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RESTCONF Client and Server Models
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Abstract

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

Editorial Note (To be removed by RFC Editor)

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

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

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

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

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

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

- o "2018-06-04" --> the publication date of this draft

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

- o Appendix A. Change Log

Status of This Memo

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

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1. Introduction

This document defines two YANG [RFC7950] modules, one module to configure a RESTCONF client and the other module to configure a RESTCONF server [RFC8040]. Both modules support the TLS [RFC5246] transport protocol with both standard RESTCONF and RESTCONF Call Home connections [RFC8071].

1.1. Terminology

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

2. The RESTCONF Client Model

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

This model, like that presented in [I-D.ietf-netconf-netconf-client-server], is designed to support any number of possible transports. RESTCONF only supports the TLS transport currently, thus this model only supports the TLS transport.

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

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


```

y-certificate-ref | ks:asymmetric-ke\
|
|   +---rw server-auth
|   |   +---rw pinned-ca-certs?
|   |   |   ta:pinned-certificates-ref
|   |   +---rw pinned-server-certs?
|   |   |   ta:pinned-certificates-ref
|   +---rw hello-params
|   |   {tls-client-hello-params-config}?
|   +---rw tls-versions
|   |   +---rw tls-version*    identityref
|   +---rw cipher-suites
|   |   +---rw cipher-suite*    identityref
+---rw 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
+---rw listen! {listen}?
|   +---rw idle-timeout?    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 client-identity
|   |   |   |   +---rw (auth-type)
|   |   |   |   |   +---:(certificate)
|   |   |   |   |   |   +---rw certificate
|   |   |   |   |   |   |   +---rw (local-or-keystore)
|   |   |   |   |   |   |   |   +---:(local)
|   |   |   |   |   |   |   |   |   +---rw algorithm
|   |   |   |   |   |   |   |   |   |   ct:key-algorithm-ref
|   |   |   |   |   |   |   |   +---rw public-key
|   |   |   |   |   |   |   |   |   binary
|   |   |   |   |   |   |   +---rw private-key

```

```

|         |         |         |         union
|         |         |         |         +---rw cert
|         |         |         |         |         ct:end-entity-cert-cms\
|         |         |         |         |
|         |         |         |         +---n certificate-expiration
|         |         |         |         |         +--- expiration-date?
|         |         |         |         |         |         yang:date-and-time
|         |         |         |         |         +---:(keystore)
|         |         |         |         |         |         {keystore-implemented}?
|         |         |         |         |         +---rw reference
|         |         |         |         |         |         ks:asymmetric-key-cert\
certificate-ref
+---rw server-auth
|   +---rw pinned-ca-certs?
|   |         ta:pinned-certificates-ref
|   +---rw pinned-server-certs?
|   |         ta:pinned-certificates-ref
+---rw hello-params
|   {tls-client-hello-params-config}?
+---rw tls-versions
|   +---rw tls-version*   identityref
+---rw cipher-suites
|   +---rw cipher-suite*   identityref

```

2.2. Example Usage

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

This example is consistent with the examples presented in Section 2.2 of [I-D.ietf-netconf-keystore].

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

```

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

  <!-- RESTCONF servers to initiate connections to -->
  <initiate>
    <restconf-server>
      <name>corp-fw1</name>
      <endpoints>
        <endpoint>
          <name>corp-fw1.example.com</name>
          <tls>
            <address>corp-fw1.example.com</address>
            <client-identity>

```

```

        <certificate>
          <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:i\
etf-crypto-types">ct:secp521r1</algorithm>
          <private-key>base64encodedvalue==</private-key>
          <public-key>base64encodedvalue==</public-key>
          <cert>base64encodedvalue==</cert>
        </certificate>
      </client-identity>
      <server-auth>
        <pinned-ca-certs>explicitly-trusted-server-ca-certs<\
/pinned-ca-certs>
        <pinned-server-certs>explicitly-trusted-server-certs\
</pinned-server-certs>
      </server-auth>
    </tls>
  </endpoint>
</endpoint>
  <name>corp-fw2.example.com</name>
  <tls>
    <address>corp-fw2.example.com</address>
    <client-identity>
      <certificate>
        <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:i\
etf-crypto-types">ct:secp521r1</algorithm>
        <private-key>base64encodedvalue==</private-key>
        <public-key>base64encodedvalue==</public-key>
        <cert>base64encodedvalue==</cert>
      </certificate>
    </client-identity>
    <server-auth>
      <pinned-ca-certs>explicitly-trusted-server-ca-certs<\
/pinned-ca-certs>
      <pinned-server-certs>explicitly-trusted-server-certs\
</pinned-server-certs>
    </server-auth>
  </tls>
</endpoint>
</endpoints>
</restconf-server>
</initiate>

<!-- endpoints to listen for RESTCONF Call Home connections on -->\
<listen>
  <endpoint>
    <name>Intranet-facing listener</name>
    <tls>
      <address>11.22.33.44</address>

```

```

    <client-identity>
      <certificate>
        <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-cr\
ypto-types">ct:secp521r1</algorithm>
        <private-key>base64encodedvalue==</private-key>
        <public-key>base64encodedvalue==</public-key>
        <cert>base64encodedvalue==</cert>
      </certificate>
    </client-identity>
    <server-auth>
      <pinned-ca-certs>explicitly-trusted-server-ca-certs</pinne\
d-ca-certs>
      <pinned-server-certs>explicitly-trusted-server-certs</pinn\
ed-server-certs>
    </server-auth>
  </tls>
</endpoint>
</listen>
</restconf-client>

```

2.3. YANG Module

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

```

<CODE BEGINS> file "ietf-restconf-client@2018-06-04.yang"
module ietf-restconf-client {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-restconf-client";
  prefix "rcc";

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

  import ietf-tls-client {
    prefix ts;
    revision-date 2018-06-04; // stable grouping definitions
    reference
      "RFC ZZZZ: YANG Groupings for TLS Clients and TLS Servers";
  }

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

```

contact

"WG Web: <<http://datatracker.ietf.org/wg/restconf/>>
WG List: <<mailto:restconf@ietf.org>>

Author: Kent Watsen
<<mailto:kwatsen@juniper.net>>

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

description

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

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

```
revision "2018-06-04" {  
  description  
    "Initial version";  
  reference  
    "RFC XXXX: RESTCONF Client and Server Models";  
}
```

```
// Features
```

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

```
feature tls-initiate {  
  if-feature initiate;  
  description  
    "The 'tls-initiate' feature indicates that the RESTCONF client
```

```
    supports initiating TLS connections to RESTCONF servers. This
    feature exists as TLS might not be a mandatory to implement
    transport in the future.";
  reference
    "RFC 8040: RESTCONF Protocol";
}

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

feature tls-listen {
  if-feature listen;
  description
    "The 'tls-listen' feature indicates that the RESTCONF client
    supports opening a port to listen for incoming RESTCONF
    server call-home TLS connections. This feature exists as
    TLS might not be a mandatory to implement transport in the
    future.";
  reference
    "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
}

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

grouping restconf-client {
  description
    "Top-level grouping for RESTCONF client configuration.";

  container initiate {
    if-feature initiate;
    presence "Enables client to initiate TCP connections";
    description
      "Configures client initiating underlying TCP connections.";
    list restconf-server {
      key name;
      min-elements 1;
      description
        "List of RESTCONF servers the RESTCONF client is to
        initiate connections to in parallel.";
    }
  }
}
```

```
leaf name {
  type string;
  description
    "An arbitrary name for the RESTCONF server.";
}
container endpoints {
  description
    "Container for the list of endpoints.";
  list endpoint {
    key name;
    min-elements 1;
    ordered-by user;
    description
      "A non-empty user-ordered list of endpoints for this
      RESTCONF client to try to connect to in sequence.
      Defining more than one enables high-availability.";
    leaf name {
      type string;
      description
        "An arbitrary name for this endpoint.";
    }
    choice transport {
      mandatory true;
      description
        "Selects between available transports. This is a
        'choice' statement so as to support additional
        transport options to be augmented in.";
      case tls {
        if-feature tls-initiate;
        container tls {
          description
            "Specifies TLS-specific transport
            configuration.";
          leaf address {
            type inet:host;
            mandatory true;
            description
              "The IP address or hostname of the endpoint.
              If a domain name is configured, then the
              DNS resolution should happen on each usage
              attempt. If the the DNS resolution results
              in multiple IP addresses, the IP addresses
              will be tried according to local preference
              order until a connection has been established
              or until all IP addresses have failed.";
          }
          leaf port {
            type inet:port-number;
```

```
        default 443;
        description
            "The IP port for this endpoint. The RESTCONF
            client will use the IANA-assigned well-known
            port for 'https' (443) if no value is
            specified.";
    }
    uses ts:tls-client-grouping {
        refine "client-identity/auth-type" {
            mandatory true;
            description
                "RESTCONF clients MUST pass some
                authentication credentials.";
        }
    }
} // end tls
} // end transport
container connection-type {
    description
        "Indicates the kind of connection to use.";
    choice connection-type {
        default persistent-connection;
        description
            "Selects between available connection types.";
        case persistent-connection {
            container persistent {
                presence
                    "Indicates that a persistent connection is
                    to be maintained.";
                description
                    "Maintain a persistent connection to the
                    RESTCONF server. If the connection goes down,
                    immediately start trying to reconnect to it,
                    using the reconnection strategy. This
                    connection type minimizes any RESTCONF server
                    to RESTCONF client data-transfer delay, albeit
                    at the expense of holding resources longer.";
            }
            leaf idle-timeout {
                type uint32;
                units "seconds";
                default 86400; // one day;
                description
                    "Specifies the maximum number of seconds
                    that the underlying TLS session may remain
                    idle. A TLS session will be dropped if it
                    is idle for an interval longer than this
                    number of seconds. If set to zero, then
```

```

        the client 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 TLS
            server.  An unresponsive TLS server will
            be dropped after approximately max-attempts
            * max-wait seconds.";
        reference
            "RFC 8071: 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 server, a TLS-level message will
                be sent to test the aliveness of the TLS
                server.";
        }
        leaf max-attempts {
            type uint8;
            default 3;
            description
                "Sets the maximum number of sequential
                keep-alive messages that can fail to
                obtain a response from the TLS server
                before assuming the TLS server is no
                longer alive.";
        }
    }
}
}
}
case periodic-connection {
    container periodic {
        presence
            "Indicates that a periodic connection is to be
            maintained.";
        description
            "Periodically connect to the RESTCONF server,
```

```
so that, e.g., the RESTCONF client can
collect data (logs) from the RESTCONF server.
Once the connection is closed, for whatever
reason, the RESTCONF client will restart its
timer until the next connection.";
leaf idle-timeout {
  type uint16;
  units "seconds";
  default 300; // five minutes
  description
    "Specifies the maximum number of seconds
    that the underlying TLS session may remain
    idle. A TLS 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.";
}
leaf reconnect-timeout {
  type uint16 {
    range "1..max";
  }
  units minutes;
  default 60;
  description
    "Sets the maximum amount of unconnected time
    the RESTCONF client will wait before re-
    establishing a connection to the RESTCONF
    server. The RESTCONF client may initiate
    a connection before this time if desired
    (e.g., to set configuration).";
}
} // end periodic-connection
} // end connection-type
} // end connection-type
container reconnect-strategy {
  description
    "The reconnection strategy directs how a RESTCONF
    client reconnects to a RESTCONF server, after
    discovering its connection to the server has
    dropped, even if due to a reboot. The RESTCONF
    client starts with the specified endpoint and
    tries to connect to it max-attempts times before
    trying the next endpoint in the list (round
    robin).";
  leaf start-with {
    type enumeration {
```

```
enum first-listed {
  description
    "Indicates that reconnections should start
    with the first endpoint listed.";
}
enum last-connected {
  description
    "Indicates that reconnections should start
    with the endpoint last connected to. If
    no previous connection has ever been
    established, then the first endpoint
    configured is used. RESTCONF clients
    SHOULD be able to remember the last
    endpoint connected to across reboots.";
}
}
default first-listed;
description
  "Specifies which of the RESTCONF server's
  endpoints the RESTCONF client should start
  with when trying to connect to the RESTCONF
  server.";
}
leaf max-attempts {
  type uint8 {
    range "1..max";
  }
  default 3;
  description
    "Specifies the number times the RESTCONF client
    tries to connect to a specific endpoint before
    moving on to the next endpoint in the list
    (round robin).";
}
} // end reconnect-strategy
} // end endpoint
} // end endpoints
} // end restconf-server
} // end initiate

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

  leaf idle-timeout {
    type uint16;
```

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

list endpoint {
  key name;
  min-elements 1;
  description
    "List of endpoints to listen for RESTCONF connections.";
  leaf name {
    type string;
    description
      "An arbitrary name for the RESTCONF listen endpoint.";
  }
  choice transport {
    mandatory true;
    description
      "Selects between available transports. This is a
       'choice' statement so as to support additional
       transport options to be augmented in.";
    case tls {
      if-feature tls-listen;
      container tls {
        description
          "TLS-specific listening configuration for inbound
           connections.";
        leaf address {
          type inet:ip-address;
          description
            "The IP address to listen on for incoming call-
             home connections. The RESTCONF client will
             listen on all configured interfaces if no
             value is specified. INADDR_ANY (0.0.0.0) or
             INADDR6_ANY (0:0:0:0:0:0:0:0 a.k.a. ::) MUST
             be used when the server is to listen on all
             IPv4 or IPv6 addresses, respectively.";
        }
        leaf port {
          type inet:port-number;
          default 4336;
        }
      }
    }
  }
}
```

```

        description
        "The port number to listen on for call-home
        connections. The RESTCONF client will listen
        on the IANA-assigned well-known port for
        'restconf-ch-tls' (4336) if no value is
        specified.";
    }
    uses ts:tls-client-grouping {
        refine "client-identity/auth-type" {
            mandatory true;
            description
            "RESTCONF clients MUST pass some authentication
            credentials.";
        }
    }
} // end transport
} // end endpoint
} // end listen
} // end restconf-client
}
<CODE ENDS>

```

3. The RESTCONF Server Model

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

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

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

3.1. Tree Diagram

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

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

```

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

```

```

+---rw listen! {listen}?
+---rw endpoint* [name]
+---rw name                string
+---rw (transport)
+---:(tls) {tls-listen}?
+---rw tls
+---rw address?             inet:ip-address
+---rw port?                inet:port-number
+---rw server-identity
+---rw (local-or-keystore)
+---:(local)
+---rw algorithm
+---rw ct:key-algorithm-ref
+---rw public-key            binary
+---rw private-key           union
+---rw cert
+---rw ct:end-entity-cert-cms
+---n certificate-expiration
+---rw expiration-date?
+---rw yang:date-and-time
+---:(keystore) {keystore-implemented}?
+---rw reference
+---rw ks:asymmetric-key-certificate-r\

ef

+---rw client-auth
+---rw pinned-ca-certs?
+---rw ta:pinned-certificates-ref
+---rw pinned-client-certs?
+---rw ta:pinned-certificates-ref
+---rw cert-maps
+---rw cert-to-name* [id]
+---rw id                    uint32
+---rw fingerprint
+---rw x509c2n:tls-fingerprint
+---rw map-type               identityref
+---rw name                   string
+---rw hello-params
+---rw {tls-server-hello-params-config}?
+---rw tls-versions
+---rw tls-version*          identityref
+---rw cipher-suites
+---rw cipher-suite*         identityref
+---rw call-home! {call-home}?
+---rw restconf-client* [name]
+---rw name                   string
+---rw endpoints
+---rw endpoint* [name]
+---rw name                   string

```

```

+--rw (transport)
  +--:(tls) {tls-call-home}?
    +--rw tls
      +--rw address                inet:host
      +--rw port?                  inet:port-number
      +--rw server-identity
        +--rw (local-or-keystore)
          +--:(local)
            +--rw algorithm
              | ct:key-algorithm-ref
            +--rw public-key
              | binary
            +--rw private-key
              | union
            +--rw cert
              | ct:end-entity-cert-cms
            +--n certificate-expiration
              +-- expiration-date?
                  yang:date-and-time
          +--:(keystore) {keystore-implemented\
            +--rw reference
              ks:asymmetric-key-certifi\
        }?
      cate-ref

+--rw client-auth
  +--rw pinned-ca-certs?
    | ta:pinned-certificates-ref
  +--rw pinned-client-certs?
    | ta:pinned-certificates-ref
  +--rw cert-maps
    +--rw cert-to-name* [id]
      +--rw id                uint32
      +--rw fingerprint
        | x509c2n:tls-fingerprint
      +--rw map-type          identityref
      +--rw name              string
  +--rw hello-params
    {tls-server-hello-params-config}?
  +--rw tls-versions
    | +--rw tls-version*      identityref
  +--rw cipher-suites
    +--rw cipher-suite*      identityref

+--rw connection-type
  +--rw (connection-type)?
    +--:(persistent-connection)
      +--rw persistent!
      +--rw 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

```

3.2. Example Usage

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

This example is consistent with the examples presented in Section 2.2 of [I-D.ietf-netconf-keystore].

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

```

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

  <!-- endpoints to listen for RESTCONF connections on -->
  <listen>
    <endpoint>
      <name>netconf/tls</name>
      <tls>
        <address>11.22.33.44</address>
        <server-identity>
          <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-cryp\
to-types">ct:secp521r1</algorithm>
          <private-key>base64encodedvalue==</private-key>
          <public-key>base64encodedvalue==</public-key>
          <cert>base64encodedvalue==</cert>
        </server-identity>
        <client-auth>
          <pinned-ca-certs>explicitly-trusted-client-ca-certs</pinne\
d-ca-certs>
          <pinned-client-certs>explicitly-trusted-client-certs</pinn\
ed-client-certs>
          <cert-maps>
            <cert-to-name>
              <id>1</id>

```

```

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

<!-- call home to a RESTCONF client with two endpoints -->
<call-home>
    <restconf-client>
        <name>config-manager</name>
        <endpoints>
            <endpoint>
                <name>east-data-center</name>
                <tls>
                    <address>22.33.44.55</address>
                    <server-identity>
                        <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-\
crypto-types">ct:secp521r1</algorithm>
                        <private-key>base64encodedvalue==</private-key>
                        <public-key>base64encodedvalue==</public-key>
                        <cert>base64encodedvalue==</cert>
                    </server-identity>
                    <client-auth>
                        <pinned-ca-certs>explicitly-trusted-client-ca-certs</p\
inned-ca-certs>
                        <pinned-client-certs>explicitly-trusted-client-certs</\
pinned-client-certs>
                    <cert-maps>
                        <cert-to-name>
                            <id>1</id>
                            <fingerprint>11:0A:05:11:00</fingerprint>
                            <map-type>x509c2n:san-any</map-type>
                        </cert-to-name>
                        <cert-to-name>
                            <id>2</id>
                            <fingerprint>B3:4F:A1:8C:54</fingerprint>
                            <map-type>x509c2n:specified</map-type>
                            <name>scooby-doo</name>
                        </cert-to-name>

```

```

        </cert-maps>
      </client-auth>
    </tls>
  </endpoint>
</endpoint>
  <name>west-data-center</name>
  <tls>
    <address>33.44.55.66</address>
    <server-identity>
      <algorithm xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-\
crypto-types">ct:secp521r1</algorithm>
      <private-key>base64encodedvalue==</private-key>
      <public-key>base64encodedvalue==</public-key>
      <cert>base64encodedvalue==</cert>
    </server-identity>
    <client-auth>
      <pinned-ca-certs>explicitly-trusted-client-ca-certs</p\
inned-ca-certs>
      <pinned-client-certs>explicitly-trusted-client-certs</\
pinned-client-certs>
      <cert-maps>
        <cert-to-name>
          <id>1</id>
          <fingerprint>11:0A:05:11:00</fingerprint>
          <map-type>x509c2n:san-any</map-type>
        </cert-to-name>
        <cert-to-name>
          <id>2</id>
          <fingerprint>B3:4F:A1:8C:54</fingerprint>
          <map-type>x509c2n:specified</map-type>
          <name>scooby-doo</name>
        </cert-to-name>
      </cert-maps>
    </client-auth>
  </tls>
</endpoint>
</endpoints>
<connection-type>
  <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>
```

3.3. YANG Module

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

```
<CODE BEGINS> file "ietf-restconf-server@2018-06-04.yang"
module ietf-restconf-server {
  yang-version 1.1;

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

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

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

  import ietf-tls-server {
    prefix ts;
    revision-date 2018-06-04; // stable grouping definitions
    reference
      "RFC ZZZZ: YANG Groupings for TLS Clients and TLS Servers";
  }

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

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

    Author:   Kent Watsen
              <mailto:kwatsen@juniper.net>

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

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

description

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

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

```
revision "2018-06-04" {  
  description  
    "Initial version";  
  reference  
    "RFC XXXX: RESTCONF Client and Server Models";  
}
```

// Features

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

```
feature tls-listen {  
  if-feature listen;  
  description  
    "The 'tls-listen' feature indicates that the RESTCONF server  
    supports opening a port to listen for incoming RESTCONF  
    client connections. This feature exists as TLS might not  
    be a mandatory to implement transport in the future.";  
  reference  
    "RFC 8040: RESTCONF Protocol";  
}
```

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

feature tls-call-home {
  if-feature call-home;
  description
    "The 'tls-call-home' feature indicates that the RESTCONF
    server supports initiating connections to RESTCONF clients.
    This feature exists as TLS might not be a mandatory to
    implement transport in the future.";
  reference
    "RFC 8071: NETCONF Call Home and RESTCONF Call Home";
}

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

grouping restconf-server {
  description
    "Top-level grouping for RESTCONF server configuration.";

  container listen {
    if-feature listen;
    presence "Enables server to listen for TCP connections";
    description "Configures listen behavior";
    list endpoint {
      key name;
      min-elements 1;
      description
        "List of endpoints to listen for RESTCONF connections.";
      leaf name {
        type string;
        description
          "An arbitrary name for the RESTCONF listen endpoint.";
      }
      choice transport {
        mandatory true;
        description

```

```
"Selects between available transports. This is a
'choice' statement so as to support additional
transport options to be augmented in.";
case tls {
  if-feature tls-listen;
  container tls {
    description
      "TLS-specific listening configuration for inbound
      connections.";
    leaf address {
      type inet:ip-address;
    }
    description
      "The IP address to listen on for incoming
      connections. The RESTCONF server will listen
      on all configured interfaces if no value is
      specified. INADDR_ANY (0.0.0.0) or INADDR6_ANY
      (0:0:0:0:0:0:0:0 a.k.a. ::) MUST be used when
      the server is to listen on all IPv4 or IPv6
      addresses, respectively.";
  }
  leaf port {
    type inet:port-number;
    default 443;
    description
      "The local port number to listen on. If no value
      is specified, the IANA-assigned port value for
      'https' (443) is used.";
  }
}
uses ts:tls-server-grouping {
  refine "client-auth" {
    must 'pinned-ca-certs or pinned-client-certs';
    description
      "RESTCONF servers MUST be able to validate
      clients.";
  }
  augment "client-auth" {
    description
      "Augments in the cert-to-name structure,
      so the RESTCONF server can map TLS-layer
      client certificates to RESTCONF usernames.";
    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 7407: A YANG Data Model for SNMP
        Configuration.";
    }
  }
} // end tls container
} // end tls case
} // end transport
} // end endpoint
} // end listen

container call-home {
  if-feature call-home;
  presence "Enables server to initiate TCP connections";
  description "Configures call-home behavior";
  list restconf-client {
    key name;
    min-elements 1;
    description
      "List of RESTCONF clients the RESTCONF server is to
      initiate call-home connections to in parallel.";
    leaf name {
      type string;
      description
        "An arbitrary name for the remote RESTCONF client.";
    }
  }
  container endpoints {
    description
      "Container for the list of endpoints.";
    list endpoint {
      key name;
      min-elements 1;
      ordered-by user;
      description
        "User-ordered list of endpoints for this RESTCONF
        client. Defining more than one enables high-
        availability.";
      leaf name {
        type string;
        description
          "An arbitrary name for this endpoint.";
      }
    }
    choice transport {
      mandatory true;
    }
  }
}
```

```
description
  "Selects between available transports. This is a
   'choice' statement so as to support additional
   transport options to be augmented in.";
case tls {
  if-feature tls-call-home;
  container tls {
    description
      "Specifies TLS-specific call-home transport
       configuration.";
    leaf address {
      type inet:host;
      mandatory true;
      description
        "The IP address or hostname of the endpoint.
         If a domain name is configured, then the
         DNS resolution should happen on each usage
         attempt. If the DNS resolution results in
         multiple IP addresses, the IP addresses will
         be tried according to local preference order
         until a connection has been established or
         until all IP addresses have failed.";
    }
    leaf port {
      type inet:port-number;
      default 4336;
      description
        "The IP port for this endpoint. The RESTCONF
         server will use the IANA-assigned well-known
         port for 'restconf-ch-tls' (4336) if no value
         is specified.";
    }
  }
  uses ts:tls-server-grouping {
    refine "client-auth" {
      must 'pinned-ca-certs or pinned-client-certs';
      description
        "RESTCONF servers MUST be able to validate
         clients.";
    }
    augment "client-auth" {
      description
        "Augments in the cert-to-name structure,
         so the RESTCONF server can map TLS-layer
         client certificates to RESTCONF usernames.";
      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 7407: A YANG Data Model for SNMP
        Configuration.";
    }
}
}
}
} // end transport
} // end endpoint
} // end endpoints
container connection-type {
    description
        "Indicates the RESTCONF client's preference for how the
        RESTCONF server's connection is maintained.";
    choice connection-type {
        default persistent-connection;
        description
            "Selects between available connection types.";
        case persistent-connection {
            container persistent {
                presence
                    "Indicates that a persistent connection is to be
                    maintained.";
                description
                    "Maintain a persistent connection to the RESTCONF
                    client. If the connection goes down, immediately
                    start trying to reconnect to 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.";
            }
            leaf idle-timeout {
                type uint32;
                units "seconds";
                default 86400; // one day;
                description
                    "Specifies the maximum number of seconds that

```

```
        the underlying TLS session may remain idle.
        A TLS 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 TLS
            client.  An unresponsive TLS client will
            be dropped after approximately (max-attempts
            * max-wait) seconds.";
        reference
            "RFC 8071: 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 maximum 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
            "Indicates that a periodic connection is to be
            maintained.";
```

```

description
    "Periodically connect to the RESTCONF client, so
     that the RESTCONF client may send requests pending
     for the RESTCONF server. Once the connection has
     been closed, for whatever reason, the server will
     restart its timer until the next connection.";
leaf idle-timeout {
    type uint16;
    units "seconds";
    default 300; // five minutes
    description
        "Specifies the maximum number of seconds that
         the underlying TLS session may remain idle.
         A TLS 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
        "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 to the RESTCONF
         client before this time if desired
         (e.g., to deliver a notification).";
}
}
}
}
}
container reconnect-strategy {
    description
        "The reconnection strategy directs how a RESTCONF
         server reconnects to a RESTCONF client after after
         discovering its connection to the client has dropped,
         even if due to a reboot. The RESTCONF server starts
         with the specified endpoint and tries to connect to
         it max-attempts times before trying the next endpoint
         in the list (round robin).";

```

```
leaf start-with {
    type enumeration {
        enum first-listed {
            description
                "Indicates that reconnections should start with
                 the first endpoint listed.";
        }
        enum last-connected {
            description
                "Indicates that reconnections should start with
                 the endpoint last connected to. If no previous
                 connection has ever been established, then the
                 first endpoint configured is used. RESTCONF
                 servers SHOULD be able to remember the last
                 endpoint connected to across reboots.";
        }
    }
}
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).";
}
}
}
}
}
}
<CODE ENDS>
```

4. Security Considerations

The YANG module defined in this document uses a grouping defined in [I-D.ietf-netconf-tls-client-server]. Please see the Security Considerations section in that document for concerns related that grouping.

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

The NETCONF access control model (NACM) [RFC6536] provides the means to restrict access for particular users to a pre-configured subset of all available protocol operations and content.

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

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

Some of the readable data nodes in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config, or notification) to these data nodes. These are the subtrees and data nodes and their sensitivity/vulnerability:

NONE

Some of the RPC operations in this YANG module may be considered sensitive or vulnerable in some network environments. It is thus important to control access to these operations. These are the operations and their sensitivity/vulnerability:

NONE

5. IANA Considerations

5.1. The IETF XML Registry

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

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

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

5.2. The YANG Module Names Registry

This document registers two YANG modules in the YANG Module Names registry [RFC7950]. Following the format in [RFC7950], the the following registrations are requested:

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

6. References

6.1. Normative References

- [I-D.ietf-netconf-keystore]
Watsen, K., "YANG Data Model for a "Keystore" Mechanism",
draft-ietf-netconf-keystore-04 (work in progress), October
2017.
- [I-D.ietf-netconf-tls-client-server]
Watsen, K. and G. Wu, "YANG Groupings for TLS Clients and
TLS Servers", draft-ietf-netconf-tls-client-server-05
(work in progress), October 2017.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate
Requirement Levels", BCP 14, RFC 2119,
DOI 10.17487/RFC2119, March 1997,
<<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC6991] Schoenwaelder, J., Ed., "Common YANG Data Types",
RFC 6991, DOI 10.17487/RFC6991, July 2013,
<<https://www.rfc-editor.org/info/rfc6991>>.

- [RFC7407] Bjorklund, M. and J. Schoenwaelder, "A YANG Data Model for SNMP Configuration", RFC 7407, DOI 10.17487/RFC7407, December 2014, <<https://www.rfc-editor.org/info/rfc7407>>.
- [RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, DOI 10.17487/RFC7950, August 2016, <<https://www.rfc-editor.org/info/rfc7950>>.
- [RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <<https://www.rfc-editor.org/info/rfc8040>>.
- [RFC8071] Watsen, K., "NETCONF Call Home and RESTCONF Call Home", RFC 8071, DOI 10.17487/RFC8071, February 2017, <<https://www.rfc-editor.org/info/rfc8071>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.

6.2. Informative References

- [I-D.ietf-netconf-netconf-client-server] Watsen, K. and G. Wu, "NETCONF Client and Server Models", draft-ietf-netconf-netconf-client-server-05 (work in progress), October 2017.
- [RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <<https://www.rfc-editor.org/info/rfc3688>>.
- [RFC5246] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", RFC 5246, DOI 10.17487/RFC5246, August 2008, <<https://www.rfc-editor.org/info/rfc5246>>.
- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <<https://www.rfc-editor.org/info/rfc6241>>.
- [RFC6536] Bierman, A. and M. Bjorklund, "Network Configuration Protocol (NETCONF) Access Control Model", RFC 6536, DOI 10.17487/RFC6536, March 2012, <<https://www.rfc-editor.org/info/rfc6536>>.

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

Appendix A. Change Log

A.1. 00 to 01

- o Renamed "keychain" to "keystore".

A.2. 01 to 02

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

A.3. 02 to 03

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

A.4. 03 to 04

- o Added RFC 8174 to Requirements Language Section.
- o Replaced refine statement in ietf-restconf-client to add a mandatory true.
- o Added refine statement in ietf-restconf-server to add a must statement.
- o Now there are containers and groupings, for both the client and server models.
- o Now tree diagrams reference ietf-netmod-yang-tree-diagrams
- o Updated examples to inline key and certificates (no longer a leafref to keystore)

A.5. 04 to 05

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

A.6. 05 to 06

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

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