NETCONF Working Group
Internet-Draft
Intended status: Standards Track
Expires: April 11, 2016

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October 9, 2015

NETCONF Server and RESTCONF Server Configuration Models
draft-ietf-netconf-server-model-08

Abstract

This draft defines a NETCONF server configuration data model and a RESTCONF server configuration data model. These data models enable configuration of the NETCONF and RESTCONF services themselves, including which transports are supported, what ports the servers listen on, call-home parameters, client authentication, and related parameters.

Editorial Note (To be removed by RFC Editor)

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

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

- draft-ietf-netconf-restconf
- draft-ietf-netconf-call-home

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

- "VVVV" --> the assigned RFC value for this draft
- "XXXX" --> the assigned RFC value for draft-ietf-netconf-restconf
- "YYYY" --> the assigned RFC value for draft-ietf-netconf-call-home

Artwork in this document contains placeholder values for ports pending IANA assignment from "draft-ietf-netconf-call-home". Please apply the following replacements:

- "7777" --> the assigned port value for "netconf-ch-ssh"

- "8888" --> the assigned port value for "netconf-ch-tls"

- "9999" --> the assigned port value for "restconf-ch-tls"

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

- "2015-10-09" --> the publication date of this draft

The following two Appendix sections are to be removed prior to publication:

- Appendix B. Change Log

- Appendix C. Open Issues

Status of This Memo

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Table of Contents

1. Introduction

This draft defines a NETCONF [RFC6241] server configuration data model and a RESTCONF [draft-ietf-netconf-restconf] server configuration data model. These data models enable configuration of the NETCONF and RESTCONF services themselves, including which transports are supported, what ports the servers listen on, call-home parameters, client authentication, and related parameters.

1.1. Terminology

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

1.2. Tree Diagrams

A simplified graphical representation of the data models is used in this document. The meaning of the symbols in these diagrams is as follows:

- Brackets "[" and "]" enclose list keys.

- Braces "{" and "}" enclose feature names, and indicate that the named feature must be present for the subtree to be present.

- Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).

- Symbols after data node names: "?" means an optional node, "!" means a presence container, and "*" denotes a list and leaf-list.

- Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").

- Ellipsis ("...") stands for contents of subtrees that are not shown.

2. Objectives

The primary purpose of the YANG modules defined herein is to enable the configuration of the NETCONF and RESTCONF services on a network element. This scope includes the following objectives:

2.1. Support all NETCONF and RESTCONF transports

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

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

2.2. Enable each transport to select which keys to use

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

2.3. Support authenticating NETCONF/RESTCONF clients certificates

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

2.4. Support mapping authenticated NETCONF/RESTCONF client certificates to usernames

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

2.5. Support both listening for connections and call home

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

2.6. For Call Home connections

The following objectives only pertain to call home connections.

2.6.1. Support more than one NETCONF/RESTCONF client

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

2.6.2. Support NETCONF/RESTCONF clients having more than one endpoint

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

2.6.3. Support a reconnection strategy

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

2.6.4. Support both persistent and periodic connections

NETCONF/RESTCONF clients may vary greatly on how frequently they need to interact with a NETCONF/RESTCONF server, how responsive interactions need to be, and how many simultaneous connections they

can support. Some clients may need a persistent connection to servers to optimize real-time interactions, while others prefer periodic interactions in order to minimize resource requirements. Therefore, when it is necessary for server to initiate connections, it should be configurable if the connection is persistent or periodic.

2.6.5. Reconnection strategy for periodic connections

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

2.6.6. Keep-alives for persistent connections

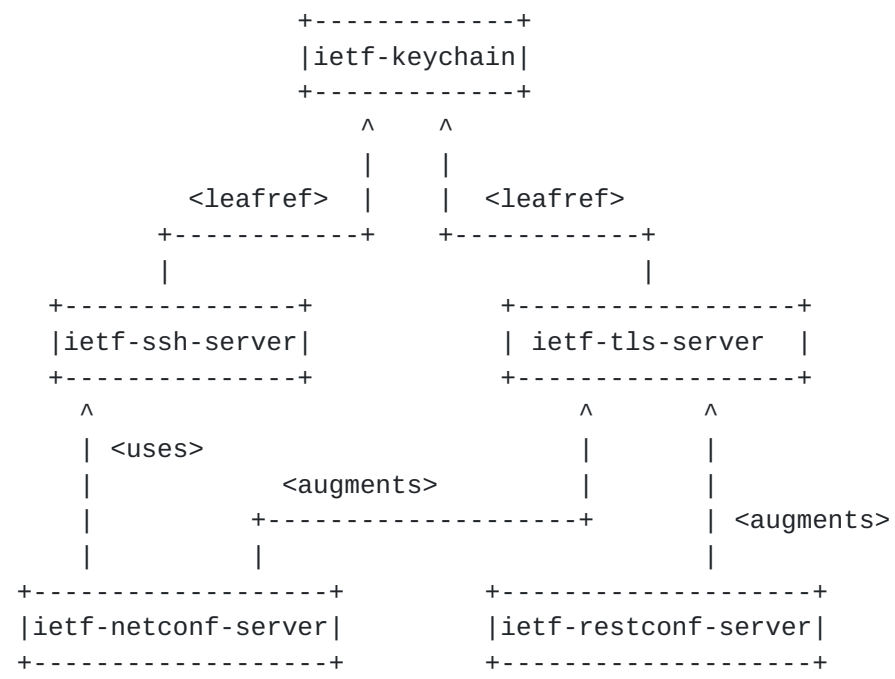
If a persistent connection is desired, it is the responsibility of the connection initiator to actively test the "aliveness" of the connection. The connection initiator must immediately work to reestablish a persistent connection as soon as the connection is lost. How often the connection should be tested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

2.6.7. Customizations for periodic connections

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

3. High-Level Design

The solution presented in this document defines a configurable keychain object, reusable groupings for SSH and TLS based servers, and, finally, the configurable NETCONF and RESTCONF server objects, which are the primary purpose for this draft. Each of these are defined in a distinct YANG module, thus a total of five YANG modules are defined in this document. The relationship between these five YANG modules is illustrated by the tree diagram below.



4. Solution

Each of the following five sections relate to one of the YANG modules depicted by the figure above.

4.1. The Keychain Model

The keychain model depicted in this section provides a configurable object having the following characteristics:

- A semi-configurable list of private keys, each with one or more associated certificates. Though private keys can only be created via an RPC (see bullet #3 below), the entries of the list may be renamed and have certificates associated with them after creation.

- A configurable list of lists of trust anchor certificates. This enables the server to have use-specific trust anchors. For instance, one list of trust anchors might be used to authenticate management connections (e.g., client certificate-based authentication for NETCONF or RESTCONF connections), and a different list of trust anchors might be used for when connecting to a specific Internet-based service (e.g., a zero touch bootstrap server).

- An RPC to request the server to generate a new private key using the specified algorithm and key length.

- An RPC to generate a certificate signing request for an existing private key, a passed subject, and an optional attributes. The signed certificate returned from an external certificate authority (CA) can be set using a standard configuration change request (e.g., <edit-config>).

4.1.1. Tree Diagram

```
module: ietf-keychain
   +--rw keychain
      +--rw private-keys
      |  +--rw private-key* [name]
      |  |  +--rw name                                    string
      |  |  +--ro algorithm?                              enumeration
      |  |  +--ro key-length?                             uint32
      |  |  +--ro public-key?                             string
      |  |  +--rw certificates
      |  |  |  +--rw certificate* [name]
      |  |  |     +--rw name     string
      |  |  |     +--rw chain?   binary
      |  |  +---x generate-certificate-signing-request
      |  |     +---w input
      |  |     |  +---w subject       binary
      |  |     |  +---w attributes?   binary
      |  |     +--ro output
      |  |        +--ro certificate-signing-request    binary
      |  +---x generate-private-key
      |     +---w input
      |        +---w name          string
      |        +---w algorithm     enumeration
      |        +---w key-length?   uint32
      +--rw trusted-certificates* [name]
         +--rw name                   string
         +--rw description?           string
         +--rw trusted-certificate* [name]
            +--rw name           string
            +--rw certificate?   binary
```

4.1.2. Example Usage

The following example illustrates the "generate-private-key" RPC in use with the RESTCONF protocol and JSON encoding.

REQUEST

['\' line wrapping added for formatting only]

```
POST https://example.com/restconf/data/ietf-keychain:keychain/\
private-keys/generate-private-key HTTP/1.1
HOST: example.com
Content-Type: application/yang.operation+json

{
  "ietf-keychain:input" : {
    "name" : "ex-key-sect571r1",
    "algorithm" : "sect571r1"
  }
}
```

RESPONSE

```
HTTP/1.1 204 No Content
Date: Mon, 31 Oct 2015 11:01:00 GMT
Server: example-server
```

The following example illustrates the action statement "generate-certificate-signing-request" action in use with the NETCONF protocol.

REQUEST

```
<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <action xmlns="urn:ietf:params:xml:ns:yang:1">
    <keychain xmlns="urn:ietf:params:xml:ns:yang:ietf-keychain">
      <private-keys>
        <private-key>
          <name>ex-key-sect571r1</name>
          <generate-certificate-signing-request>
            <subject>
             cztvaWRoc2RmZ2tqaHNkZmdramRzZnZzZGtmam5idnNvO2R
             manZvO3NkZmJpdmhzZGZpbHVidjtvc2lkZmhidml1bHNlmO
             Z2aXNiZGZpYmhzZG87ZmJvO3NkZ25iO29pLmR6Zgo=
            </subject>
            <attributes>
             bwtakWRoc2RmZ2tqaHNkZmdramRzZnZzZGtmam5idnNvut4
             arnZvO3NkZmJpdmhzZGZpbHVidjtvc2lkZmhidml1bHNkYm
```

```
                Z2aXNiZGZpYmhzZG87ZmJvO3NkZ25iO29pLmC6Rhp=
              </attributes>
            </generate-certificate-signing-request>
          </private-key>
        </private-keys>
      </keychain>
    </action>
  </rpc>
```

RESPONSE

```
  <rpc-reply message-id="101"
     xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
     <certificate-signing-request
       xmlns="urn:ietf:params:xml:ns:yang:ietf-keychain">
       LS0tLS1CRUdJTiBDRVJUSUZJQ0FURS0tLS0tCk1JSUNrekNDQWZ5Z
       0F3SUJBZ0lKQUpRT2t3bGpNK2pjTUEwR0NTcUdTSWIzRFFFQkJRVU
       FNRFF4Q3pBSkJnTlYKQkFZVEFsVlRNUkF3RGdZRFZRUUtFd2RsZUd
       GdGNHeGxNUk13RVFZRFZRUURFd3BEVWt3Z1NYTnpkV1Z5TUI0WApE
       diR1V4RXpBUkJnTlZCQU1UQ2tOU1RDQkpjM04xWlhJd2daOHdEUVl
       KS29aSWh2Y04KQVFFQkJRQURnWTBBTUlHSkFvR0JBTXVvZmFPNEV3
       El1QWMrQ1RsTkNmc0d6cEw1Um5ydXZsOFRIcUJTdGZQY3N0Zk1KT1
       FaNzlnNlNWVldsMldzaHE1bUViCkJNNitGNzdjbTAvU25FcFE0TnV
       bXBDT2YKQWdNQkFBR2pnYXd3Z2Frd0hRWURWUjBPQkJZRUZKY1o2W
       URiR0lPNDB4ajlPb3JtREdsRUNCVTFNR1FHQTFVZApJd1JkTUZ1QU
       ZKY1o2WURiR0lPNDB4ajlPb3JtREdsRUNCVTFvVGlrTmpBME1Rc3d
       mMKTUE0R0ExVWREd0VCL3dRRUF3SUNCREFTQmdOVkhSTUJBZjhFQ0
       RBR0FRSC9BZ0VBTUEwR0NTcUdTSWIzRFFFQgpCUVVBQTRHQkFMMmx
       rWmFGNWcyaGR6MVNhZnZPbnBneHA4eG00SHRhbStadHpLazFlS3Bx
       TXp4YXJCbFpDSHlLCklVbC9GVzRtV1RQS1VDeEtFTE40NEY2Zmk2d
       c4d0tSSElkYW1WL0pGTmlQS0VXSTF4K1I1aDZmazcrQzQ1QXg1RWV
       SWHgzZjdVM2xZTgotLS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
     </certificate-signing-request>
  </rpc-reply>
```

The following example illustrates what a fully configured keychain object might look like. The private-key shown below is consistent with the generate-private-key and generate-certificate-signing-request examples above. This example also assumes that the resulting CA-signed certificate has been configured back onto the server. Lastly, this example shows that three lists of trusted certificates having been configured.

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

```
    <!-- private keys and associated certificates -->
    <private-keys>
      <private-key>
        <name>ex-key-sect571r1</name>
        <algorithm>sect571r1</algorithm>
        <public-key>
          cztvaWRoc2RmZ2tqaHNkZmdramRzZnZzZGtmam5idnNvO2RmanZvO3NkZ
          mJpdmhzZGZpbHVidjtvc2lkZmhidml1bHNkYmZ2aXNiZGZpYmhzZG87Zm
          JvO3NkZ25iO29pLmR6Zgo=
        </public-key>
        <certificates>
          <certificate>
            <name>ex-key-sect571r1-cert</name>
            <data>
              LS0tLS1CRUdJTiBDRVJUSUZJQ0FURS0tLS0tCk1JSUNrekNDQWZ5Z
              0F3SUJBZ0lKQUpRT2t3bGpNK2pjTUEwR0NTcUdTSWIzRFFFQkJRVU
              FNRFF4Q3pBSkJnTlYKQkFZVEFsVlRNUkF3RGdZRFZRUUtFd2RsZUd
              GdGNHeGxNUk13RVFZRFZRUURFd3BEVWt3Z1NYTnpkV1Z5TUI0WApE
              diR1V4RXpBUkJnTlZCQU1UQ2tOU1RDQkpjM04xWlhJd2daOHdEUVl
              KS29aSWh2Y04KQVFFQkJRQURnWTBBTUlHSkFvR0JBTXVvZmFPNEV3
              El1QWMrQ1RsTkNmc0d6cEw1Um5ydXZsOFRIcUJTdGZQY3N0Zk1KT1
              FaNzlnNlNWVldsMldzaHE1bUViCkJNNitGNzdjbTAvU25FcFE0TnV
              bXBDT2YKQWdNQkFBR2pnYXd3Z2Frd0hRWURWUjBPQkJZRUZKY1o2W
              URiR0lPNDB4ajlPb3JtREdsRUNCVTFNR1FHQTFVZApJd1JkTUZ1QU
              ZKY1o2WURiR0lPNDB4ajlPb3JtREdsRUNCVTFvVGlrTmpBME1Rc3d
              mMKTUE0R0ExVWREd0VCL3dRRUF3SUNCREFTQmdOVkhSTUJBZjhFQ0
              RBR0FRSC9BZ0VBTUEwR0NTcUdTSWIzRFFFQgpCUVVBQTRHQkFMMmx
              rWmFGNWcyaGR6MVNhZnZPbnBneHA4eG00SHRhbStadHpLazFlS3Bx
              TXp4YXJCbFpDSHlLCklVbC9GVzRtV1RQS1VDeEtFTE40NEY2Zmk2d
              c4d0tSSElkYW1WL0pGTmlQS0VXSTF4K1I1aDZmazcrQzQ1QXg1RWV
              SWHgzZjdVM2xZTgotLS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
            </data>
          </certificate>
        </certificates>
      </private-key>
    </private-keys>

    <!-- trusted netconf/restconf client certificates -->
    <trusted-certificates>
      <name>explicitly-trusted-client-certs</name>
      <description>
        Specific client authentication certificates that are to be
        explicitly trusted NETCONF/RESTCONF clients.  These are
        needed for client certificates not signed by our CA.
      </description>
      <trusted-certificate>
        <name>George Jetson</name>
        <certificate>
```

```
          QmdOVkJBWVRBbFZUTVJBd0RnWURWUVFLRXdkbAplR0Z0Y0d4bE1RNHdEQ
          MkF6a3hqUDlVQWtHR0dvS1U1eUc1SVR0Wm0vK3B0R2FieXVDMjBRd2kvZ
          25PZnpZNEhONApXY0pTaUpZK2xtYWs3RTRORUZXZS9RdGp4NUlXZmdvN2
          RV0JCU2t2MXI2SFNHeUFUVkpwSmYyOWtXbUU0NEo5akJrQmdOVkhTTUVY
          VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER
          UxNQWtHQTFVRUJoTUNWVk14RURBT0JnTlZCQW9UQjJWNApZVzF3YkdVeE
          V6QVJCZ05WQkFNVENrTlNUQ0JKYzNOMVpYS0NDUUNVRHBNSll6UG8zREF
          NQmdOVkhSTUJBZjhFCkFqQUFNQTRHQTFVZER3RUIvd1FFQXdJSGdEQnBC
          Z05WSFI4RVlqQmdNRjZnSXFBZ2hoNW9kSFJ3T2k4dlpYaGgKYlhCc1pTN
          WpiMjB2WlhoaGJYQnNaUzVqY215aU9LUTJNRFF4Q3pBSkJnTlZCQVlUQW
          xWVE1SQXdEZ1lEVlFRSwpFd2RsZUdGdGNHeGxNUk13RVFZRFZRUURFd3B
          EVWt3Z1NYTnpkV1Z5TUEwR0NTcUdTSWIzRFFFQkJRVUFBNEdCCkFFc3BK
          WmdsK2gyTTg3QmtGMjhWbW1CdFFVaWc3OEgrRkYyRTFwdSt4ZVRJbVFFM
          TQzcjFZSjk0M1FQLzV5eGUKN2QxMkxCV0dxUjUrbEl5N01YL21ka2M4al
          zSFNwSDdwVXBCYnA4dmtNanFtZjJma3RqZHBxeFppUUtTbndWZTF2Zwot
          LS0tLUVORCBDRVJUSUZJQ0FURS0tLS0tCg==
        </certificate>
      </trusted-certificate>
      <trusted-certificate>
        <name>Fred Flinstone</name>
        <certificate>
          VlEVlFRREV3Vm9ZWEJ3ZVRDQm56QU5CZ2txaGtpRzl3MEJBUUVGQUFPQm
          pRQXdnWWtDCmdZRUE1RzRFSWZsS1p2bDlXTW44eUhyM2hObUFRaUhVUzV
          rRUpPQy9hSFA3eGJXQW1ra054ZStUa2hrZnBsL3UKbVhsTjhSZUd1ODhG
          NGcEk3UE90cnNFVjRwTUNBd0VBQWFPQ0FSSXdnZ0VPCk1CMEdBMVVkRGd
          VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER
          V6QVJCZ05WQkFNVENrTlNUQ0JKYzNOMVpYS0NDUUNVRHBNSll6UG8zREF
          NQmdOVkhSTUJBZjhFCkFqQUFNQTRHQTFVZER3RUIvd1FFQXdJSGdEQnBC
          Z05WSFI4RVlqQmdNRjZnSXFBZ2hoNW9kSFJ3T2k4dlpYaGgKYlhCc1pTN
          WpiMjB2WlhoaGJYQnNaUzVqY215aU9LUTJNRFF4Q3pBSkJnTlZCQVlUQW
          xWVE1SQXdEZ1lEVlFRSwpFd2RsZUdGdGNHeGxNUk13RVFZRFZRUURFd3B
          EVWt3Z1NYTnpkV1Z5TUEwR0NTcUdTSWIzRFFFQkJRVUFBNEdCCkFFc3BK
          WmdsK2gyTTg3QmtGMjhWbW1CdFFVaWc3OEgrRkYyRTFwdSt4ZVRJbVFFM
          lLQllsdWpOcjFTMnRLR05EMUc2OVJpK2FWNGw2NTdZNCtadVJMZgpRYjk
          zSFNwSDdwVXBCYnA4dmtNanFtZjJma3RqZHBxeFppUUtTbndWZTF2Zwot
          QWtUOCBDRVUUZJ0RUF==
        </certificate>
      </trusted-certificate>
    </trusted-certificates>

    <!-- trust anchors for netconf/restconf clients -->
    <trusted-certificates>
      <name>deployment-specific-ca-certs</name>
      <description>
        Trust anchors used only to authenticate NETCONF/RESTCONF
        client connections.  Since our security policy only allows
        authentication for clients having a certificate signed by
        our CA, we only configure its certificate below.
```

```
      </description>
      <trusted-certificate>
        <name>ca.example.com</name>
        <certificate>
          WmdsK2gyTTg3QmtGMjhWbW1CdFFVaWc3OEgrRkYyRTFwdSt4ZVRJbVFFM
          lLQllsdWpOcjFTMnRLR05EMUc2OVJpK2FWNGw2NTdZNCtadVJMZgpRYjk
          zSFNwSDdwVXBCYnA4dmtNanFtZjJma3RqZHBxeFppUUtTbndWZTF2Zwot
          NGcEk3UE90cnNFVjRwTUNBd0VBQWFPQ0FSSXdnZ0VPCk1CMEdBMVVkRGd
          VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER
          V6QVJCZ05WQkFNVENrTlNUQ0JKYzNOMVpYS0NDUUNVRHBNSll6UG8zREF
          NQmdOVkhSTUJBZjhFCkFqQUFNQTRHQTFVZER3RUIvd1FFQXdJSGdEQnBC
          Z05WSFI4RVlqQmdNRjZnSXFBZ2hoNW9kSFJ3T2k4dlpYaGgKYlhCc1pTN
          WpiMjB2WlhoaGJYQnNaUzVqY215aU9LUTJNRFF4Q3pBSkJnTlZCQVlUQW
          QmdOVkJBWVRBbFZUTVJBd0RnWURWUVFLRXdkbAplR0Z0Y0d4bE1RNHdEQ
          MkF6a3hqUDlVQWtHR0dvS1U1eUc1SVR0Wm0vK3B0R2FieXVDMjBRd2kvZ
          25PZnpZNEhONApXY0pTaUpZK2xtYWs3RTRORUZXZS9RdGp4NUlXZmdvN2
          RJSUJQFRStS0Cg==
        </certificate>
      </trusted-certificate>
    </trusted-certificates>

    <!-- trust anchors for random HTTPS servers on Internet -->
    <trusted-certificates>
      <name>common-ca-certs</name>
      <description>
        Trusted certificates to authenticate common HTTPS servers.
        These certificates are similar to those that might be
        shipped with a web browser.
      </description>
      <trusted-certificate>
        <name>ex-certificate-authority</name>
        <certificate>
          NGcEk3UE90cnNFVjRwTUNBd0VBQWFPQ0FSSXdnZ0VPCk1CMEdBMVVkRGd
          VEJiZ0JTWEdlbUEKMnhpRHVOTVkvVHFLNWd4cFJBZ1ZOYUU0cERZd05ER
          V6QVJCZ05WQkFNVENrTlNUQ0JKYzNOMVpYS0NDUUNVRHBNSll6UG8zREF
          Z05WSFI4RVlqQmdNRjZnSXFBZ2hoNW9kSFJ3T2k4dlpYaGgKYlhCc1pTN
          QmdOVkJBWVRBbFZUTVJBd0RnWURWUVFLRXdkbAplR0Z0Y0d4bE1RNHdEQ
          MkF6a3hqUDlVQWtHR0dvS1U1eUc1SVR0Wm0vK3B0R2FieXVDMjBRd2kvZ
          NQmdOVkhSTUJBZjhFCkFqQUFNQTRHQTFVZER3RUIvd1FFQXdJSGdEQnBC
          WmdsK2gyTTg3QmtGMjhWbW1CdFFVaWc3OEgrRkYyRTFwdSt4ZVRJbVFFM
          lLQllsdWpOcjFTMnRLR05EMUc2OVJpK2FWNGw2NTdZNCtadVJMZgpRYjk
          zSFNwSDdwVXBCYnA4dmtNanFtZjJma3RqZHBxeFppUUtTbndWZTF2Zwot
          25PZnpZNEhONApXY0pTaUpZK2xtYWs3RTRORUZXZS9RdGp4NUlXZmdvN2
          WpiMjB2WlhoaGJYQnNaUzVqY215aU9L=
        </certificate>
      </trusted-certificate>
    </trusted-certificates>
```

```
   </keychain>
```

4.1.3. YANG Model

```
   <CODE BEGINS> file "ietf-keychain@2015-10-09.yang"

   module ietf-keychain {
     yang-version 1.1;

     namespace "urn:ietf:params:xml:ns:yang:ietf-keychain";
     prefix "kc";

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

     contact
      "WG Web:   <http://tools.ietf.org/wg/netconf/>
       WG List:  <mailto:netconf@ietf.org>

       WG Chair: Mehmet Ersue
                 <mailto:mehmet.ersue@nsn.com>

       WG Chair: Mahesh Jethanandani
                 <mailto:mjethanandani@gmail.com>

       Editor:   Kent Watsen
                 <mailto:kwatsen@juniper.net>";


     description
      "This module defines a keychain to centralize management of
       security credentials.

       Copyright (c) 2014 IETF Trust and the persons identified as
       authors of the code. All rights reserved.

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

       This version of this YANG module is part of RFC VVVV; see
       the RFC itself for full legal notices.";

     revision "2015-10-09" {
```

```
      description
       "Initial version";
      reference
       "RFC VVVV: NETCONF Server and RESTCONF Server Configuration
                  Models";
    }

    container keychain {
      description
        "A list of private-keys and their associated certificates, as
         well as lists of trusted certificates for client certificate
         authentication.  RPCs are provided to generate a new private
         key and to generate a certificate signing requests.";

      container private-keys {
        description
          "A list of private key maintained by the keychain.";
        list private-key {
          key name;
          description
            "A private key.";
          leaf name {
            type string;
            description
              "An arbitrary name for the private key.";
          }
          leaf algorithm {
            type enumeration {
              enum rsa { description "TBD"; }
              enum dsa { description "TBD"; }
              enum secp192r1 { description "TBD"; }
              enum sect163k1 { description "TBD"; }
              enum sect163r2 { description "TBD"; }
              enum secp224r1 { description "TBD"; }
              enum sect233k1 { description "TBD"; }
              enum sect233r1 { description "TBD"; }
              enum secp256r1 { description "TBD"; }
              enum sect283k1 { description "TBD"; }
              enum sect283r1 { description "TBD"; }
              enum secp384r1 { description "TBD"; }
              enum sect409k1 { description "TBD"; }
              enum sect409r1 { description "TBD"; }
              enum secp521r1 { description "TBD"; }
              enum sect571k1 { description "TBD"; }
              enum sect571r1 { description "TBD"; }
            }
            config false;
            description
```

```
            "The algorithm used by the private key.";
          }
          leaf key-length {
            type uint32;
            config false;
            description
              "The key-length used by the private key.";
          }
          leaf public-key {
            type string;
            config false;
            description
              "The public-key matching the private key.";
          }
          container certificates {
            list certificate {
              key name;
              description
                "A certificate for this public key.";
              leaf name {
                type string;
                description
                  "An arbitrary name for the certificate.";
              }
              leaf chain {
                type binary;
                description
                  "The certificate itself, as well as an ordered
                   sequence of intermediate certificates leading
                   to a trust anchor, as specified by RFC 5246,
                   Section 7.4.2.";
                reference
                  "RFC 5246: The Transport Layer Security (TLS)
                              Protocol Version 1.2";
              }
            }
            description
              "A list of certificates for this public key.";
          }
          action generate-certificate-signing-request {
            description
              "Generates a certificate signing request structure for
               the associated private key using the passed subject
               and attribute values.";
            input {
              leaf subject {
                type binary;
                mandatory true;
```

```
            description
              "The distinguished name of the certificate subject
               (the entity whose public key is to be certified).
               This field is encoded the same as the 'subject'
               field in the CertificationRequestInfo type defined
               in RFC 2986, Section 4.1.";
            reference
              "RFC 2986: PKCS #10: Certification Request Syntax
                         Specification Version 1.7";
          }
          leaf attributes {
            type binary;
            description
              "A collection of attributes providing additional
               information about the subject of the certificate.
               This field is encoded the same as the 'attributes'
               field  in the CertificationRequestInfo type defined
               in RFC 2986, Section 4.1.";
            reference
              "RFC 2986: PKCS #10: Certification Request Syntax
                         Specification Version 1.7";
          }
        }
        output {
          leaf certificate-signing-request {
            type binary;
            mandatory true;
            description
              "The certificate signing request to be signed by
               a certificate authority.  This field is encoded
               as the CertificationRequest type defined in
               RFC 2986, Section 4.2.";
            reference
              "RFC 2986: PKCS #10: Certification Request Syntax
                         Specification Version 1.7";
          }
        }
      }
    }
    action generate-private-key {
      description
        "Generates a private key using the specified algorithm and
         key length.";
      input {
        leaf name {
          type string;
          mandatory true;
          description
```

```
                "The name this private-key should have when listed
                 in /keychain/private-keys.  As such, the passed
                 value must not match any existing 'name' value.";
            }
            leaf algorithm {
              type enumeration {
                enum rsa { description "TBD"; }
                enum dsa { description "TBD"; }
                enum secp192r1 { description "TBD"; }
                enum sect163k1 { description "TBD"; }
                enum sect163r2 { description "TBD"; }
                enum secp224r1 { description "TBD"; }
                enum sect233k1 { description "TBD"; }
                enum sect233r1 { description "TBD"; }
                enum secp256r1 { description "TBD"; }
                enum sect283k1 { description "TBD"; }
                enum sect283r1 { description "TBD"; }
                enum secp384r1 { description "TBD"; }
                enum sect409k1 { description "TBD"; }
                enum sect409r1 { description "TBD"; }
                enum secp521r1 { description "TBD"; }
                enum sect571k1 { description "TBD"; }
                enum sect571r1 { description "TBD"; }
              }
              mandatory true;
              description
                "The algorithm to be used.";
            }
            leaf key-length {
              type uint32;
              description
                "For algorithms that need a key length specified
                 when generating the key.";
            }
          }
        }
      }

      list trusted-certificates {
        key name;
        description
          "A list of lists of trusted certificates.";
        leaf name {
          type string;
          description
            "An arbitrary name for this list of trusted
             certificates.";
        }
```

```
        leaf description {
          type string;
          description
            "An arbitrary description for this list of trusted
             certificates.";
        }
        list trusted-certificate {
          key name;
          description
            "A list of trusted certificates for a specific use.";
          leaf name {
            type string;
            description
              "An arbitrary name for this trusted certificate.";
          }
          leaf certificate {
            type binary;
            description
              "The binary certificate structure as specified by RFC
               5246, Section 7.4.6, i.e.,: opaque ASN.1Cert<1..2^24>;
              ";
            reference
              "RFC 5246: The Transport Layer Security (TLS)
                         Protocol Version 1.2";
          }
        }
      }
    }
  }
```

<CODE ENDS>

4.2. The SSH Server Model

The SSH Server model presented in this section presents two YANG groupings, one for a server that opens a socket to accept TCP connections on, and another for a server that has had the TCP connection opened for it already (e.g., inetd).

The SSH Server model (like the TLS Server model presented below) is provided as a grouping so that it can be used in different contexts. For instance, the NETCONF Server model presented in Section 4.4 uses one grouping to configure a NETCONF server listening for connections and the other grouping to configure NETCONF call home.

A shared characteristic between both groupings is the ability to configure which host key is presented to clients, the private key for

which is held in the keychain configuration presented before. Another shared characteristic is the ability to configure which trusted CA or client certificates the server should be used to authenticate clients when using X.509 based client certificates [RFC6187].

4.2.1. Tree Diagram

The following tree diagram represents the data model for the grouping used to configure an SSH server to listen for TCP connections. The tree diagram for the other grouping is not provided, but it is the same except without the "address" and "port" fields.

NOTE: the diagram below shows "listening-ssh-server" as a YANG container (not a grouping). This temporary container was created only to enable the `pyang` tool to output the tree diagram, as groupings by themselves have no protocol accessible nodes, and hence `pyang` would output an empty tree diagram.

```
module: ietf-ssh-server
   +--rw listening-ssh-server
      +--rw address?            inet:ip-address
      +--rw port                inet:port-number
      +--rw host-keys
      |  +--rw host-key* [name]
      |     +--rw name           string
      |     +--rw (type)?
      |        +--:(public-key)
      |        |  +--rw public-key?    -> /kc:keychain/private-keys/pri
vate-key/name
      |        +--:(certificate)
      |           +--rw certificate?   -> /kc:keychain/private-keys/pri
vate-key/certificates/certificate/name {ssh-x509-certs}?
      +--rw client-cert-auth {ssh-x509-certs}?
         +--rw trusted-ca-certs?       -> /kc:keychain/trusted-certific
ates/name
         +--rw trusted-client-certs?   -> /kc:keychain/trusted-certific
ates/name
```

4.2.2. Example Usage

This section shows how it would appear if the temporary listening-ssh-server container just mentioned above were populated with some data. This example is consistent with the examples presented earlier in this document.

```
   <listening-ssh-server
     xmlns="urn:ietf:params:xml:ns:yang:ietf-ssh-server">
     <port>830</port>
     <host-keys>
       <host-key>
         <name>deployment-specific-certificate</name>
         <certificate>ex-key-sect571r1-cert</certificate>
       </host-key>
     </host-keys>
     </certificates>
     <client-cert-auth>
       <trusted-ca-certs>
         deployment-specific-ca-certs
       </trusted-ca-certs>
       <trusted-client-certs>
         explicitly-trusted-client-certs
       </trusted-client-certs>
     </client-cert-auth>
   </listening-ssh-server>
```

4.2.3. YANG Model

```
   <CODE BEGINS> file "ietf-ssh-server@2015-10-09.yang"

   module ietf-ssh-server {
     yang-version 1.1;

     namespace "urn:ietf:params:xml:ns:yang:ietf-ssh-server";
     prefix "ts";

     import ietf-inet-types {           // RFC 6991
       prefix inet;
     }
     import ietf-keychain {
       prefix kc;                       // RFC VVVV
       revision-date 2015-10-09;
     }

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

     contact
      "WG Web:   <http://tools.ietf.org/wg/netconf/>
       WG List:  <mailto:netconf@ietf.org>

       WG Chair: Mehmet Ersue
                 <mailto:mehmet.ersue@nsn.com>
```

```
       WG Chair: Mahesh Jethanandani
                 <mailto:mjethanandani@gmail.com>

       Editor:   Kent Watsen
                 <mailto:kwatsen@juniper.net>";


     description
      "This module defines a reusable grouping for a SSH server that
       can be used as a basis for specific SSH server instances.

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       authors of the code. All rights reserved.

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       License set forth in Section 4.c of the IETF Trust's
       Legal Provisions Relating to IETF Documents
       (http://trustee.ietf.org/license-info).

       This version of this YANG module is part of RFC VVVV; see
       the RFC itself for full legal notices.";

     revision "2015-10-09" {
       description
        "Initial version";
       reference
        "RFC VVVV: NETCONF Server and RESTCONF Server Configuration
                   Models";
     }

     // features
     feature ssh-x509-certs {
       description
         "The ssh-x509-certs feature indicates that the NETCONF
          server supports RFC 6187";
       reference
         "RFC 6187: X.509v3 Certificates for Secure Shell
          Authentication";
     }

     // grouping
     grouping non-listening-ssh-server-grouping {
       description
         "A reusable grouping for a SSH server that can be used as a
          basis for specific SSH server instances.";
```

```
      container host-keys {
        description
          "The list of host-keys the SSH server will present when
           establishing a SSH connection.";
        list host-key {
          key name;
          min-elements 1;
          ordered-by user;
          description
            "An ordered list of host keys the SSH server advertises
             when sending its ??? message.";
          reference
            "RFC ????: ...";
          leaf name {
            type string;
            mandatory true;
            description
              "An arbitrary name for this host-key";
          }
          choice type {
            description
              "The type of host key being specified";
            leaf public-key {
              type leafref {
                path "/kc:keychain/kc:private-keys/kc:private-key/"
                     + "kc:name";
              }
              description
                "The name of a private-key in the keychain.";
            }
            leaf certificate {
              if-feature ssh-x509-certs;
              type leafref {
                path "/kc:keychain/kc:private-keys/kc:private-key/"
                     + "kc:certificates/kc:certificate/kc:name";
              }
              description
                "The name of a certificate in the keychain.";
            }
          }
        }
      }

      container client-cert-auth {
        if-feature ssh-x509-certs;
        description
          "A reference to a list of trusted certificate authority (CA)
           certificates and a reference to a list of trusted client
```

```
           certificates.";
        leaf trusted-ca-certs {
          type leafref {
            path "/kc:keychain/kc:trusted-certificates/kc:name";
          }
          description
            "A reference to a list of certificate authority (CA)
             certificates used by the SSH server to authenticate
             SSH client certificates.";
        }

        leaf trusted-client-certs {
          type leafref {
            path "/kc:keychain/kc:trusted-certificates/kc:name";
          }
          description
            "A reference to a list of client certificates used by
             the SSH server to authenticate SSH client certificates.
             A clients certificate is authenticated if it is an
             exact match to a configured trusted client certificate.";
        }
      }
    }


    grouping listening-ssh-server-grouping {
      description
        "A reusable grouping for a SSH server that can be used as a
         basis for specific SSH server instances.";
      leaf address {
        type inet:ip-address;
        description
         "The IP address of the interface to listen on. The SSH
          server will listen on all interfaces if no value is
          specified.";
      }
      leaf port {
        type inet:port-number;
        mandatory true;  // will a default augmented in work?
        description
         "The local port number on this interface the SSH server
          listens on.";
      }
      uses non-listening-ssh-server-grouping;
    }

    // RFC Editor: please remove the following container block
    //             when publishing this document as an RFC.
```

```
    container listening-ssh-server {
      description
        "This container is only present to enable `pyang`
         tree diagram output, as a grouping by itself has
         no protocol accessible nodes to output.";

         uses listening-ssh-server-grouping;
    }


  }
```

<CODE ENDS>

4.3. The TLS Server Model

The TLS Server model presented in this section presents two YANG groupings, one for a server that opens a socket to accept TCP connections on, and another for a server that has had the TCP connection opened for it already (e.g., inetd).

The TLS Server model (like the SSH Server model presented above) is provided as a grouping so that it can be used in different contexts. For instance, the NETCONF Server model presented in Section 4.4 uses one grouping to configure a NETCONF server listening for connections and the other grouping to configure NETCONF call home.

A shared characteristic between both groupings is the ability to configure which server certificate is presented to clients, the private key for which is held in the keychain model presented in Section 4.1. Another shared characteristic is the ability to configure which trusted CA or client certificates the server should be used to authenticate clients.

4.3.1. Tree Diagram

The following tree diagram represents the data model for the grouping used to configure an TLS server to listen for TCP connections. The tree diagram for the other grouping is not provided, but it is the same except without the "address" and "port" fields.

NOTE: the diagram below shows "listening-ssh-server" as a YANG container (not a grouping). This temporary container was created only to enable the `pyang` tool to output the tree diagram, as groupings by themselves have no protocol accessible nodes, and hence `pyang` would output an empty tree diagram.

```
module: ietf-tls-server
   +--rw listening-tls-server
      +--rw address?        inet:ip-address
      +--rw port            inet:port-number
      +--rw certificates
      |  +--rw certificate* [name]
      |     +--rw name    -> /kc:keychain/private-keys/private-key/cert
ificates/certificate/name
      +--rw client-auth
         +--rw trusted-ca-certs?       -> /kc:keychain/trusted-certific
ates/name
         +--rw trusted-client-certs?   -> /kc:keychain/trusted-certific
ates/name
```

4.3.2. Example Usage

```
  <listening-tls-server
    xmlns="urn:ietf:params:xml:ns:yang:ietf-tls-server">
    <port>6513</port>
    <certificates>
      <certificate>
        <name>ex-key-sect571r1-cert</name>
      </certificate>
    </certificates>
    <client-auth>
      <trusted-ca-certs>
        deployment-specific-ca-certs
      </trusted-ca-certs>
      <trusted-client-certs>
        explicitly-trusted-client-certs
      </trusted-client-certs>
    </client-auth>
  </listening-tls-server>
```

4.3.3. YANG Model

```
  <CODE BEGINS> file "ietf-tls-server@2015-10-09.yang"

  module ietf-tls-server {
    yang-version 1.1;

    namespace "urn:ietf:params:xml:ns:yang:ietf-tls-server";
    prefix "ts";

    import ietf-inet-types {          // RFC 6991
      prefix inet;
    }
```

```
     import ietf-keychain {
       prefix kc;                        // RFC VVVV
       revision-date 2015-10-09;
     }

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

     contact
      "WG Web:   <http://tools.ietf.org/wg/netconf/>
       WG List:  <mailto:netconf@ietf.org>

       WG Chair: Mehmet Ersue
                 <mailto:mehmet.ersue@nsn.com>

       WG Chair: Mahesh Jethanandani
                 <mailto:mjethanandani@gmail.com>

       Editor:   Kent Watsen
                 <mailto:kwatsen@juniper.net>";


     description
      "This module defines a reusable grouping for a TLS server that
       can be used as a basis for specific TLS server instances.

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       authors of the code. All rights reserved.

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

       This version of this YANG module is part of RFC VVVV; see
       the RFC itself for full legal notices.";

     revision "2015-10-09" {
       description
        "Initial version";
       reference
        "RFC VVVV: NETCONF Server and RESTCONF Server Configuration
                   Models";
     }
```

```
     // grouping
     grouping non-listening-tls-server-grouping {
       description
         "A reusable grouping for a TLS server that can be used as a
          basis for specific TLS server instances.";
       container certificates {
         description
           "The list of certificates the TLS server will present when
            establishing a TLS connection.";
         list certificate {
           key name;
           min-elements 1;
           description
             "An unordered list of certificates the TLS server can pick
              from when sending its Server Certificate message.";
           reference
             "RFC 5246: The TLS Protocol, Section 7.4.2";
           leaf name {
             type leafref {
               path "/kc:keychain/kc:private-keys/kc:private-key/"
                    + "kc:certificates/kc:certificate/kc:name";
             }
             description
               "The name of the certificate in the keychain.";
           }
         }
       }

       container client-auth {
         description
           "A reference to a list of trusted certificate authority (CA)
            certificates and a reference to a list of trusted client
            certificates.";
         leaf trusted-ca-certs {
           type leafref {
             path "/kc:keychain/kc:trusted-certificates/kc:name";
           }
           description
             "A reference to a list of certificate authority (CA)
              certificates used by the TLS server to authenticate
              TLS client certificates.";
         }

         leaf trusted-client-certs {
           type leafref {
             path "/kc:keychain/kc:trusted-certificates/kc:name";
           }
           description
```

```
            "A reference to a list of client certificates used by
             the TLS server to authenticate TLS client certificates.
             A clients certificate is authenticated if it is an
             exact match to a configured trusted client certificate.";
        }
      }
    }


    grouping listening-tls-server-grouping {
      description
        "A reusable grouping for a TLS server that can be used as a
         basis for specific TLS server instances.";
      leaf address {
        type inet:ip-address;
        description
         "The IP address of the interface to listen on. The TLS
          server will listen on all interfaces if no value is
          specified.";
      }
      leaf port {
        type inet:port-number;
        mandatory true;  // will a default augmented in work?
        description
         "The local port number on this interface the TLTLS server
          listens on.";
      }
      uses non-listening-tls-server-grouping;
    }



    // RFC Editor: please remove the following container block
    //             when publishing this document as an RFC.
    container listening-tls-server {
      description
        "This container is only present to enable `pyang`
         tree diagram output, as a grouping by itself has
         no protocol accessible nodes to output.";

         uses listening-tls-server-grouping;
    }


  }
```

<CODE ENDS>

4.4. The NETCONF Server Model

The NETCONF Server model presented in this section supports servers both listening for connections to accept as well as initiating call-home connections. This model also supports both the SSH and TLS transport protocols, using the SSH Server and TLS Server groupings presented in Section 4.2 and Section 4.3 respectively. All private keys and trusted certificates are held in the keychain model presented in Section 4.1. YANG feature statements are used to enable implementations to advertise which parts of the model the NETCONF server supports.

4.4.1. Tree Diagram

The following tree diagram uses line-wrapping in order to comply with xml2rfc validation. This is annoying as I find that drafts (even txt drafts) look just fine with long lines - maybe xml2rfc should remove this warning? - or pyang could have an option to suppress printing leafref paths?

```
module: ietf-netconf-server
   +--rw netconf-server
      +--rw session-options
      |  +--rw hello-timeout?   uint16
      +--rw listen {(ssh-listen or tls-listen)}?
      |  +--rw max-sessions?   uint16
      |  +--rw idle-timeout?   uint16
      |  +--rw endpoint* [name]
      |     +--rw name    string
      |     +--rw (transport)
      |        +--:(ssh) {ssh-listen}?
      |        |  +--rw ssh
      |        |     +--rw address?            inet:ip-address
      |        |     +--rw port                inet:port-number
      |        |     +--rw host-keys
      |        |     |  +--rw host-key* [name]
      |        |     |     +--rw name           string
      |        |     |     +--rw (type)?
      |        |     |        +--:(public-key)
      |        |     |        |  +--rw public-key?    -> /kc:keychain/p
rivate-keys/private-key/name
      |        |     |        +--:(certificate)
      |        |     |           +--rw certificate?   -> /kc:keychain/p
rivate-keys/private-key/certificates/certificate/name {ssh-x509-certs}?
      |        |     +--rw client-cert-auth {ssh-x509-certs}?
      |        |        +--rw trusted-ca-certs?       -> /kc:keychain/t
```

```
 rusted-certificates/name
       |        |        +--rw trusted-client-certs?   -> /kc:keychain/t
 rusted-certificates/name
       |        +--:(tls) {tls-listen}?
       |           +--rw tls
       |              +--rw address?        inet:ip-address
       |              +--rw port            inet:port-number
       |              +--rw certificates
       |              |  +--rw certificate* [name]
       |              |     +--rw name    -> /kc:keychain/private-keys/p
 rivate-key/certificates/certificate/name
       |              +--rw client-auth
       |                 +--rw trusted-ca-certs?       -> /kc:keychain/t
 rusted-certificates/name
       |                 +--rw trusted-client-certs?   -> /kc:keychain/t
 rusted-certificates/name
       |                 +--rw cert-maps
       |                    +--rw cert-to-name* [id]
       |                       +--rw id             uint32
       |                       +--rw fingerprint    x509c2n:tls-fingerpr
 int
       |                       +--rw map-type       identityref
       |                       +--rw name           string
       +--rw call-home {(ssh-call-home or tls-call-home)}?
          +--rw netconf-client* [name]
             +--rw name                  string
             +--rw (transport)
             |  +--:(ssh) {ssh-call-home}?
             |  |  +--rw ssh
             |  |     +--rw endpoints
             |  |     |  +--rw endpoint* [name]
             |  |     |     +--rw name       string
             |  |     |     +--rw address    inet:host
             |  |     |     +--rw port?      inet:port-number
             |  |     +--rw host-keys
             |  |     |  +--rw host-key* [name]
             |  |     |     +--rw name           string
             |  |     |     +--rw (type)?
             |  |     |        +--:(public-key)
             |  |     |        |  +--rw public-key?    -> /kc:keychain/p
 rivate-keys/private-key/name
             |  |     |        +--:(certificate)
             |  |     |           +--rw certificate?   -> /kc:keychain/p
 rivate-keys/private-key/certificates/certificate/name {ssh-x509-certs}?
             |  |     +--rw client-cert-auth {ssh-x509-certs}?
             |  |        +--rw trusted-ca-certs?       -> /kc:keychain/t
 rusted-certificates/name
             |  |        +--rw trusted-client-certs?   -> /kc:keychain/t
```

```
 rusted-certificates/name
             |  +--:(tls) {tls-call-home}?
             |     +--rw tls
             |        +--rw endpoints
             |        |  +--rw endpoint* [name]
             |        |     +--rw name       string
             |        |     +--rw address    inet:host
             |        |     +--rw port?      inet:port-number
             |        +--rw certificates
             |        |  +--rw certificate* [name]
             |        |     +--rw name    -> /kc:keychain/private-keys/p
 rivate-key/certificates/certificate/name
             |        +--rw client-auth
             |           +--rw trusted-ca-certs?       -> /kc:keychain/t
 rusted-certificates/name
             |           +--rw trusted-client-certs?   -> /kc:keychain/t
 rusted-certificates/name
             |           +--rw cert-maps
             |              +--rw cert-to-name* [id]
             |                 +--rw id             uint32
             |                 +--rw fingerprint    x509c2n:tls-fingerpr
 int
             |                 +--rw map-type       identityref
             |                 +--rw name           string
             +--rw connection-type
             |  +--rw (connection-type)?
             |     +--:(persistent-connection)
             |     |  +--rw persistent!
             |     |     +--rw idle-timeout?   uint32
             |     |     +--rw keep-alives
             |     |        +--rw max-wait?       uint16
             |     |        +--rw max-attempts?   uint8
             |     +--:(periodic-connection)
             |        +--rw periodic!
             |           +--rw idle-timeout?        uint16
             |           +--rw reconnect_timeout?   uint16
             +--rw reconnect-strategy
                +--rw start-with?     enumeration
                +--rw max-attempts?   uint8
```

4.4.2. Example Usage

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 other examples presented in this document.

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

    <!-- listening for SSH connections -->
    <endpoint>
      <name>netconf/ssh</name>
      <ssh>
        <address>11.22.33.44</address>
        <host-keys>
          <host-key>
            <public-key>my-rsa-key</public-key>
          </host-key>
          <host-key>
            <certificate>TPM key</certificate>
          </host-key>
        </host-keys>
        <client-cert-auth>
          <trusted-ca-certs>
            deployment-specific-ca-certs
          </trusted-ca-certs>
          <trusted-client-certs>
            explicitly-trusted-client-certs
          </trusted-client-certs>
        </client-cert-auth>
      </ssh>
    </endpoint>

    <!-- listening for TLS connections -->
    <endpoint>
      <name>netconf/tls</name>
      <tls>
        <address>11.22.33.44</address>
        <certificates>
          <certificate>ex-key-sect571r1-cert</certificate>
        </certificates>
        <client-auth>
          <trusted-ca-certs>
            deployment-specific-ca-certs
          </trusted-ca-certs>
          <trusted-client-certs>
            explicitly-trusted-client-certs
          </trusted-client-certs>
          <cert-maps>
            <cert-to-name>
```

```
                <id>1</id>
                <fingerprint>11:0A:05:11:00</fingerprint>
                <map-type>x509c2n:san-any</map-type>
              </cert-to-name>
              <cert-to-name>
                <id>2</id>
                <fingerprint>B3:4F:A1:8C:54</fingerprint>
                <map-type>x509c2n:specified</map-type>
                <name>scooby-doo</name>
              </cert-to-name>
            </cert-maps>
          </client-auth>
        </tls>
      </endpoint>

    </listen>
    <call-home>

      <!-- calling home to an SSH-based NETCONF client -->
      <netconf-client>
        <name>config-mgr</name>
        <ssh>
          <endpoints>
            <endpoint>
              <name>east-data-center</name>
              <address>11.22.33.44</address>
            </endpoint>
            <endpoint>
              <name>west-data-center</name>
              <address>55.66.77.88</address>
            </endpoint>
          </endpoints>
          <host-keys>
            <host-key>
              <certificate>TPM key</certificate>
            </host-key>
          </host-keys>
          <client-cert-auth>
            <trusted-ca-certs>
              deployment-specific-ca-certs
            </trusted-ca-certs>
            <trusted-client-certs>
              explicitly-trusted-client-certs
            </trusted-client-certs>
          </client-cert-auth>
        </ssh>
        <connection-type>
          <periodic>
```

```
            <idle-timeout>300</idle-timeout>
            <reconnect-timeout>60</reconnect-timeout>
          </periodic>
        </connection-type>
        <reconnect-strategy>
          <start-with>last-connected</start-with>
          <max-attempts>3</max-attempts>
        </reconnect-strategy>
      </netconf-client>

      <!-- calling home to a TLS-based NETCONF client -->
      <netconf-client>
        <name>event-correlator</name>
        <tls>
          <endpoints>
            <endpoint>
              <name>east-data-center</name>
              <address>22.33.44.55</address>
            </endpoint>
            <endpoint>
              <name>west-data-center</name>
              <address>33.44.55.66</address>
            </endpoint>
          </endpoints>
          <certificates>
            <certificate>ex-key-sect571r1-cert</certificate>
          </certificates>
          <client-auth>
            <trusted-ca-certs>
              deployment-specific-ca-certs
            </trusted-ca-certs>
            <trusted-client-certs>
              explicitly-trusted-client-certs
            </trusted-client-certs>
            <cert-maps>
              <cert-to-name>
                <id>1</id>
                <fingerprint>11:0A:05:11:00</fingerprint>
                <map-type>x509c2n:san-any</map-type>
              </cert-to-name>
              <cert-to-name>
                <id>2</id>
                <fingerprint>B3:4F:A1:8C:54</fingerprint>
                <map-type>x509c2n:specified</map-type>
                <name>scooby-doo</name>
              </cert-to-name>
            </cert-maps>
          </client-auth>
```

```
        </tls>
        <connection-type>
          <persistent>
            <idle-timeout>300</idle-timeout>
            <keep-alives>
              <max-wait>30</max-wait>
              <max-attempts>3</max-attempts>
            </keep-alives>
          </persistent>
        </connection-type>
        <reconnect-strategy>
          <start-with>first-listed</start-with>
          <max-attempts>3</max-attempts>
        </reconnect-strategy>
      </netconf-client>

    </call-home>
  </netconf-server>
```

4.4.3. YANG Model

This YANG module imports YANG types from [RFC6991] and [RFC7407].

```
<CODE BEGINS> file "ietf-netconf-server@2015-10-09.yang"

module ietf-netconf-server {
  yang-version 1.1;

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

  import ietf-inet-types {           // RFC 6991
    prefix inet;
  }
  import ietf-x509-cert-to-name {    // RFC 7407
    prefix x509c2n;
  }
  import ietf-ssh-server {           // RFC VVVV
    prefix ss;
    revision-date 2015-10-09;
  }
  import ietf-tls-server {           // RFC VVVV
    prefix ts;
    revision-date 2015-10-09;
  }
```

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

    contact
     "WG Web:   <http://tools.ietf.org/wg/netconf/>
      WG List:  <mailto:netconf@ietf.org>

      WG Chair: Mehmet Ersue
                <mailto:mehmet.ersue@nsn.com>

      WG Chair: Mahesh Jethanandani
                <mailto:mjethanandani@gmail.com>

      Editor:   Kent Watsen
                <mailto:kwatsen@juniper.net>";


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

      Copyright (c) 2014 IETF Trust and the persons identified as
      authors of the code. All rights reserved.

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

      This version of this YANG module is part of RFC VVVV; see
      the RFC itself for full legal notices.";

    revision "2015-10-09" {
      description
       "Initial version";
      reference
       "RFC VVVV: NETCONF Server and RESTCONF Server Configuration
                  Models";
    }


    // 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 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 YYYY: NETCONF Call Home and RESTCONF Call Home";
    }

    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 5539: Using the NETCONF Protocol over Transport
                  Layer Security (TLS) with Mutual X.509
                  Authentication";
    }

    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 YYYY: NETCONF Call Home and RESTCONF Call Home";
    }

    feature ssh-x509-certs {
      description
        "The ssh-x509-certs feature indicates that the NETCONF
         server supports RFC 6187";
      reference
        "RFC 6187: X.509v3 Certificates for Secure Shell
         Authentication";
    }


    // top-level container  (groupings below)
    container netconf-server {
      description
```

```
        "Top-level container for NETCONF server configuration.";

      container session-options {  // SHOULD WE REMOVE THIS ALTOGETHER?
        description
          "NETCONF session options, independent of transport
           or connection strategy.";
        leaf hello-timeout {
          type uint16;
          units "seconds";
          default 600;
          description
            "Specifies the maximum number of seconds that a SSH/TLS
             connection may wait for a hello message to be received.
             A connection will be dropped if no hello message is
             received before this number of seconds elapses.  If set
             to zero, then the server will wait forever for a hello
             message.";
        }
      }

      container listen {
        if-feature "(ssh-listen or tls-listen)";
        description
          "Configures listen behavior";
        leaf max-sessions {
          type uint16;
          default 0;
          description
            "Specifies the maximum number of concurrent sessions
             that can be active at one time.  The value 0 indicates
             that no artificial session limit should be used.";
        }
        leaf idle-timeout {
          type uint16;
          units "seconds";
          default 3600; // one hour
          description
            "Specifies the maximum number of seconds that a NETCONF
             session may remain idle. A NETCONF session will be dropped
             if it is idle for an interval longer than this number of
             seconds.  If set to zero, then the server will never drop
             a session because it is idle.  Sessions that have a
             notification subscription active are never dropped.";
        }
        list endpoint {
          key name;
          description
            "List of endpoints to listen for NETCONF connections on.";
```

```
          leaf name {
            type string;
            description
              "An arbitrary name for the NETCONF listen endpoint.";
          }
          choice transport {
            mandatory true;
            description
              "Selects between available transports.";
            case ssh {
              if-feature ssh-listen;
              container ssh {
                description
                  "SSH-specific listening configuration for inbound
                   connections.";
                uses ss:listening-ssh-server-grouping {
                  refine port {
                    default 830;
                  }
                }
              }
            }
            case tls {
              if-feature tls-listen;
              container tls {
                description
                  "TLS-specific listening configuration for inbound
                   connections.";
                uses ts:listening-tls-server-grouping {
                  refine port {
                    default 6513;
                  }
                  augment "client-auth" {
                    description
                      "Augments in the cert-to-name structure.";
                    uses cert-maps-grouping;
                  }
                }
              }
            }
          }
        }
      }

      container call-home {
        if-feature "(ssh-call-home or tls-call-home)";
        description
          "Configures call-home behavior";
```

```
        list netconf-client {
          key name;
          description
            "List of NETCONF clients the NETCONF server is to initiate
             call-home connections to.";
          leaf name {
            type string;
            description
              "An arbitrary name for the remote NETCONF client.";
          }
          choice transport {
            mandatory true;
            description
              "Selects between available transports.";
            case ssh {
              if-feature ssh-call-home;
              container ssh {
                description
                  "Specifies SSH-specific call-home transport
                   configuration.";
                uses endpoints-container {
                  refine endpoints/endpoint/port {
                    default 7777;
                  }
                }
                uses ss:non-listening-ssh-server-grouping;
              }
            }
            case tls {
              if-feature tls-call-home;
              container tls {
                description
                  "Specifies TLS-specific call-home transport
                   configuration.";
                uses endpoints-container {
                  refine endpoints/endpoint/port {
                    default 8888;
                  }
                }
                uses ts:non-listening-tls-server-grouping {
                  augment "client-auth" {
                    description
                      "Augments in the cert-to-name structure.";
                    uses cert-maps-grouping;
                  }
                }
              }
            }
```

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

                    This connection type minimizes any NETCONF client
                    to NETCONF server data-transfer delay, albeit at
                    the expense of holding resources longer.";
                  leaf idle-timeout {
                    type uint32;
                    units "seconds";
                    default 86400;  // one day;
                    description
                      "Specifies the maximum number of seconds that a
                       a NETCONF session may remain idle. A NETCONF
                       session will be dropped if it is idle for an
                       interval longer than this number of seconds.
                       If set to zero, then the server will never drop
                       a session because it is idle.  Sessions that
                       have a notification subscription active are
                       never dropped.";
                  }
                  container keep-alives {
                    description
                      "Configures the keep-alive policy, to proactively
                       test the aliveness of the SSH/TLS client.  An
                       unresponsive SSH/TLS client will be dropped after
                       approximately max-attempts * max-wait seconds.";
                    reference
                      "RFC YYYY: NETCONF Call Home and RESTCONF Call
                       Home, Section 3.1, item S6";
                    leaf max-wait {
                      type uint16 {
                        range "1..max";
                      }
                      units seconds;
                      default 30;
```

```
                description
                 "Sets the amount of time in seconds after which
              if no data has been received from the SSH/TLS
              client, a SSH/TLS-level message will be sent
                       to test the aliveness of the SSH/TLS client.";
                }
                leaf max-attempts {
                  type uint8;
                  default 3;
                  description
                   "Sets the number of maximum number of sequential
                    keep-alive messages that can fail to obtain a
                    response from the SSH/TLS client before assuming
                    the SSH/TLS client is no longer alive.";
                }
              }
            }
            case periodic-connection {
              container periodic {
                presence true;
                description
                 "Periodically connect to the NETCONF client, so that
                  the NETCONF client may deliver messages pending for
                  the NETCONF server.  The NETCONF client is expected
                  to close the connection when it is ready to release
                  it, thus starting the NETCONF server's timer until
                  next connection.";
                leaf idle-timeout {
                  type uint16;
                  units "seconds";
                  default 300; // five minutes
                  description
                    "Specifies the maximum number of seconds that a
                     a NETCONF session may remain idle. A NETCONF
                     session will be dropped if it is idle for an
                     interval longer than this number of seconds.
                     If set to zero, then the server will never drop
                     a session because it is idle.  Sessions that
                     have a notification subscription active are
                     never dropped.";
                }
                leaf reconnect_timeout {
                  type uint16 {
                    range "1..max";
                  }
                  units minutes;
                  default 60;
```

```
                description
                 "Sets the maximum amount of unconnected time the
                  NETCONF server will wait before re-establishing
                  a connection to the NETCONF client.  The NETCONF
                  server may initiate a connection before this
                  time if desired (e.g., to deliver an event
                  notification message).";
              }
            }
          }
        }
      }
      container reconnect-strategy {
        description
         "The reconnection strategy guides how a NETCONF server
          reconnects to a NETCONF client, after discovering its
          connection to the client has dropped.  The NETCONF
          server starts with the specified endpoint and tries
          to connect to it max-attempts times before trying the
          next endpoint in the list (round robin).";
        leaf start-with {
          type enumeration {
            enum first-listed {
              description
                "Indicates that reconnections should start with
                 the first endpoint listed.";
            }
            enum last-connected {
              description
                "Indicates that reconnections should start with
                 the endpoint last connected to.  If no previous
                 connection has ever been established, then the
                 first endpoint configured is used.   NETCONF
                 servers SHOULD be able to remember the last
                 endpoint connected to across reboots.";
            }
          }
          default first-listed;
          description
           "Specifies which of the NETCONF client's endpoints the
            NETCONF server should start with when trying to connect
            to the NETCONF client.";
        }
        leaf max-attempts {
          type uint8 {
            range "1..max";
          }
          default 3;
```

```
            description
             "Specifies the number times the NETCONF server tries to
              connect to a specific endpoint before moving on to the
              next endpoint in the list (round robin).";
          }
        }
      }
    }
  }

  grouping cert-maps-grouping {
    description
      "A grouping that defines a container around the
       cert-to-name structure defined in RFC 7407.";
    container cert-maps {
      uses x509c2n:cert-to-name;
      description
       "The cert-maps container is used by a TLS-based NETCONF
        server to map the NETCONF client's presented X.509
        certificate to a NETCONF username.  If no matching and
        valid cert-to-name list entry can be found, then the
        NETCONF server MUST close the connection, and MUST NOT
        accept NETCONF messages over it.";
      reference
        "RFC WWWW: NETCONF over TLS, Section 7";
    }
  }

  grouping endpoints-container {
    description
      "This grouping is used by both the ssh and tls containers
       for call-home configurations.";
    container endpoints {
      description
        "Container for the list of endpoints.";
      list endpoint {
        key name;
        min-elements 1;
        ordered-by user;
        description
          "User-ordered list of endpoints for this NETCONF client.
           Defining more than one enables high-availability.";
        leaf name {
          type string;
          description
            "An arbitrary name for this endpoint.";
```

```
          }
          leaf address {
            type inet:host;
            mandatory true;
            description
             "The IP address or hostname of the endpoint.  If a
              hostname is configured and the DNS resolution results
              in more than one IP address, the NETCONF server
              will process the IP addresses as if they had been
              explicitly configured in place of the hostname.";
          }
          leaf port {
            type inet:port-number;
            description
             "The IP port for this endpoint. The NETCONF server will
              use the IANA-assigned well-known port if no value is
              specified.";
          }
        }
      }
    }

  }


  <CODE ENDS>
```

4.5. The RESTCONF Server Model

The RESTCONF Server model presented in this section supports servers both listening for connections to accept as well as initiating call-home connections. This model supports the TLS transport only, as RESTCONF only supports HTTPS, using the TLS Server groupings presented in Section 4.3. All private keys and trusted certificates are held in the keychain model presented in Section 4.1. YANG feature statements are used to enable implementations to advertise which parts of the model the RESTCONF server supports.

4.5.1. Tree Diagram

The following tree diagram uses line-wrapping in order to comply with xml2rfc validation. This is annoying as I find that drafts (even txt drafts) look just fine with long lines - maybe xml2rfc should remove this warning? - or pyang could have an option to suppress printing leafref paths?

```
 module: ietf-restconf-server
    +--rw restconf-server
```

```
      +--rw listen {tls-listen}?
      |  +--rw max-sessions?   uint16
      |  +--rw endpoint* [name]
      |     +--rw name    string
      |     +--rw (transport)
      |        +--:(tls) {tls-listen}?
      |           +--rw tls
      |              +--rw address?        inet:ip-address
      |              +--rw port            inet:port-number
      |              +--rw certificates
      |              |  +--rw certificate* [name]
      |              |     +--rw name    -> /kc:keychain/private-keys/p
rivate-key/certificates/certificate/name
      |              +--rw client-auth
      |                 +--rw trusted-ca-certs?       -> /kc:keychain/t
rusted-certificates/name
      |                 +--rw trusted-client-certs?   -> /kc:keychain/t
rusted-certificates/name
      |                 +--rw cert-maps
      |                    +--rw cert-to-name* [id]
      |                       +--rw id             uint32
      |                       +--rw fingerprint    x509c2n:tls-fingerpr
int
      |                       +--rw map-type       identityref
      |                       +--rw name           string
      +--rw call-home {tls-call-home}?
         +--rw restconf-client* [name]
            +--rw name                  string
            +--rw (transport)
            |  +--:(tls) {tls-call-home}?
            |     +--rw tls
            |        +--rw endpoints
            |        |  +--rw endpoint* [name]
            |        |     +--rw name       string
            |        |     +--rw address    inet:host
            |        |     +--rw port?      inet:port-number
            |        +--rw certificates
            |        |  +--rw certificate* [name]
            |        |     +--rw name    -> /kc:keychain/private-keys/p
rivate-key/certificates/certificate/name
            |        +--rw client-auth
            |           +--rw trusted-ca-certs?       -> /kc:keychain/t
rusted-certificates/name
            |           +--rw trusted-client-certs?   -> /kc:keychain/t
rusted-certificates/name
            |           +--rw cert-maps
            |              +--rw cert-to-name* [id]
            |                 +--rw id             uint32
```

```
            |                +--rw fingerprint    x509c2n:tls-fingerpr
 int
            |                +--rw map-type       identityref
            |                +--rw name           string
            +--rw connection-type
            |  +--rw (connection-type)?
            |     +--:(persistent-connection)
            |     |  +--rw persistent!
            |     |     +--rw keep-alives
            |     |        +--rw max-wait?       uint16
            |     |        +--rw max-attempts?   uint8
            |     +--:(periodic-connection)
            |        +--rw periodic!
            |           +--rw reconnect-timeout?   uint16
            +--rw reconnect-strategy
               +--rw start-with?     enumeration
               +--rw max-attempts?   uint8
```

4.5.2. Example Usage

Configuring a RESTCONF Server to listen for RESTCONF client connections, as well as configuring call-home to one RESTCONF client.

This example is consistent with other examples presented in this document.

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

  <!-- listening for TLS (HTTPS) connections -->
  <listen>
    <endpoint>
      <name>netconf/tls</name>
      <tls>
        <address>11.22.33.44</address>
        <certificates>
          <certificate>ex-key-sect571r1-cert</certificate>
        </certificates>
        <client-auth>
          <trusted-ca-certs>
            deployment-specific-ca-certs
          </trusted-ca-certs>
          <trusted-client-certs>
            explicitly-trusted-client-certs
          </trusted-client-certs>
          <cert-maps>
            <cert-to-name>
              <id>1</id>
```

```
                <fingerprint>11:0A:05:11:00</fingerprint>
                <map-type>x509c2n:san-any</map-type>
              </cert-to-name>
              <cert-to-name>
                <id>2</id>
                <fingerprint>B3:4F:A1:8C:54</fingerprint>
                <map-type>x509c2n:specified</map-type>
                <name>scooby-doo</name>
              </cert-to-name>
            </cert-maps>
          </client-auth>
        </tls>

      </endpoint>
    </listen>

    <!-- calling home to a RESTCONF client -->
    <call-home>
      <restconf-client>
        <name>config-manager</name>
        <tls>
          <endpoints>
            <endpoint>
              <name>east-data-center</name>
              <address>22.33.44.55</address>
            </endpoint>
            <endpoint>
              <name>west-data-center</name>
              <address>33.44.55.66</address>
            </endpoint>
          </endpoints>
          <certificates>
            <certificate>ex-key-sect571r1-cert</certificate>
          </certificates>
          <client-auth>
            <trusted-ca-certs>
              deployment-specific-ca-certs
            </trusted-ca-certs>
            <trusted-client-certs>
              explicitly-trusted-client-certs
            </trusted-client-certs>
            <cert-maps>
              <cert-to-name>
                <id>1</id>
                <fingerprint>11:0A:05:11:00</fingerprint>
                <map-type>x509c2n:san-any</map-type>
              </cert-to-name>
              <cert-to-name>
```

```
                <id>2</id>
                <fingerprint>B3:4F:A1:8C:54</fingerprint>
                <map-type>x509c2n:specified</map-type>
                <name>scooby-doo</name>
              </cert-to-name>
            </cert-maps>
          </client-auth>
        </tls>
        <connection-type>
          <periodic>
            <idle-timeout>300</idle-timeout>
            <reconnect-timeout>60</reconnect-timeout>
          </periodic>
        </connection-type>
        <reconnect-strategy>
          <start-with>last-connected</start-with>
          <max-attempts>3</max-attempts>
        </reconnect-strategy>
      </restconf-client>
    </call-home>

  </restconf-server>
```

4.5.3. YANG Model

This YANG module imports YANG types from [RFC6991] and [RFC7407].

```
<CODE BEGINS> file "ietf-restconf-server@2015-10-09.yang"

module ietf-restconf-server {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-restconf-server";
  prefix "rcserver";

  //import ietf-netconf-acm {
  //  prefix nacm;                    // RFC 6536
  //}
  import ietf-inet-types {           // RFC 6991
    prefix inet;
  }
  import ietf-x509-cert-to-name {    // RFC 7407
    prefix x509c2n;
  }
  import ietf-tls-server {           // RFC VVVV
    prefix ts;
    revision-date 2015-10-09;
```

```
  }

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

  contact
   "WG Web:   <http://tools.ietf.org/wg/netconf/>
    WG List:  <mailto:netconf@ietf.org>

    WG Chair: Mehmet Ersue
              <mailto:mehmet.ersue@nsn.com>

    WG Chair: Mahesh Jethanandani
              <mailto:mjethanandani@gmail.com>

    Editor:   Kent Watsen
              <mailto:kwatsen@juniper.net>";


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

    Copyright (c) 2014 IETF Trust and the persons identified as
    authors of the code. All rights reserved.

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

    This version of this YANG module is part of RFC VVVV; see
    the RFC itself for full legal notices.";

  revision "2015-10-09" {
    description
     "Initial version";
    reference
     "RFC VVVV: NETCONF Server and RESTCONF Server Configuration
                Models";
  }


  // Features

  feature tls-listen {
```

```
    description
     "The listen feature indicates that the RESTCONF server
      supports opening a port to listen for incoming RESTCONF
      client connections.";
    reference
     "RFC XXXX: RESTCONF Protocol";
  }

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

  feature client-cert-auth {
    description
     "The client-cert-auth feature indicates that the RESTCONF
      server supports the ClientCertificate authentication scheme.";
    reference
     "RFC ZZZZ: Client Authentication over New TLS Connection";
  }


  // top-level container
  container restconf-server {
    description
      "Top-level container for RESTCONF server configuration.";

    container listen {
      if-feature tls-listen;
      description
        "Configures listen behavior";
      leaf max-sessions {
        type uint16;
        default 0;   // should this be 'max'?
        description
          "Specifies the maximum number of concurrent sessions
           that can be active at one time.  The value 0 indicates
           that no artificial session limit should be used.";
      }
      list endpoint {
        key name;
        description
          "List of endpoints to listen for RESTCONF connections on.";
        leaf name {
          type string;
```

```
          description
            "An arbitrary name for the RESTCONF listen endpoint.";
        }
        choice transport {
          mandatory true;
          description
            "Selects between available transports.";
          case tls {
            if-feature tls-listen;
            container tls {
              description
                "TLS-specific listening configuration for inbound
                 connections.";
              uses ts:listening-tls-server-grouping {
                refine port {
                  default 443;
                }
                augment "client-auth" {
                  description
                    "Augments in the cert-to-name structure.";
                  uses cert-maps-grouping;
                }
              }
            }
          }
        }
      }
    }

    container call-home {
      if-feature tls-call-home;
      description
        "Configures call-home behavior";
      list restconf-client {
        key name;
        description
          "List of RESTCONF clients the RESTCONF server is to
           initiate call-home connections to.";
        leaf name {
          type string;
          description
            "An arbitrary name for the remote RESTCONF client.";
        }
        choice transport {
          mandatory true;
          description
            "Selects between TLS and any transports augmented in.";
          case tls {
```

```
            if-feature tls-call-home;
            container tls {
              description
                "Specifies TLS-specific call-home transport
                 configuration.";
              uses endpoints-container {
                refine endpoints/endpoint/port {
                  default 9999;
                }
              }
              uses ts:non-listening-tls-server-grouping {
                augment "client-auth" {
                  description
                    "Augments in the cert-to-name structure.";
                  uses cert-maps-grouping;
                }
              }
            }
          }
        }
        container connection-type {
          description
           "Indicates the RESTCONF client's preference for how the
            RESTCONF server's connection is maintained.";
          choice connection-type {
            description
              "Selects between available connection types.";
            case persistent-connection {
              container persistent {
                presence true;
                description
                 "Maintain a persistent connection to the RESTCONF
                  client. If the connection goes down, immediately
                  start trying to reconnect to it, using the
                  reconnection strategy.

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

                container keep-alives {
                  description
                    "Configures the keep-alive policy, to proactively
                     test the aliveness of the TLS client.  An
                     unresponsive TLS client will be dropped after
                     approximately (max-attempts * max-wait) seconds.";
                  reference
                    "RFC YYYY: NETCONF Call Home and RESTCONF Call Home,
```

```
                   Section 3.1, item S6";
                leaf max-wait {
                  type uint16 {
                    range "1..max";
                  }
                  units seconds;
                  default 30;
                  description
                   "Sets the amount of time in seconds after which
                    if no data has been received from the TLS
            client, a TLS-level message will be sent to
                    test the aliveness of the TLS client.";
                }
                leaf max-attempts {
                  type uint8;
                  default 3;
                  description
                   "Sets the number of sequential keep-alive messages
                    that can fail to obtain a response from the TLS
                    client before assuming the TLS client is no
                    longer alive.";
                }
              }
            }
          }
          case periodic-connection {
            container periodic {
              presence true;
              description
               "Periodically connect to the RESTCONF client, so that
                the RESTCONF client may deliver messages pending for
                the RESTCONF server.  The RESTCONF client is expected
                to close the connection when it is ready to release
                it, thus starting the RESTCONF server's timer until
                next connection.";
              leaf reconnect-timeout {
                type uint16 {
                  range "1..max";
                }
                units minutes;
                default 60;
                description
                 "The maximum amount of unconnected time the RESTCONF
                  server will wait before re-establishing a connection
                  to the RESTCONF client.  The RESTCONF server may
                  initiate a connection before this time if desired
                  (e.g., to deliver a notification).";
              }
```

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

```
  }


  grouping cert-maps-grouping {
    description
      "A grouping that defines a container around the
       cert-to-name structure defined in RFC 7407.";
    container cert-maps {
      uses x509c2n:cert-to-name;
      description
       "The cert-maps container is used by a TLS-based RESTCONF
        server to map the RESTCONF client's presented X.509
        certificate to a RESTCONF username.  If no matching and
        valid cert-to-name list entry can be found, then the
        RESTCONF server MUST close the connection, and MUST NOT
        accept RESTCONF messages over it.";
      reference
        "RFC XXXX: The RESTCONF Protocol";
    }
  }


  grouping endpoints-container {
    description
      "This grouping is used by tls container for call-home
       configurations.";
    container endpoints {
      description
        "Container for the list of endpoints.";
      list endpoint {
        key name;
        min-elements 1;
        ordered-by user;
        description
          "User-ordered list of endpoints for this RESTCONF client.
           Defining more than one enables high-availability.";
        leaf name {
          type string;
          description
            "An arbitrary name for this endpoint.";
        }
        leaf address {
          type inet:host;
          mandatory true;
          description
           "The IP address or hostname of the endpoint.  If a
            hostname is configured and the DNS resolution results
            in more than one IP address, the RESTCONF server
```

```
            will process the IP addresses as if they had been
            explicitly configured in place of the hostname.";
        }
        leaf port {
          type inet:port-number;
          description
           "The IP port for this endpoint. The RESTCONF server will
            use the IANA-assigned well-known port if no value is
            specified.";
        }
      }
    }
  }

}
```

<CODE ENDS>

5. Security Considerations

This section needs to be filled in...

6. IANA Considerations

This document registers two URIs in the IETF XML registry [RFC2119]. Following the format in [RFC3688], the following registrations are requested:

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

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

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

```
      name:         ietf-keychain
      namespace:    urn:ietf:params:xml:ns:yang:ietf-keychain
      prefix:       kc
      reference:    RFC VVVV

      name:         ietf-ssh-server
      namespace:    urn:ietf:params:xml:ns:yang:ietf-ssh-server
      prefix:       ssvr
      reference:    RFC VVVV

      name:         ietf-tls-server
      namespace:    urn:ietf:params:xml:ns:yang:ietf-tls-server
      prefix:       tsvr
      reference:    RFC VVVV

      name:         ietf-netconf-server
      namespace:    urn:ietf:params:xml:ns:yang:ietf-netconf-server
      prefix:       ncsvr
      reference:    RFC VVVV

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

7. Other Considerations

The YANG modules define herein do not themselves support virtual routing and forwarding (VRF). It is expected that external modules will augment in VRF designations when needed.

8. Acknowledgements

The authors would like to thank for following for lively discussions on list and in the halls (ordered by last name): Andy Bierman, Martin Bjorklund, Benoit Claise, Mehmet Ersue, David Lamparter, Alan Luchuk, Ladislav Lhotka, Radek Krejci, Tom Petch, Phil Shafer, and Bert Wijnen.

Juergen Schoenwaelder and was partly funded by Flamingo, a Network of Excellence project (ICT-318488) supported by the European Commission under its Seventh Framework Programme.

9. References

9.1. Normative References

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[RFC6020] Bjorklund, M., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, October 2010.

[RFC6187] Igoe, K. and D. Stebila, "X.509v3 Certificates for Secure Shell Authentication", RFC 6187, March 2011.

[RFC6241] Enns, R., Bjorklund, M., Schoenwaelder, J., and A. Bierman, "Network Configuration Protocol (NETCONF)", RFC 6241, June 2011.

[RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", RFC 6242, June 2011.

[RFC6991] Schoenwaelder, J., "Common YANG Data Types", RFC 6991, July 2013.

[RFC7407] Bjorklund, M. and J. Schoenwaelder, "A YANG Data Model for SNMP Configuration", RFC 7407, December 2014.

[RFC7589] Badra, M., Luchuk, A., and J. Schoenwaelder, "Using the NETCONF Protocol over Transport Layer Security (TLS) with Mutual X.509 Authentication", RFC 7589, June 2015.

[draft-ietf-netconf-call-home]
Watsen, K., "NETCONF Call Home and RESTCONF Call Home", draft-ieft-netconf-call-home-02 (work in progress), 2014.

[draft-ietf-netconf-restconf]
Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", draft-ieft-netconf-restconf-04 (work in progress), 2014.

9.2. Informative References

[RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, January 2004.

Appendix A. Change Log

A.1. 00 to 01

- Restructured document so it flows better
- Added trusted-ca-certs and trusted-client-certs objects into the ietf-system-tls-auth module

A.2. 01 to 02

- removed the "one-to-many" construct
- removed "address" as a key field
- removed "network-manager" terminology
- moved open issues to github issues
- brought TLS client auth back into model

A.3. 02 to 03

- fixed tree diagrams and surrounding text

A.4. 03 to 04

- reduced the number of grouping statements
- removed psk-maps and associated feature statements
- added ability for listen/call-home instances to specify which host-keys/certificates (of all listed) to use
- clarified that last-connected should span reboots
- added missing "objectives" for selecting which keys to use, authenticating client-certificates, and mapping authenticated client-certificates to usernames
- clarified indirect client certificate authentication
- added keep-alive configuration for listen connections
- added global-level NETCONF session parameters

A.5. 04 to 05

- Removed all refs to the old ietf-system-tls-auth module
- Removed YANG 1.1 style if-feature statements (loss some expressiveness)
- Removed the read-only (config false) lists of SSH host-keys and TLS certs
- Added an if-feature around session-options container
- Added ability to configure trust-anchors for SSH X.509 client certs
- Now imports by revision, per best practice
- Added support for RESTCONF server
- Added RFC Editor instructions

A.6. 05 to 06

- Removed feature statement on the session-options container (issue #21).
- Added NACM statements to YANG modules for sensitive nodes (issue #24).
- Fixed default RESTCONF server port value to be 443 (issue #26).
- Added client-cert-auth subtree to ietf-restconf-server module (issue #27).
- Updated draft-ietf-netmod-snmp-cfg reference to RFC 7407 (issue #28).
- Added description statements for groupings (issue #29).
- Added description for braces to tree diagram section (issue #30).
- Renamed feature from "rfc6187" to "ssh-x509-certs" (issue #31).

A.7. 06 to 07

- Replaced "application" with "NETCONF/RESTCONF client" (issue #32).
- Reverted back to YANG 1.1 if-feature statements (issue #34).

- Removed import by revisions (issue #36).
- Removed groupings only used once (issue #37).
- Removed upper-bound on hello-timeout, idle-timeout, and max-sessions (issue #38).
- Clarified that when no listen address is configured, the NETCONF/RESTCONF server will listen on all addresses (issue #41).
- Update keep-alive reference to new section in Call Home draft (issue #42).
- Modified connection-type/persistent/keep-alives/interval-secs default value, removed the connection-type/periodic/linger-secs node, and also removed the reconnect-strategy/interval-secs node (issue #43).
- Clarified how last-connected reconnection type should work across reboots (issue #44).
- Clarified how DNS-expanded hostnames should be processed (issue #45).
- Removed text on how to implement keep-alives (now in the call-home draft) and removed the keep-alive configuration for listen connections (issue #46).
- Clarified text for .../periodic-connection/timeout-mins (issue #47).
- Fixed description on the "trusted-ca-certs" leaf-list (issue #48).
- Added optional keychain-based solution in appendix A (issue #49).
- Fixed description text for the interval-secs leaf (issue #50).
- moved idle-time into the listen, persistent, and periodic subtrees (issue #51).
- put presence statements on containers where it makes sense (issue #53).

A.8. 07 to 08

- Per WG consensus, replaced body with the keychain-based approach described in -07's Appendix.

- Added a lot of introductory text, improved examples, and what not.

Appendix B. Open Issues

Please see: https://github.com/netconf-wg/server-model/issues.

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