-certs or ee-certs';  
        description  
          "NETCONF/TLS servers MUST validate client  
          certificates. This configures certificates  
          at the socket-level (i.e. bags). More  
          discriminating client-certificate checks  
          SHOULD be implemented by the application.";  
        reference  
          "RFC 7589:  
          Using the NETCONF Protocol over Transport Layer  
          Security (TLS) with Mutual X.509 Authentication";  
      }  
    }  
  }  
  container netconf-server-parameters {  
    description  
      "NETCONF-level server parameters to listen  
      for NETCONF over TLS connections.";
```

```

        uses ncs:netconf-server-grouping {
            refine "client-identity-mappings/cert-to-name" {
                min-elements 1;
                description
                    "The TLS transport requires a mapping.";
            }
        }
    }
}

grouping netconf-server-callhome-stack-grouping {
    description
        "A grouping for configuring a NETCONF server
        'call-home' protocol stack, for a single outbound
        connection.";
    choice transport {
        mandatory true;
        description
            "Selects between available transports.";
        case ssh {
            if-feature "ssh-call-home";
            container ssh {
                description
                    "TCP, SSH, and NETCONF configuration to initiate
                    a NETCONF over SSH Call Home connection.";
                container tcp-client-parameters {
                    description
                        "TCP-level client parameters to initiate a
                        NETCONF over SSH Call Home connection.";
                    uses tcpc:tcp-client-grouping {
                        refine "remote-port" {
                            default "4334";
                            description
                                "The NETCONF server will attempt to connect
                                to the IANA-assigned well-known port for
                                'netconf-ch-ssh' (4334) if no value is
                                specified.";
                        }
                    }
                }
            }
        }
        container ssh-server-parameters {
            description
                "SSH-level server parameters to initiate a
                NETCONF over SSH Call Home connection.";
            uses sshs:ssh-server-grouping;
        }
    }
}

```

```
}
container netconf-server-parameters {
  description
    "NETCONF-level server parameters to initiate a
    NETCONF over SSH Call Home connection.";
  uses ncs:netconf-server-grouping {
    refine "client-identity-mappings" {
      if-feature "sshcmn:ssh-x509-certs";
      description
        "Adds in an 'if-feature' statement
        ensuring the 'client-identity-mappings'
        descendant is enabled only when SSH
        supports X.509 certificates.";
    }
    augment "client-identity-mappings" {
      description
        "Adds a flag indicating if a cert-to-name
        is required.";
      leaf mapping-required {
        type boolean;
        description
          "Indicates that the cert-to-name mapping
          is required (i.e., the SSH-level username
          is ignored).";
      }
    }
  }
}
}
}
}
}
}
}
case tls {
  if-feature "tls-call-home";
  container tls {
    description
      "TCP, TLS, and NETCONF configuration to initiate
      a NETCONF over TLS Call Home connection.";
    container tcp-client-parameters {
      description
        "TCP-level client parameters to initiate a
        NETCONF over TLS Call Home connection.";
      uses tcpc:tcp-client-grouping {
        refine "remote-port" {
          default "4335";
          description
            "The NETCONF server will attempt to connect
            to the IANA-assigned well-known port for
            'netconf-ch-tls' (4335) if no value is
            specified.";
```

```

    }
  }
}
container tls-server-parameters {
  description
    "TLS-level server parameters to initiate a
    NETCONF over TLS Call Home connection.";
  uses tlss:tls-server-grouping {
    refine "client-authentication" {
      must 'ca-certs or ee-certs';
      description
        "NETCONF/TLS servers MUST validate client
        certificates. This configures certificates
        at the socket-level (i.e. bags). More
        discriminating client-certificate checks
        SHOULD be implemented by the application.";
      reference
        "RFC 7589:
        Using the NETCONF Protocol over Transport Layer
        Security (TLS) with Mutual X.509 Authentication";
    }
  }
}
container netconf-server-parameters {
  description
    "NETCONF-level server parameters to initiate a
    NETCONF over TLS Call Home connection.";
  uses ncs:netconf-server-grouping {
    refine "client-identity-mappings/cert-to-name" {
      min-elements 1;
      description
        "The TLS transport requires a mapping.";
    }
  }
}
}
}
}
}
}
}
}

grouping netconf-server-app-grouping {
  description
    "A grouping for configuring a NETCONF server
    application that supports both 'listen' and 'call-home'
    protocol stacks for a multiplicity of connections.";
  container listen {
    if-feature "ssh-listen or tls-listen";
    presence

```

```
    "Indicates that server-listening ports have been configured.
    This statement is present so the mandatory descendant
    nodes do not imply that this node must be configured.";
  description
    "Configures listen behavior";
  leaf idle-timeout {
    type uint16;
    units "seconds";
    default "180"; // three minutes
    description
      "Specifies the maximum number of seconds that a NETCONF
      session may remain idle. A NETCONF session will be
      dropped if it is idle for an interval longer than this
      number of seconds. If set to zero, then the server
      will never drop a session because it is idle.";
  }
  container endpoints {
    description
      "Container for a list of endpoints.";
    list endpoint {
      key "name";
      min-elements 1;
      description
        "List of endpoints to listen for NETCONF connections.";
      leaf name {
        type string;
        description
          "An arbitrary name for the NETCONF listen endpoint.";
      }
      uses netconf-server-listen-stack-grouping;
    }
  }
}

container call-home {
  if-feature "ssh-call-home or tls-call-home";
  presence
    "Indicates that server-initiated call home connections have
    been configured. This statement is present so the mandatory
    descendant nodes do not imply that this node must be
    configured.";
  description
    "Configures the NETCONF server to initiate the underlying
    transport connection to NETCONF clients.";
  list netconf-client {
    key "name";
    min-elements 1;
    description
      "List of NETCONF clients the NETCONF server is to
```



```
        maintain simultaneous call-home connections with.";
    leaf name {
        type string;
        description
            "An arbitrary name for the remote NETCONF client.";
    }
    container endpoints {
        description
            "Container for the list of endpoints.";
        list endpoint {
            key "name";
            min-elements 1;
            ordered-by user;
            description
                "A non-empty user-ordered list of endpoints for this
                 NETCONF server to try to connect to in sequence.
                 Defining more than one enables high-availability.";
            leaf name {
                type string;
                description
                    "An arbitrary name for this endpoint.";
            }
            uses netconf-server-callhome-stack-grouping;
        }
    }
    container connection-type {
        description
            "Indicates the NETCONF server's preference for how the
             NETCONF 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 NETCONF
                         client. If the connection goes down, immediately
                         start trying to reconnect to the NETCONF client,
                         using the reconnection strategy.

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

```
}
case periodic-connection {
  container periodic {
    presence "Indicates that a periodic connection is
              to be maintained.";
    description
      "Periodically connect to the NETCONF client.

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

      The NETCONF client SHOULD gracefully close the
      connection using <close-session> upon completing
      planned activities. If the NETCONF session is
      not closed gracefully, the NETCONF server MUST
      immediately attempt to reestablish the connection.

      Connections are established at the same start
      time regardless how long the previous connection
      stayed open.

      In the case that the previous connection is still
      active (i.e., the NETCONF 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 '[0-9]{4}-(1[0-2]|0[1-9])-(0[1-9]|[1-2]'
          + '[0-9]|3[0-1])T(0[0-9]|1[0-9]|2[0-3]):['
          + '0-5][0-9]:00(Z|[\+-])((1[0-3]|0[0-9]):'
          + '([0-5][0-9])|14:00))?'
      }
      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.

        If an 'anchor-time' is not provided, then the
```

server may implicitly set it to the time when this configuraton is applied (e.g., on boot).

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 "180"; // three minutes
  description
    "Specifies the maximum number of seconds that
     a NETCONF session may remain idle. A NETCONF
     session will be dropped if it is idle for an
     interval longer than this number of seconds.
     If set to zero, then the server will never
     drop a session because it is idle.";
}
} // case periodic-connection
} // choice connection-type
} // container connection-type
container reconnect-strategy {
  description
    "The reconnection strategy directs how a NETCONF server
     reconnects to a NETCONF client, after discovering its
     connection to the client has dropped, even if due to a
     reboot. The NETCONF server starts with the specified
     endpoint and tries to connect to it max-attempts times
     before trying the next endpoint in the list (round
     robin).";
  leaf start-with {
    type enumeration {
      enum first-listed {
        description
          "Indicates that reconnections SHOULD start with
           the first endpoint listed.";
      }
      enum last-connected {
        description
          "Indicates that reconnections SHOULD start with
           the endpoint last connected to, if known. If
           no previous connection is known, then the
           first endpoint configured is used.";
      }
    }
    enum random-selection {
```

```
        description
            "Indicates that reconnections SHOULD start with
             a random endpoint.";
    }
}
default "first-listed";
description
    "Specifies which of the NETCONF client's endpoints
     the NETCONF server SHOULD start with when trying
     to connect to the NETCONF client.";
}
leaf max-wait {
    type uint16 {
        range "1..max";
    }
    units "seconds";
    default "5";
    description
        "Specifies the amount of time in seconds after which,
         if the connection is not established, an endpoint
         connection attempt is considered unsuccessful.";
}
leaf max-attempts {
    type uint8 {
        range "1..max";
    }
    default "3";
    description
        "Specifies the number times the NETCONF server tries
         to connect to a specific endpoint before moving on
         to the next endpoint in the list (round robin).";
}
} // container reconnect-strategy
} // list netconf-client
} // container call-home
} // grouping netconf-server-app-grouping

// Protocol accessible node for servers that implement this module.
container netconf-server {
    if-feature central-netconf-server-supported;
    uses netconf-server-app-grouping;
    description
        "Top-level container for NETCONF server configuration.";
}
}

<CODE ENDS>
```

4. Security Considerations

4.1. Considerations for the "ietf-netconf-client" YANG Module

This section is modeled after the template defined in Section 3.7.1 of [RFC8407].

The "ietf-netconf-client" YANG module defines data nodes that are designed to be accessed via YANG-based management protocols, such as NETCONF [RFC6241] and RESTCONF [RFC8040]. The YANG-based management protocols have to use a secure transport layer such as SSH [RFC4252], TLS [RFC8446], or QUIC [RFC9000]. The YANG-based management protocols also have to use mutual authentication.

The Network 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.

This YANG module uses groupings from other YANG modules that define nodes that may be considered sensitive or vulnerable in network environments. Please review the Security Considerations for dependent YANG modules for information as to which nodes may be considered sensitive or vulnerable in network environments.

This YANG module uses groupings defined in other RFCs that define data nodes that do set the NACM "default-deny-all" and "default-deny-write" extensions.

None of the readable data nodes defined in this YANG module are considered sensitive or vulnerable in network environments. The NACM "default-deny-all" extension has not been set for any data nodes defined in this module.

None of the writable data nodes defined in this YANG module are considered sensitive or vulnerable in network environments. The NACM "default-deny-write" extension has not been set for any data nodes defined in this module.

This module does not define any RPCs, actions, or notifications, and thus the security consideration for such is not provided here.

4.2. Considerations for the "ietf-netconf-server" YANG Module

This section is modeled after the template defined in Section 3.7.1 of [RFC8407].

The "ietf-netconf-server" YANG module defines data nodes that are designed to be accessed via YANG-based management protocols, such as NETCONF [RFC6241] and RESTCONF [RFC8040]. The YANG-based management protocols have to use a secure transport layer such as SSH [RFC4252], TLS [RFC8446], or QUIC [RFC9000]. The YANG-based management protocols also have to use mutual authentication.

The Network 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.

This YANG module uses groupings from other YANG modules that define nodes that may be considered sensitive or vulnerable in network environments. Please review the Security Considerations for dependent YANG modules for information as to which nodes may be considered sensitive or vulnerable in network environments.

This YANG module uses groupings defined in other RFCs that define data nodes that do set the NACM "default-deny-all" and "default-deny-write" extensions.

None of the readable data nodes defined in this YANG module are considered sensitive or vulnerable in network environments. The NACM "default-deny-all" extension has not been set for any data nodes defined in this module.

None of the writable data nodes defined in this YANG module are considered sensitive or vulnerable in network environments. The NACM "default-deny-write" extension has not been set for any data nodes defined in this module.

This YANG module does not define any RPCs, actions, or notifications, and thus the security consideration for such is not provided here.

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-netconf-client
Registrant Contact: The IESG
XML: N/A, the requested URI is an XML namespace.

URI: urn:ietf:params:xml:ns:yang:ietf-netconf-server
Registrant Contact: The IESG
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 following registrations are requested:

Name: ietf-netconf-client
Namespace: urn:ietf:params:xml:ns:yang:ietf-netconf-client
Prefix: ncc
Reference: RFC HHHH
Maintained by IANA: N

Name: ietf-netconf-server
Namespace: urn:ietf:params:xml:ns:yang:ietf-netconf-server
Prefix: ncs
Reference: RFC HHHH
Maintained by IANA: N

6. References

6.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <<https://www.rfc-editor.org/info/rfc6020>>.
- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <<https://www.rfc-editor.org/info/rfc6241>>.
- [RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", RFC 6242, DOI 10.17487/RFC6242, June 2011, <<https://www.rfc-editor.org/info/rfc6242>>.

- [RFC6991] Schoenwaelder, J., Ed., "Common YANG Data Types", RFC 6991, DOI 10.17487/RFC6991, July 2013, <<https://www.rfc-editor.org/info/rfc6991>>.
- [RFC7407] Bjorklund, M. and J. Schoenwaelder, "A YANG Data Model for SNMP Configuration", RFC 7407, DOI 10.17487/RFC7407, December 2014, <<https://www.rfc-editor.org/info/rfc7407>>.
- [RFC7589] Badra, M., Luchuk, A., and J. Schoenwaelder, "Using the NETCONF Protocol over Transport Layer Security (TLS) with Mutual X.509 Authentication", RFC 7589, DOI 10.17487/RFC7589, June 2015, <<https://www.rfc-editor.org/info/rfc7589>>.
- [RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, DOI 10.17487/RFC7950, August 2016, <<https://www.rfc-editor.org/info/rfc7950>>.
- [RFC8071] Watsen, K., "NETCONF Call Home and RESTCONF Call Home", RFC 8071, DOI 10.17487/RFC8071, February 2017, <<https://www.rfc-editor.org/info/rfc8071>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.
- [RFC9642] Watsen, K., "A YANG Data Model for a Keystore", RFC 9642, DOI 10.17487/RFC9642, October 2024, <<https://www.rfc-editor.org/info/rfc9642>>.
- [RFC9643] Watsen, K. and M. Scharf, "YANG Groupings for TCP Clients and TCP Servers", RFC 9643, DOI 10.17487/RFC9643, October 2024, <<https://www.rfc-editor.org/info/rfc9643>>.
- [RFC9644] Watsen, K., "YANG Groupings for SSH Clients and SSH Servers", RFC 9644, DOI 10.17487/RFC9644, October 2024, <<https://www.rfc-editor.org/info/rfc9644>>.
- [RFC9645] Watsen, K., "YANG Groupings for TLS Clients and TLS Servers", RFC 9645, DOI 10.17487/RFC9645, October 2024, <<https://www.rfc-editor.org/info/rfc9645>>.

6.2. Informative References

- [I-D.ietf-netconf-http-client-server]
Watsen, K., "YANG Groupings for HTTP Clients and HTTP Servers", Work in Progress, Internet-Draft, draft-ietf-netconf-http-client-server-25, 12 February 2025, <<https://datatracker.ietf.org/doc/html/draft-ietf-netconf-http-client-server-25>>.
- [I-D.ietf-netconf-netconf-client-server]
Watsen, K., "NETCONF Client and Server Models", Work in Progress, Internet-Draft, draft-ietf-netconf-netconf-client-server-38, 12 February 2025, <<https://datatracker.ietf.org/doc/html/draft-ietf-netconf-netconf-client-server-38>>.
- [I-D.ietf-netconf-restconf-client-server]
Watsen, K., "RESTCONF Client and Server Models", Work in Progress, Internet-Draft, draft-ietf-netconf-restconf-client-server-42, 14 April 2025, <<https://datatracker.ietf.org/doc/html/draft-ietf-netconf-restconf-client-server-42>>.
- [I-D.ietf-netmod-system-config]
Ma, Q., Wu, Q., and C. Feng, "System-defined Configuration", Work in Progress, Internet-Draft, draft-ietf-netmod-system-config-12, 12 February 2025, <<https://datatracker.ietf.org/doc/html/draft-ietf-netmod-system-config-12>>.
- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <<https://www.rfc-editor.org/info/rfc3688>>.
- [RFC4252] Ylonen, T. and C. Lonvick, Ed., "The Secure Shell (SSH) Authentication Protocol", RFC 4252, DOI 10.17487/RFC4252, January 2006, <<https://www.rfc-editor.org/info/rfc4252>>.
- [RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <<https://www.rfc-editor.org/info/rfc8040>>.
- [RFC8340] Bjorklund, M. and L. Berger, Ed., "YANG Tree Diagrams", BCP 215, RFC 8340, DOI 10.17487/RFC8340, March 2018, <<https://www.rfc-editor.org/info/rfc8340>>.
- [RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", STD 91, RFC 8341, DOI 10.17487/RFC8341, March 2018, <<https://www.rfc-editor.org/info/rfc8341>>.

- [RFC8342] Bjorklund, M., Schoenwaelder, J., Shafer, P., Watsen, K., and R. Wilton, "Network Management Datastore Architecture (NMDA)", RFC 8342, DOI 10.17487/RFC8342, March 2018, <<https://www.rfc-editor.org/info/rfc8342>>.
- [RFC8407] Bierman, A., "Guidelines for Authors and Reviewers of Documents Containing YANG Data Models", BCP 216, RFC 8407, DOI 10.17487/RFC8407, October 2018, <<https://www.rfc-editor.org/info/rfc8407>>.
- [RFC8446] Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <<https://www.rfc-editor.org/info/rfc8446>>.
- [RFC9000] Iyengar, J., Ed. and M. Thomson, Ed., "QUIC: A UDP-Based Multiplexed and Secure Transport", RFC 9000, DOI 10.17487/RFC9000, May 2021, <<https://www.rfc-editor.org/info/rfc9000>>.
- [RFC9640] Watsen, K., "YANG Data Types and Groupings for Cryptography", RFC 9640, DOI 10.17487/RFC9640, October 2024, <<https://www.rfc-editor.org/info/rfc9640>>.
- [RFC9641] Watsen, K., "A YANG Data Model for a Truststore", RFC 9641, DOI 10.17487/RFC9641, October 2024, <<https://www.rfc-editor.org/info/rfc9641>>.

Appendix A. Change Log

A.1. 00 to 01

- * Renamed "keychain" to "keystore".

A.2. 01 to 02

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

A.3. 02 to 03

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

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

A.4. 03 to 04

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

A.5. 04 to 05

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

A.6. 05 to 06

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

A.7. 06 to 07

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

A.8. 07 to 08

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

A.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.

A.10. 09 to 10

- * Reformatted YANG modules.

A.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.

A.12. 11 to 12

- * Removed the "Design Considerations" section.
- * 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-connection" description statements to be more like the RESTCONF draft, especially where it described dropping the underlying TCP connection.

- * 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.

A.13. 12 to 13

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

A.14. 13 to 14

- * Adjusting from change in TLS client model (removing the top-level 'certificate' container), by swapping refining-in a 'mandatory true' statement with a 'must' statement outside the 'uses' statement.
- * Updated examples to reflect ietf-crypto-types change (e.g., identities --> enumerations)

A.15. 14 to 15

- * Refactored both the client and server modules similar to how the ietf-restconf-server module was refactored in -13 of that draft, and the ietf-restconf-client grouping.

A.16. 15 to 16

- * Added refinement to make "cert-to-name/fingerprint" be mandatory false.
- * Commented out refinement to "tls-server-grouping/client-authentication" until a better "must" expression is defined.

A.17. 16 to 17

- * Updated examples to include the "-key-format" nodes.
- * Updated examples to remove the "required" nodes.
- * Updated examples to remove the "client-auth-defined-elsewhere" nodes.

A.18. 17 to 18

- * Updated examples to reflect new "bag" addition to truststore.

A.19. 18 to 19

- * Updated examples to remove the 'algorithm' nodes.
- * Updated examples to reflect the new TLS keepalives structure.
- * Added keepalives to the tcp-client-parameters section in the netconf-server SSH-based call-home example.
- * Added a TLS-based call-home example to the netconf-client example.
- * Added a "Note to Reviewers" note to first page.

A.20. 19 to 20

- * Expanded "Data Model Overview section(s) [remove "wall" of tree diagrams].
- * Removed expanded tree diagrams that were listed in the Appendix.
- * Updated the Security Considerations section.

A.21. 20 to 21

- * Cleaned up titles in the IANA Considerations section
- * Fixed issues found by the SecDir review of the "keystore" draft.

A.22. 21 to 22

- * Addressed comments raised by YANG Doctor in the ct/ts/ks drafts.

A.23. 22 to 23

- * Floated an 'if-feature' statement in a grouping down to where the grouping is used.
- * Clarified 'client-identity-mappings' for both the SSH and TLS transports.
- * For netconf-client, augmented-in a 'mapping-required' flag into 'client-identity-mappings' only for the SSH transport, and refined-in a 'min-elements 1' only for the TLS transport.

- * Aligned modules with 'pyang -f' formatting.

A.24. 23 to 24

- * Replaced "base64encodedvalue==" with "BASE64VALUE=" in examples.
- * Minor editorial nits

A.25. 24 to 25

- * Fixed up the 'WG Web' and 'WG List' lines in YANG module(s)
- * Fixed up copyright (i.e., s/Simplified/Revised/) in YANG module(s)

A.26. 25 to 26

- * Added feature "central-netconf-client-supported" to top-level node "netconf-client".
- * Added feature "central-netconf-server-supported" to top-level node "netconf-server".
- * Clarified container "netconf-client-parameters" description statement.
- * Removed unnecessary "xmlns:x509c2n" in a NETCONF server configuration example.

A.27. 26 to 27

- * Updated per Shepherd reviews impacting the suite of drafts.
- * Added "max-wait" leaf to the "reconnect-strategy" nodes.

A.28. 27 to 28

- * Updated per Shepherd reviews impacting the suite of drafts.

A.29. 28 to 29

- * Updated (implicitly) via Tom Petch reviews.
- * Fixed pattern statement for "leaf anchor-time".

A.30. 29 to 30

- * Addresses AD review comments.

- * Added note to Editor to fix line foldings.
- * Removed netconf-client-grouping, since it was empty.
- * Removed erroneous statement "client-identity-mappings" must be enabled by a "feature".
- * Added Security Considerations text to also look a SC-section from imported modules.
- * Removed "A wrapper around the foobar parameters to avoid name collisions" text.
- * Added container "endpoints" to wrap list "endpoint".

A.31. 30 to 31

- * Addresses AD review by Rob Wilton.

A.32. 31 to 32

- * Addresses 1st-round of IESG reviews.

A.33. 32 to 34

- * Addresses issues found in OpsDir review of the ssh-client-server draft.
- * s/defines/presents/ in a few places.
- * Add refs to where the 'operational' and 'system' datastores are defined.
- * Renamed Security Considerations section s/Template for/ Considerations for/

A.34. 34 to 36

- * Nothing changed. Only bumped for automation...

A.35. 37 to 38

- * Updated 2nd paragraph in Security Considerations section to match RFC Editor's version for other drafts in the suite of client-server drafts.

A.36. 38 to 39

- * Updated to reflect some of Med's AD-review comments.

Acknowledgements

The authors would like to thank the following for lively discussions on list and in the halls (ordered by first name): Alan Luchuk, Andy Bierman, Balazs Kovacs, Benoit Claise, Bert Wijnen, David Lamparter, J端rgen Schindler, Ladislav Lhotka, Martin Björklund, Med Boucladair, Mehmet Ersue, Michal Váňko, Phil Shafer, Qiufang Ma, Radek Krejci, Ramkumar Dhanapal, Rob Wilton, Sean Turner, and Tom Petch.

Author's Address

Kent Watsen
Watsen Networks
Email: kent+ietf@watsen.net