Operations and Management Area Working Group
Internet-Draft
Obsoletes: 9105 (if approved)
Intended status: Standards Track
Expires: 8 January 2026

M. Boucadair, Ed.
Orange
B. Wu
Huawei Technologies

7 July 2025

A YANG Data Model for Terminal Access Controller Access-Control System Plus (TACACS+)

draft-ietf-opsawg-secure-tacacs-yang-13

Abstract

This document defines a Terminal Access Controller Access-Control System Plus (TACACS+) client YANG module that augments the System Management data model, defined in RFC 7317, to allow devices to make use of TACACS+ servers for centralized Authentication, Authorization, and Accounting (AAA). Specifically, this document defines a YANG module for TACACS+ over TLS 1.3.

This document obsoletes RFC 9105.

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

The System Management data model [RFC7317] defines separate functionality to support local and Remote Authentication Dial In User Service (RADIUS) authentication:

User Authentication Model: Defines a list of user names with associated passwords and a configuration leaf to decide the order in which local or RADIUS authentication is used.

RADIUS Client Model: Defines a list of RADIUS servers used by a device for centralized user authentication.

[RFC9105] defines a YANG module ("ietf-system-tacacs-plus") that augments the System Management data model [RFC7317] for the management of Terminal Access Controller Access-Control System Plus (TACACS+) clients as an alternative to RADIUS servers [RFC2865].

Typically, the "ietf-system-tacacs-plus" module is used to configure a TACACS+ client on a device to support deployment scenarios with centralized authentication, authorization, and accounting servers.

This document defines a YANG module for managing TACACS+ clients (Section 4), including TACACS+ over TLS 1.3 clients [I-D.ietf-opsawg-tacacs-tls13]. This document obsoletes [RFC9105].

The YANG module in this document conforms to the Network Management Datastore Architecture (NMDA) defined in [RFC8342].

1.1. Changes Since RFC 9105

The following changes have been made to [RFC9105]:

* Add support for TLS [I-D.ietf-opsawg-tacacs-tls13]
* Add a constraint to ensure that the list of servers is unique per address/port number
* Update the description of ’address’ to be consistent with the type
* Fix a must statement under ’tacacs-plus’
* Fix errors in the example provided in Appendix A of [RFC9105]
* Add an example to illustrate the use of VRF
* Add new examples to illustrate the use of TACACS+TLS data nodes

Detailed YANG changes are listed in Section 4.

1.2. Editorial Note (To be removed by RFC Editor)

Note to the RFC Editor: This section is to be removed prior to publication.

This document contains placeholder values that need to be replaced with finalized values at the time of publication. This note summarizes all of the substitutions that are needed.

Please apply the following replacements:

* XXXX --> the assigned RFC number for this I-D
* SSSS --> the assigned RFC number for [I-D.ietf-opsawg-tacacs-tls13]

* TBD --> the assigned port number in Section 7 of [I-D.ietf-opsawg-tacacs-tls13]

* 2024-12-11 --> the actual date of the publication of this document

2. Conventions and Definitions

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.

The terminology for describing YANG data models is defined in [RFC7950].

The document uses the terms defined in Section 2 of [I-D.ietf-opsawg-tacacs-tls13] and Section 3 of [RFC8907].

'client' refers to TACACS+ client, while 'server' refers to TACACS+ server.

2.1. Tree Diagrams

The tree diagram used in this document follows the notation defined in [RFC8340].

3. Design of the TACACS+ Data Model

This module is used to configure a TACACS+ client on a device to support deployment scenarios with centralized authentication, authorization, and accounting servers. Authentication is used to validate a user's username and password, authorization allows the user to access and execute commands at various privilege levels assigned to the user, and accounting keeps track of the activity of a user who has accessed the device.

The "ietf-system-tacacs-plus" module augments the '/sys:system' path defined in the "ietf-system" module with the contents of the 'tacacs-plus' grouping. Therefore, a device can use local, RADIUS, or TACACS+ authentication to validate users who attempt to access the device by several mechanisms, e.g., a command line interface or a web-based user interface.

The 'server' list, which is directly under the 'tacacs-plus' container, holds a list of TACACS+ servers and uses 'server-type' to distinguish between Authentication, Authorization, and Accounting (AAA) services. The list of servers is for redundancy.

When there are multiple interfaces connected to a TACACS+ client or server, the source address of outgoing TACACS+ packets could be specified, or the source address could be specified through the interface IP address setting or derived from the outbound interface from the local Forwarding Information Base (FIB). For a TACACS+ server located in a Virtual Private Network (VPN), a VPN Routing and Forwarding (VRF) instance needs to be specified.

The 'statistics' container under the 'server' list is a collection of read-only counters for sent and received messages from a configured server.

The YANG module for TACACS+ client has the structure shown in Figure 1.

```
augment /sys:system:
  +--rw tacacs-plus
     +--rw client-credentials* [id] {credential-reference}?
     |  +--rw id                          string
     |  +--rw (auth-type)?
     |     +--:(certificate)
     |     |  ...
     |     +--:(raw-public-key) {tlsc:client-ident-raw-public-key}?
     |     |  ...
     |     +--:(tls13-epsk) {tlsc:client-ident-tls13-epsk}?
     |        ...
     +--rw server-credentials* [id] {credential-reference}?
     |  +--rw id                  string
     |  +--rw ca-certs!
     |  |  ...
     |  +--rw ee-certs!
     |  |  ...
     |  +--rw raw-public-keys! {tlsc:server-auth-raw-public-key}?
     |  |  ...
     |  +--rw tls13-epsks?       empty
     |           {tlsc:server-auth-tls13-epsk}?
     +--rw server* [name]
        +--rw name                             string
        +--rw server-type
        |       tacacs-plus-server-type
        +--rw domain-name?                     inet:domain-name
        +--rw sni-enabled?                     boolean
        +--rw address                          inet:host
        +--rw port                             inet:port-number
        +--rw (security)
        |  +--:(tls)
        |  |  +--rw client-identity!
        |  |  |  +--rw (ref-or-explicit)?
```

```
|  |  |     +--:(ref)
|  |  |     |  +--rw credentials-reference?
|  |  |     |          sys-tcs-plus:client-credentials-ref
|  |  |     |          {credential-reference}?
|  |  |     +--:(explicit)
|  |  |        +--rw (auth-type)?
|  |  |           +--:(certificate)
|  |  |           |  ...
|  |  |           +--:(raw-public-key)
|  |  |           |     {tlsc:client-ident-raw-public-key}?
|  |  |           |  ...
|  |  |           +--:(tls13-epsk)
|  |  |                 {tlsc:client-ident-tls13-epsk}?
|  |  |              ...
|  |  +--rw server-authentication
|  |  |  +--rw (ref-or-explicit)?
|  |  |     +--:(ref)
|  |  |     |  +--rw credentials-reference?
|  |  |     |          sys-tcs-plus:server-credentials-ref
|  |  |     |          {credential-reference}?
|  |  |     +--:(explicit)
|  |  |        +--rw ca-certs!
|  |  |        |  ...
|  |  |        +--rw ee-certs!
|  |  |        |  ...
|  |  |        +--rw raw-public-keys!
|  |  |        |       {tlsc:server-auth-raw-public-key}?
|  |  |        |  ...
|  |  |        +--rw tls13-epsks?             empty
|  |  |                 {tlsc:server-auth-tls13-epsk}
|  |  +--rw hello-params {tlscmn:hello-params}?
|  |     +--rw tls-versions
|  |     |  +--rw min?   identityref
|  |     |  +--rw max?   identityref
|  |     +--rw cipher-suites
|  |        +--rw cipher-suite*
|  |                 tlscsa:tls-cipher-suite-algorithm
|  +--:(obfuscation)
|     +--rw shared-secret?           string
+--rw (source-type)?
|  +--:(source-ip)
|  |  +--rw source-ip?               inet:ip-address
|  +--:(source-interface)
|     +--rw source-interface?        if:interface-ref
+--rw vrf-instance?
|       -> /ni:network-instances/network-instance/name
+--rw single-connection?             boolean
+--rw timeout?                       uint16
```

```
          +--ro statistics
             +--ro discontinuity-time?    yang:date-and-time
             +--ro connection-opens?      yang:counter64
             +--ro connection-closes?     yang:counter64
             +--ro connection-aborts?     yang:counter64
             +--ro connection-failures?   yang:counter64
             +--ro connection-timeouts?   yang:counter64
             +--ro messages-sent?         yang:counter64
             +--ro messages-received?     yang:counter64
             +--ro errors-received?       yang:counter64
             +--ro sessions?              yang:counter64
             +--ro cert-errors?           yang:counter64
             +--ro rpk-errors?            yang:counter64
                     {tlsc:server-auth-raw-public-key}?
```

Figure 1: Tree Structure Overview

Specifically, the module is designed to cover the following key requirements specified in [I-D.ietf-opsawg-tacacs-tls13]:

* Minimum TLS 1.3 [RFC8446] MUST be used for transport.

* Earlier TLS versions MUST NOT be used.

* The cipher suites offered or accepted SHOULD be configurable.

* Implementations MAY support Raw Public Keys (RPKs) and Pre-Shared Keys (PSKs).

* Implementations MUST support the ability to configure the server's domain name, so that it may be included in the TLS Server Name Indication (SNI) extension.

The following new data nodes are supported compared to [RFC9105]:

'client-credentials' and 'server-credentials': Defines a set credentials that can be globally provisioned and then referenced under specific servers.

'domain-name': Provides a domain name of the server per Section 3.3 of [I-D.ietf-opsawg-tacacs-tls13]. This is the TLS TACACS+ server's domain name that is included in the SNI extension. This domain name is distinct from the IP address/hostname used for the underlying transport connection.

'sni-enabled': Controls activation of Server Name Indication (SNI) (Section 3 of [RFC6066]). This parameter can be used only if a domain name is provided.

'client-identity': Specifies the identity credentials that the client may present when establishing a connection to a server. Client identities can be configured at the top level and then referenced for specific server instances. Alternatively, client identities can be configured explicitly under each server instance.

'server-authentication': Specifies how a client authenticates servers. Server credentials can be configured at the top level and then referenced for specific server instances. Alternatively, client identities can be configured explicitly under each server instance.

'hello-params': Controls TLS versions and cipher suites to be used when establishing TLS sessions.

'discontinuity-time': The time of the most recent occasion at which the client suffered a discontinuity (a configuration action to reset all counters, re-initialization, etc.).

'cert-errors': Number of connection failures due to certificate issues.

'rpk-errors': Number of raw public key related connection failures.

4. TACACS+ Client Module

This YANG module uses types and groupings defined in [RFC6991], [RFC8341], [RFC8343], [RFC8529], [RFC9640], [RFC9641], [RFC9642], and [RFC9645].

The module augments [RFC7317].

The module also cites [RFC6520], [RFC9257], and [RFC9258].

<CODE BEGINS> file "ietf-system-tacacs-plus@2025-01-23.yang"

```
module ietf-system-tacacs-plus {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-system-tacacs-plus";
  prefix sys-tcs-plus;

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

```
      reference
        "RFC 6991: Common YANG Data Types";
    }
    import ietf-system {
      prefix sys;
      reference
        "RFC 7317: A YANG Data Model for System Management";
    }
    import ietf-netconf-acm {
      prefix nacm;
      reference
        "RFC 8341: Network Configuration Access Control Model";
    }
    import ietf-interfaces {
      prefix if;
      reference
        "RFC 8343: A YANG Data Model for Interface Management";
    }
    import ietf-network-instance {
      prefix ni;
      reference
        "RFC 8529: YANG Data Model for Network Instances";
    }
    import ietf-crypto-types {
      prefix ct;
      reference
        "RFC 9640: YANG Data Types and Groupings for Cryptography";
    }
    import ietf-truststore {
      prefix ts;
      reference
        "RFC 9641: A YANG Data Model for a Truststore";
    }
    import ietf-keystore {
      prefix ks;
      reference
        "RFC 9642: A YANG Data Model for a Keystore";
    }
    import ietf-tls-common {
      prefix tlscmn;
      reference
        "RFC 9645: YANG Groupings for TLS Clients and TLS Servers";
    }
    import ietf-tls-client {
      prefix tlsc;
      reference
        "RFC 9645: YANG Groupings for TLS Clients and TLS Servers";
    }
```

```
     organization
       "IETF OPSAWG (Operations and Management Area Working Group)";
     contact
       "WG Web:   <https://datatracker.ietf.org/wg/opsawg/>
        WG List:  <mailto:opsawg@ietf.org>

        Editor:   Mohamed Boucadair
                  <mailto:mohamed.boucadair@orange.com>
        Author:   Bo Wu
                  <lana.wubo@huawei.com>
        Author:   Guangying Zheng
                  <zhengguangying@huawei.com>";
     description
       "This module provides management of TACACS+ clients.

        The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL
        NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED',
        'MAY', and 'OPTIONAL' in this document are to be interpreted as
        described in BCP 14 (RFC 2119) (RFC 8174) when, and only when,
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        (https://trustee.ietf.org/license-info).

        All revisions of IETF and IANA published modules can be found
        at the YANG Parameters registry
        (https://www.iana.org/assignments/yang-parameters).

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

     revision 2025-01-23 {
       description
         "This revision adds TLS support. Specifically, this revision
          adds:
            - a new feature 'credential-reference'
            - a new container 'client-credentials'
            - a new container 'server-credentials'
            - a new leaf 'domain-name'
            - a new leaf 'sni-enabled'
            - TLS as a new security choice
```

```
            - a new leaf 'discontinuity-time' under 'statistics'
            - a new leaf 'cert-errors' under 'statistics'
            - a new leaf 'rpk-errors' under 'statistics'
          Also, this revision:
            - updates the reference of 'tacacs-plus' identity
              to also cite RFC SSSS
            - fixes a must statement under 'tacacs-plus' by adding
              a missing prefix
            - requires that the servers list must be unique per
              address/port number.
            - updates the description of the 'name' under 'server'
              list to better reflect the intended use and clarifies
              the difference with the new domain-name
            - updates the description of the 'address' to be
              consistent with the type
            - removes the default statement for the 'port' under
              'server' list because a distinct default port number
              is used for TACACS+TLS
            - updates the 'port' leaf under 'server' list to enumerate
              the various TACACS+ default port numbers
            - added a constraint on the VRF with 'source-interface'
              is also provided
            - updates the description of timeout to remove redundant
              text with the default statement";
        reference
          "RFC XXXX: A YANG Data Model for Terminal Access Controller
                     Access-Control System Plus (TACACS+)";
      }

      revision 2021-08-05 {
        description
          "Initial revision.";
        reference
          "RFC 9105: A YANG Data Model for Terminal Access Controller
                     Access-Control System Plus (TACACS+)";
      }

      feature credential-reference {
        description
          "Indicates whether service credentials references are
           supported.";
      }

      identity tacacs-plus {
        base sys:authentication-method;
        description
          "Indicates AAA operation using TACACS+.";
        reference
```

```
        "RFC SSSS: Terminal Access Controller Access-Control
                   System Plus (TACACS+) over TLS 1.3
         RFC 8907: The TACACS+ Protocol";
    }

    typedef tacacs-plus-server-type {
      type bits {
        bit authentication {
          description
            "Indicates that the TACACS+ server is providing
             authentication services.";
        }
        bit authorization {
          description
            "Indicates that the TACACS+ server is providing
             authorization services.";
        }
        bit accounting {
          description
            "Indicates that the TACACS+ server is providing accounting
             services.";
        }
      }
      description
        "The type can be set to authentication, authorization,
         accounting, or any combination of the three types.";
    }

    typedef client-credentials-ref {
      type leafref {
        path "/sys:system/sys-tcs-plus:tacacs-plus"
           + "/sys-tcs-plus:client-credentials/sys-tcs-plus:id";
      }
      description
        "Defines a type to reference client credentials.";
    }

    typedef server-credentials-ref {
      type leafref {
        path "/sys:system/sys-tcs-plus:tacacs-plus"
           + "/sys-tcs-plus:server-credentials/sys-tcs-plus:id";
      }
      description
        "Defines a type to reference server credentials.";
    }

    grouping statistics {
      description
```

```
    "Grouping for TACACS+ statistics attributes, including TLS
     specifics.";
   container statistics {
     config false;
     description
       "A collection of server-related statistics objects.";
     leaf discontinuity-time {
       type yang:date-and-time;
       description
         "The time on the most recent occasion at which the
          TACACS+ client suffered a discontinuity. Examples of
          discontinuity can be a configuration action to reset
          all counters, re-initialization of the system, or any
          other events that prevent reliable contiguous tracking
          of counters.";
     }
     leaf connection-opens {
       type yang:counter64;
       description
         "Number of new connection requests sent to the server,
          e.g., socket open.";
     }
     leaf connection-closes {
       type yang:counter64;
       description
         "Number of connection close requests sent to the server,
          e.g., socket close.";
     }
     leaf connection-aborts {
       type yang:counter64;
       description
         "Number of aborted connections to the server. These do
          not include connections that are closed gracefully.";
     }
     leaf connection-failures {
       type yang:counter64;
       description
         "Number of connection failures to the server.";
     }
     leaf connection-timeouts {
       type yang:counter64;
       description
         "Number of connection timeouts to the server.";
     }
     leaf messages-sent {
       type yang:counter64;
       description
         "Number of messages sent to the server.";
```

```
        }
        leaf messages-received {
          type yang:counter64;
          description
            "Number of messages received from the server.";
        }
        leaf errors-received {
          type yang:counter64;
          description
            "Number of error messages received from the server.";
        }
        leaf sessions {
          type yang:counter64;
          description
            "Number of TACACS+ sessions completed with the server.
             If the Single Connection Mode was not enabled, the number
             of sessions is the same as the number of
             'connection-closes'. If the Single Connection Mode was
             enabled, a single TCP connection may contain multiple
             TACACS+ sessions.";
        }
        leaf cert-errors {
          type yang:counter64;
          description
            "Number of connection failures due to certificate
             issues.";
        }
        leaf rpk-errors {
          if-feature "tlsc:server-auth-raw-public-key";
          type yang:counter64;
          description
            "Number of RPK-related connection failures.";
        }
      }
    }

    grouping certificate {
      description
        "Specifies a certificate that can be used for client
         identity.";
      uses "ks:inline-or-keystore-end-entity-cert-with-key-"
         + "grouping" {
        refine "inline-or-keystore/inline/inline-definition" {
          must 'not(public-key-format) or derived-from-or-self'
             + '(public-key-format, "ct:subject-public-key-'
             + 'info-format")';
        }
        refine "inline-or-keystore/central-keystore/"
```

```
            + "central-keystore-reference/asymmetric-key" {
          must 'not(deref(.)/../ks:public-key-format) or '
             + 'derived-from-or-self(deref(.)/../ks:public-'
             + 'key-format, "ct:subject-public-key-info-'
             + 'format")';
        }
      }
    }

    grouping raw-private-key {
      description
        "Specifies raw private key (RPK) that can be used for
         client identity.";
      uses ks:inline-or-keystore-asymmetric-key-grouping {
        refine "inline-or-keystore/inline/inline-definition" {
          must 'not(public-key-format) or derived-from-or-self'
             + '(public-key-format, "ct:subject-public-key-'
             + 'info-format")';
        }
        refine "inline-or-keystore/central-keystore/"
             + "central-keystore-reference" {
          must 'not(deref(.)/../ks:public-key-format) or '
             + 'derived-from-or-self(deref(.)/../ks:public-'
             + 'key-format, "ct:subject-public-key-info-format")';
        }
      }
    }

    grouping tls13-epsk {
      description
        "An External Pre-Shared Key (EPSK) is established or
         provisioned out-of-band, i.e., not from a TLS connection.
         An EPSK is a tuple of (Base Key, External Identity, Hash).
         When Pre-Shared Keys (PSKs) are provisioned out of band,
         the PSK identity and the Key Derivation Function (KDF) hash
         algorithm to be used with the PSK must also be
         provisioned.";
      reference
        "RFC 8446: The Transport Layer Security (TLS) Protocol
                   Version 1.3, Section 4.2.11
         RFC 9257: Guidance for External Pre-Shared Key (PSK) Usage
                   in TLS, Section 6
         RFC 9258: Importing External Pre-Shared Keys (PSKs) for
                   TLS 1.3, Section 5.1";
      uses ks:inline-or-keystore-symmetric-key-grouping;
      leaf external-identity {
        type string;
        mandatory true;
```

```
        description
          "A sequence of bytes used to identify an EPSK. A label for
           a pre-shared key established externally.";
        reference
          "RFC 8446: The Transport Layer Security (TLS) Protocol
                     Version 1.3, Section 4.2.11
           RFC 9257: Guidance for External Pre-Shared Key (PSK)
                     Usage in TLS, Section 4.1";
      }
      leaf hash {
        type tlscmn:epsk-supported-hash;
        default "sha-256";
        description
          "For externally established PSKs, the Hash algorithm must be
           set when the PSK is established or default to SHA-256 if no
           such algorithm is defined.";
        reference
          "RFC 8446: The Transport Layer Security (TLS) Protocol
                     Version 1.3, Section 4.2.11";
      }
      leaf context {
        type string;
        description
          "The context used to determine the EPSK, if any exists. For
           example, context may include information about peer roles or
           identities to mitigate Selfie-style reflection attacks.";
        reference
          "RFC 9258: Importing External Pre-Shared Keys (PSKs) for
                     TLS 1.3, Section 5.1 ";
      }
      leaf target-protocol {
        type uint16;
        description
          "Specifies the protocol for which a PSK is imported for
           use.";
        reference
          "RFC 9258: Importing External Pre-Shared Keys (PSKs) for
                     TLS 1.3, Section 3 ";
      }
      leaf target-kdf {
        type uint16;
        description
          "The KDF for which a PSK is imported for use.";
        reference
          "RFC 9258: Importing External Pre-Shared Keys (PSKs) for
                     TLS 1.3, Section 3";
      }
    }
```

```
    grouping client-identity {
      description
        "Identity credentials that a TLS client may present when
         establishing a connection to a TLS server. When configured,
         and requested by the TLS server when establishing a TLS
         session, these credentials are passed in the Certificate
         message.";
      reference
        "RFC 8446: The Transport Layer Security (TLS) Protocol
                   Version 1.3, Section 4.4.2";
      choice auth-type {
        description
          "A choice amongst authentication types.";
        case certificate {
          container certificate {
            description
              "Specifies the client identity using a certificate.";
            uses certificate;
          }
        }
        case raw-public-key {
          if-feature "tlsc:client-ident-raw-public-key";
          container raw-private-key {
            description
              "Specifies the client identity using RPK.";
            uses raw-private-key;
          }
        }
        case tls13-epsk {
          if-feature "tlsc:client-ident-tls13-epsk";
          container tls13-epsk {
            description
              "An EPSK is established or provisioned out-of-band.";
            uses tls13-epsk;
          }
        }
      }
    }

    grouping client-identity-with-ref {
      description
        "Identity credentials that the TLS client may present when
         establishing a connection to a TLS server. When configured,
         and requested by the TLS server when establishing a TLS
         session, these credentials are passed in the Certificate
         message.";
      choice ref-or-explicit {
        description
```

```
          "A choice between a reference or explicit configuration.";
        case ref {
          description
            "Provides a reference to a client identity.";
          leaf credentials-reference {
            if-feature "credential-reference";
            type sys-tcs-plus:client-credentials-ref;
            description
              "Specifies the client credentials reference.";
          }
        }
        case explicit {
          description
            "Explicit configuration of the client identity.";
          uses client-identity;
        }
      }
    }

    grouping server-authentication {
      description
        "Specifies how a TLS client can authenticate TLS servers.
         Any combination of credentials is additive and unordered.";
      container ca-certs {
        presence "Indicates that Certification Authority (CA)
                  certificates have been configured.
                  This statement is present so the mandatory descendant
                  nodes do not imply that this node must be
                  configured.";
        description
          "A set of CA certificates used by the TLS client to
           authenticate TLS server certificates.
           A server certificate is authenticated if it has a valid
           chain of trust to a configured CA certificate.";
        reference
          "RFC 9641: A YANG Data Model for a Truststore";
        uses ts:inline-or-truststore-certs-grouping;
      }
      container ee-certs {
        presence "Indicates that End Entity (EE) certificates have been
                  configured.
                  This statement is present so the mandatory descendant
                  nodes do not imply that this node must be
                  configured.";
        description
          "A set of server certificates (i.e., end entity certificates)
           used by a TLS client to authenticate certificates
           presented by TLS servers. A server certificate is
```

```
           authenticated if it is an exact match to a configured server
           certificate.";
        reference
          "RFC 9641: A YANG Data Model for a Truststore";
        uses ts:inline-or-truststore-certs-grouping;
      }
      container raw-public-keys {
        if-feature "tlsc:server-auth-raw-public-key";
        presence "Indicates that raw public keys have been configured.
                  This statement is present so the mandatory descendant
                  nodes do not imply that this node must be
                  configured.";
        description
          "A set of raw public keys used by a TLS client to
           authenticate raw public keys presented by the TLS server.
           A raw public key is authenticated if it is an exact match
           to a configured raw public key.";
        reference
          "RFC 9641: A YANG Data Model for a Truststore";
        uses ts:inline-or-truststore-public-keys-grouping {
          refine "inline-or-truststore/inline/inline-definition/"
               + "public-key" {
            must 'derived-from-or-self(public-key-format,'
               + ' "ct:subject-public-key-info-format")';
          }
          refine "inline-or-truststore/central-truststore/"
               + "central-truststore-reference" {
            must 'not(deref(.)/../ts:public-key/ts:public-key-'
               + 'format[not(derived-from-or-self(., "ct:subject-'
               + 'public-key-info-format"))])';
          }
        }
      }
      leaf tls13-epsks {
        if-feature "tlsc:server-auth-tls13-epsk";
        type empty;
        description
          "Indicates that a TLS client can authenticate TLS servers
           using configured EPSKs.";
      }
    }

    grouping server-authentication-with-ref {
      description
        "Specifies how a TLS client can authenticate TLS servers.";
      choice ref-or-explicit {
        description
          "A choice between a reference of explicit configuration.";
```

```
        case ref {
          description
            "Provides a reference to server credentials.";
          leaf credentials-reference {
            if-feature "credential-reference";
            type sys-tcs-plus:server-credentials-ref;
            description
              "Specifies the server credentials reference.";
          }
        }
        case explicit {
          description
            "Explicit configuration of credentials of a server.";
          uses server-authentication;
        }
      }
    }

    grouping hello-params {
      description
        "Configurable parameters for the TLS Hello message.";
      reference
        "RFC SSSS: Terminal Access Controller Access-Control
                   System Plus (TACACS+) over TLS 1.3,
                   Section 5.1";
      uses tlscmn:hello-params-grouping {
        refine "tls-versions/min" {
          must "not(derived-from-or-self(current(), "
             + "'tlscmn:tls12'))" {
            error-message
              "TLS 1.2 is not supported as min TLS version";
          }
        }
        refine "tls-versions/max" {
          must "not(derived-from-or-self(current(), "
             + "'tlscmn:tls12'))" {
            error-message
              "TLS 1.2 is not supported as max TLS version";
          }
        }
      }
    }

    grouping tls-client {
      description
        "A grouping for configuring a TLS client without any
         consideration for how an underlying TCP session is
         established.";
```

```
      container client-identity {
        presence "Indicates that a TLS-level client identity has been
                  configured.
                  This statement is present so the mandatory descendant
                  do not imply that this node must be configured.";
        description
          "Identity credentials that a TLS client may present when
           establishing a connection to a TLS server.";
        uses client-identity-with-ref;
      }
      container server-authentication {
        must 'credentials-reference or ca-certs or ee-certs or '
           + 'raw-public-keys or tls13-epsks';
        description
          "Specifies how a TLS client can authenticate TLS servers.";
        uses server-authentication-with-ref;
      }
      container hello-params {
        if-feature "tlscmn:hello-params";
        description
          "Configurable parameters for the TLS Hello message.";
        uses hello-params;
      }
    }

    grouping tacacs-plus {
      description
        "Grouping for TACACS+ attributes.";
      container tacacs-plus {
        must "not(derived-from-or-self(../sys:authentication"
           + "/sys:user-authentication-order, "
           + "'sys-tcs-plus:tacacs-plus'))"
           + " or bit-is-set(server/server-type,'authentication')" {
          error-message
            "When 'tacacs-plus' is used as a system authentication
             method, a TACACS+ authentication server must be
             configured.";
          description
            "When 'tacacs-plus' is used as an authentication method,
             a TACACS+ server must be configured.";
        }
        description
          "Container for TACACS+ configurations and operations.";
        list client-credentials {
          if-feature "credential-reference";
          key "id";
          description
            "Identity credentials that a TLS client may present
```

```
            when establishing a connection to a TLS server.
            A list of client credentials that can be referenced
            when configuring server instances.";
          nacm:default-deny-write;
          leaf id {
            type string;
            description
              "An identifier that uniquely identifies a client
               identity within the device configuration.";
          }
          uses client-identity;
        }
        list server-credentials {
          if-feature "credential-reference";
          key "id";
          description
            "Identity credentials that a TLS client may use
             to authenticate a TLS server.";
          nacm:default-deny-write;
          leaf id {
            type string;
            description
              "An identifier that uniquely identify server
               credentials within the device configuration.";
          }
          uses server-authentication;
        }
        list server {
          key "name";
          unique "address port";
          ordered-by user;
          description
            "List of TACACS+ servers used by the device.";
          leaf name {
            type string;
            description
              "A name that is used to uniquely identify a TACACS+
               server within the device configuration.
               This name is not to be confused with the domain-name.";
          }
          leaf server-type {
            type tacacs-plus-server-type;
            mandatory true;
            description
              "Server type: authentication/authorization/accounting and
               various combinations.";
          }
          leaf domain-name {
```

```
            type inet:domain-name;
            description
              "Provides a domain name of the TACACS+ server.";
            reference
              "RFC SSSS: Terminal Access Controller Access-Control
                         System Plus (TACACS+) over TLS 1.3,
                         Section 3.4.2";
          }
          leaf sni-enabled {
            type boolean;
            must '../domain-name' {
              error-message
                "A domain name must be provided to make use of Server
                 Name Indication (SNI).";
            }
            description
              "Enables the use of SNI, when set to true. Disables the
               use of SNI, when set to false.";
            reference
              "RFC 6066: Transport Layer Security (TLS) Extensions:
                         Extension Definitions, Section 3
               RFC SSSS: Terminal Access Controller Access-Control
                         System Plus (TACACS+) over TLS 1.3,
                         Section 3.4.2";
          }
          leaf address {
            type inet:host;
            mandatory true;
            description
              "The IP address or name of the TACACS+ server.";
          }
          leaf port {
            type inet:port-number;
            mandatory true;
            description
              "The port number of TACACS+ server.
               Default port number for legacy TACACS+ is 49,
               while it is TBD for TACACS+TLS.";
          }
          choice security {
            mandatory true;
            description
              "Security mechanism between TACACS+ client and server.";
            case tls {
              description
                "TLS is used to secure TACACS+ exchanges.";
              reference
                "RFC SSSS: Terminal Access Controller Access-Control
```

```
                        System Plus (TACACS+) over TLS 1.3";
          uses tls-client;
        }
        case obfuscation {
          leaf shared-secret {
            type string {
              length "1..max";
            }
            description
              "The shared secret, which is known to both the
               TACACS+ client and server. TACACS+ server
               administrators SHOULD configure a shared secret with
               a minimum length of 16 characters.
               It is highly recommended that this shared secret is
               at least 32 characters long and sufficiently complex
               with a mix of different character types,
               i.e., upper case, lower case, numeric, and
               punctuation.  Note that this security mechanism is
               best described as 'obfuscation' and not 'encryption'
               as it does not provide any meaningful integrity,
               privacy, or replay protection.

               The use of obfuscation is deprecated in favor
               of TLS.

               This choice is provided in the model to accommodate
               installed base.";
            reference
              "RFC 8907: The TACACS+ Protocol
               RFC SSSS: Terminal Access Controller Access-Control
                         System Plus (TACACS+) over TLS 1.3";
            nacm:default-deny-all;
          }
        }
      }
      choice source-type {
        description
          "The source address type for outbound TACACS+ packets.";
        case source-ip {
          leaf source-ip {
            type inet:ip-address;
            description
              "Specifies the source IP address for TACACS+ outbound
               packets.";
          }
        }
        case source-interface {
          leaf source-interface {
```

```
            type if:interface-ref;
            description
              "Specifies the interface from which the IP address
               is derived for use as the source for outbound
               TACACS+ packets.";
          }
        }
      }
      leaf vrf-instance {
        type leafref {
          path "/ni:network-instances/ni:network-instance/ni:name";
        }
        must "(not(../source-interface)) or "
           + "(current() = /if:interfaces/if:interface"
           + "[if:name = current()/../source-interface]"
           + "/ni:bind-ni-name)" {
          error-message
            "VRF instance must match the network instance of the
             source interface.";
        }
        description
          "Specifies the VPN Routing and Forwarding (VRF) instance
           to use to communicate with the TACACS+ server.
           If 'source-interface' is configured, this value MUST
           match the network instance bound to the source interface
           (via bind-ni-name).";
        reference
          "RFC 8529: YANG Data Model for Network Instances";
      }
      leaf single-connection {
        type boolean;
        default "false";
        description
          "Indicates whether the Single Connection Mode is enabled
           for the server.";
        reference
          "RFC 8907: The TACACS+ Protocol, Section 4.3";
      }
      leaf timeout {
        type uint16 {
          range "1..max";
        }
        units "seconds";
        default "5";
        description
          "The number of seconds that the device will wait for a
           response from each TACACS+ server before trying with a
           different server.";
```

```
            }
            uses statistics;
          }
        }
      }

      augment "/sys:system" {
        description
          "Augments the system model with the tacacs-plus data nodes.";
        uses tacacs-plus;
      }
    }
    <CODE ENDS>
```

5. Operational Considerations

The same operational considerations discussed in Section 6 of [I-D.ietf-opsawg-tacacs-tls13] apply for this document.

6. Security Considerations

This section is modeled after the template described in Section 3.7 of [I-D.ietf-netmod-rfc8407bis].

The "ietf-ac-common" YANG module defines a data model that is designed to be accessed via YANG-based management protocols, such as NETCONF [RFC6241] and RESTCONF [RFC8040]. These YANG-based management protocols (1) have to use a secure transport layer (e.g., SSH [RFC4252], TLS [RFC8446], and QUIC [RFC9000]) and (2) have to use mutual authentication.

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF 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). All writable data nodes are likely to be sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) and delete operations to these data nodes without proper protection or authentication can have a negative effect on network operations. The following subtrees and data nodes have particular sensitivities/vulnerabilities:

'server': This list contains the data nodes used to control the

TACACS+ servers used by the device. Unauthorized access to this list could enable an attacker to assume complete control over the device by pointing to a compromised TACACS+ server, or to modify the counters to hide attacks against the device.

'shared-secret': This leaf controls the key known to both the TACACS+ client and server. Unauthorized access to this leaf could make the device vulnerable to attacks; therefore, it has been restricted using the "default-deny-all" access control defined in [RFC8341]. When setting, it is highly recommended that the leaf is at least 32 characters long and sufficiently complex with a mix of different character types, i.e., upper case, lower case, numeric, and punctuation.

'client-identity' and 'server-authentication': Any modification to a key or reference to a key may dramatically alter the implemented security policy. For this reason, the NACM extension "default-deny-write" has been set.

This YANG module uses groupings from other YANG modules that define nodes that may be considered sensitive or vulnerable in network environments. Refer to Section 5.3 of [RFC9642] and Section 5.3 of [RFC9645] for information as to which nodes may be considered sensitive or vulnerable in network environments.

7. IANA Considerations

IANA is requested to update the following URI in the "ns" subregistry within the "IETF XML Registry" [RFC3688]:

URI: urn:ietf:params:xml:ns:yang:ietf-system-tacacs-plus
Registrant Contact: The IESG.
XML: N/A; the requested URI is an XML namespace.

IANA is requested to register the following YANG module in the "YANG Module Names" registry [RFC6020] within the "YANG Parameters" registry group:

Name: ietf-system-tacacs-plus
Namespace: urn:ietf:params:xml:ns:yang:ietf-system-tacacs-plus
Prefix: sys-tcs-plus
Maintained by IANA? N
Reference: RFC XXXX

8. References

8.1. Normative References

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Appendix A. Example TACACS+ Authentication Configuration with Shared Secret

Figure 2 shows an example where a TACACS+ authentication server instance is configured using shared secret for authentication. This mode is not recommended per [I-D.ietf-opsawg-tacacs-tls13].

```
{
  "ietf-system:system": {
    "authentication": {
      "user-authentication-order": [
        "ietf-system-tacacs-plus:tacacs-plus",
        "ietf-system:local-users"
      ]
    },
    "ietf-system-tacacs-plus:tacacs-plus": {
      "server": [
        {
          "name": "tac_plus1",
          "server-type": "authentication",
          "address": "192.0.2.2",
          "shared-secret": "QaEfThUkO198010075460923+h3TbE8n",
          "source-ip": "192.0.2.12",
          "timeout": 10
        }
      ]
    }
  }
}
```

Figure 2: Example with Shared Secret

Figure 3 provides an example to associate a TACACS+ server with a VRF.

```
{
  "ietf-network-instance:network-instances": {
    "network-instance": [
      {
        "name": "MANAGEMENT_VRF",
        "description": "Management VRF for TACACS+ traffic isolation"
      }
    ]
  },
  "ietf-system:system": {
    "authentication": {
      "user-authentication-order": [
        "ietf-system-tacacs-plus:tacacs-plus",
        "ietf-system:local-users"
      ]
    },
    "ietf-system-tacacs-plus:tacacs-plus": {
      "server": [
        {
          "name": "tac_plus1",
          "server-type": "authentication",
          "address": "192.0.2.2",
          "shared-secret": "QaEfThUkO198010075460923+h3TbE8n",
          "source-ip": "192.0.2.12",
          "vrf-instance": "MANAGEMENT_VRF",
          "timeout": 10
        }
      ]
    }
  }
}
```

Figure 3: Example with VRF

Appendix B. TACACS+TLS Examples

This section provides examples to illustrate the configuration of TACACS+TLS clients.

These examples follow the convention used in Section 1.5 of [RFC9645] for binary data that has been base64 encoded.

B.1. Example TACACS+ Authentication Configuration with Explicit Certificate Definitions

Figure 4 shows a configuration example with ’inline-definition’ for the client identity and server authentication.

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

   {
     "ietf-system:system": {
       "authentication": {
         "user-authentication-order": [
           "ietf-system-tacacs-plus:tacacs-plus",
           "ietf-system:local-users"
         ]
       },
       "ietf-system-tacacs-plus:tacacs-plus": {
         "server": [
           {
             "name": "instance-1",
             "server-type": "authentication",
             "domain-name": "tacacs.example.com",
             "sni-enabled": true,
             "address": "2001:db8::1",
             "port": 1234,
             "client-identity": {
               "certificate": {
                 "inline-definition": {
                   "public-key-format": "ietf-crypto-types:subject-\
                                         public-key-info-format",
                   "public-key": "BASE64VALUE=",
                   "private-key-format": "ietf-crypto-types:rsa-private\
                                                 -key-format",
                   "cleartext-private-key": "BASE64VALUE=",
                   "cert-data": "BASE64VALUE="
                 }
               }
             },
             "server-authentication": {
               "ca-certs": {
                 "inline-definition": {
                   "certificate": [
                     {
                       "name": "CA-Certificate-1",
                       "cert-data": "BASE64VALUE="
                     }
                   ]
                 }
               }
             },
             "hello-params": {
               "tls-versions": {
                 "min": "ietf-tls-common:tls13",
                 "max": "ietf-tls-common:tls13"
```

```
              },
              "cipher-suites": {
                "cipher-suite": [
                  "TLS_AES_128_GCM_SHA256"
                ]
              }
            },
            "single-connection": false,
            "timeout": 10
          }
        ]
      }
    }
  }
```

Figure 4: Example with TACACS+TLS with Inline Certificate Definitions

B.2. Example TACACS+ Authentication Configuration with Certificate References

Figure 5 shows a configuration example with credential references for multiple service instances: four server instances are configured with all using the same credentials. These instances form a redundancy group for both IPv4 and IPv6.

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

{
  "ietf-system:system": {
    "ietf-system-tacacs-plus:tacacs-plus": {
      "client-credentials": [
        {
          "id": "client-cred-1",
          "certificate": {
            "inline-definition": {
              "public-key-format": "ietf-crypto-types:subject-public\
                                                    -key-info-format",
              "public-key": "BASE64VALUE=",
              "private-key-format": "ietf-crypto-types:rsa-private-\
                                                          key-format",
              "cleartext-private-key": "BASE64VALUE=",
              "cert-data": "BASE64VALUE="
            }
          }
        }
      ],
      "server-credentials": [
        {
```

```
            "id": "server-cred-1",
            "ca-certs": {
              "inline-definition": {
                "certificate": [
                  {
                    "name": "CA-Certificate-1",
                    "cert-data": "BASE64VALUE="
                  }
                ]
              }
            }
          }
        ],
        "server": [
          {
            "name": "primary-v6",
            "server-type": "authentication",
            "domain-name": "tacacs.example.com",
            "sni-enabled": true,
            "address": "2001:db8::1",
            "port": 1234,
            "client-identity": {
              "credentials-reference": "client-cred-1"
            },
            "server-authentication": {
              "credentials-reference": "server-cred-1"
            }
          },
          {
            "name": "backup-v6",
            "server-type": "authentication",
            "domain-name": "tacacs.example.com",
            "sni-enabled": true,
            "address": "2001:db8::2",
            "port": 1234,
            "client-identity": {
              "credentials-reference": "client-cred-1"
            },
            "server-authentication": {
              "credentials-reference": "server-cred-1"
            }
          },
          {
            "name": "primary-v4",
            "server-type": "authentication",
            "domain-name": "tacacs.example.com",
            "sni-enabled": true,
            "address": "192.0.2.1",
```

```
            "port": 49,
            "client-identity": {
              "credentials-reference": "client-cred-1"
            },
            "server-authentication": {
              "credentials-reference": "server-cred-1"
            }
          },
          {
            "name": "backup-v4",
            "server-type": "authentication",
            "domain-name": "tacacs.example.com",
            "sni-enabled": true,
            "address": "192.0.2.2",
            "port": 49,
            "client-identity": {
              "credentials-reference": "client-cred-1"
            },
            "server-authentication": {
              "credentials-reference": "server-cred-1"
            }
          }
        ]
      }
    }
  }
```

Figure 5: Example with TACACS+TLS with References

Appendix C. Full Tree

The full tree structure is shown below:

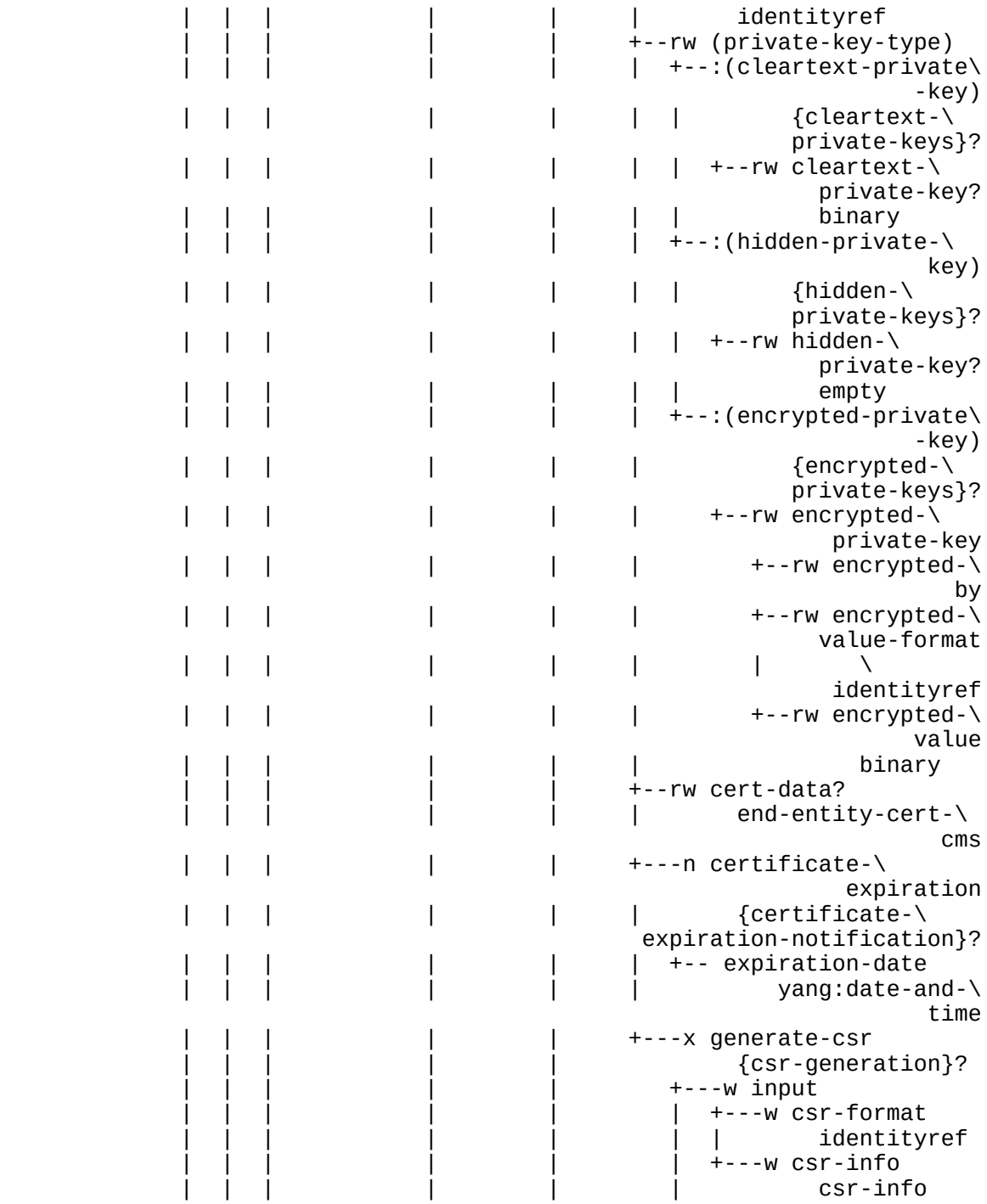
```
=============== NOTE: '\' line wrapping per RFC 8792 ================

module: ietf-system-tacacs-plus

  augment /sys:system:
    +--rw tacacs-plus
       +--rw client-credentials* [id] {credential-reference}?
       |  +--rw id                          string
       |  +--rw (auth-type)?
       |     +--:(certificate)
       |     |  +--rw certificate
       |     |     +--rw (inline-or-keystore)
       |     |        +--:(inline) {inline-definitions-supported}?
       |     |        |  +--rw inline-definition
       |     |        |     +--rw public-key-format?
```

```
          |     |        |     |       identityref
          |     |        |     +--rw public-key?
          |     |        |     |       binary
          |     |        |     +--rw private-key-format?
          |     |        |     |       identityref
          |     |        |     +--rw (private-key-type)
          |     |        |     |  +--:(cleartext-private-key)
          |     |        |     |  |        {cleartext-private-keys}?
          |     |        |     |  |  +--rw cleartext-private-key?
          |     |        |     |  |          binary
          |     |        |     |  +--:(hidden-private-key)
          |     |        |     |  |        {hidden-private-keys}?
          |     |        |     |  |  +--rw hidden-private-key?
          |     |        |     |  |          empty
          |     |        |     |  +--:(encrypted-private-key)
          |     |        |     |           {encrypted-private-keys}?
          |     |        |     |     +--rw encrypted-private-key
          |     |        |     |        +--rw encrypted-by
          |     |        |     |        +--rw encrypted-value-format
          |     |        |     |        |       identityref
          |     |        |     |        +--rw encrypted-value
          |     |        |     |                binary
          |     |        |     +--rw cert-data?
          |     |        |     |       end-entity-cert-cms
          |     |        |     +---n certificate-expiration
          |     |        |     |       {certificate-expiration-\
                                                  notification}?
          |     |        |     |  +-- expiration-date
          |     |        |     |          yang:date-and-time
          |     |        |     +---x generate-csr {csr-generation}?
          |     |        |        +---w input
          |     |        |        |  +---w csr-format    identityref
          |     |        |        |  +---w csr-info      csr-info
          |     |        |        +--ro output
          |     |        |           +--ro (csr-type)
          |     |        |              +--:(p10-csr)
          |     |        |                 +--ro p10-csr?   p10-csr
          |     |        +--:(central-keystore)
          |     |                 {central-keystore-supported,\
                                                 asymmetric-keys}?
          |     |           +--rw central-keystore-reference
          |     |              +--rw asymmetric-key?
          |     |              |       ks:central-asymmetric-key-ref
          |     |              |       {central-keystore-supported,\
                                                 asymmetric-keys}?
          |     |              +--rw certificate?      leafref
          |     +--:(raw-public-key) {tlsc:client-ident-raw-public-key}?
          |     |  +--rw raw-private-key
```

```
          |     |     +--rw (inline-or-keystore)
          |     |        +--:(inline) {inline-definitions-supported}?
          |     |        |  +--rw inline-definition
          |     |        |     +--rw public-key-format?
          |     |        |     |       identityref
          |     |        |     +--rw public-key?
          |     |        |     |       binary
          |     |        |     +--rw private-key-format?
          |     |        |     |       identityref
          |     |        |     +--rw (private-key-type)
          |     |        |        +--:(cleartext-private-key)
          |     |        |        |        {cleartext-private-keys}?
          |     |        |        |  +--rw cleartext-private-key?
          |     |        |        |          binary
          |     |        |        +--:(hidden-private-key)
          |     |        |        |        {hidden-private-keys}?
          |     |        |        |  +--rw hidden-private-key?
          |     |        |        |          empty
          |     |        |        +--:(encrypted-private-key)
          |     |        |                 {encrypted-private-keys}?
          |     |        |           +--rw encrypted-private-key
          |     |        |              +--rw encrypted-by
          |     |        |              +--rw encrypted-value-format
          |     |        |              |       identityref
          |     |        |              +--rw encrypted-value
          |     |        |                      binary
          |     |        +--:(central-keystore)
          |     |                 {central-keystore-supported,\
                                                  asymmetric-keys}?
          |     |           +--rw central-keystore-reference?
          |     |                   ks:central-asymmetric-key-ref
          |     +--:(tls13-epsk) {tlsc:client-ident-tls13-epsk}?
          |        +--rw tls13-epsk
          |           +--rw (inline-or-keystore)
          |           |  +--:(inline) {inline-definitions-supported}?
          |           |  |  +--rw inline-definition
          |           |  |     +--rw key-format?
          |           |  |     |       identityref
          |           |  |     +--rw (key-type)
          |           |  |        +--:(cleartext-symmetric-key)
          |           |  |        |  +--rw cleartext-symmetric-key?
          |           |  |        |          binary
          |           |  |        |          {cleartext-symmetric-keys}?
          |           |  |        +--:(hidden-symmetric-key)
          |           |  |        |        {hidden-symmetric-keys}?
          |           |  |        |  +--rw hidden-symmetric-key?
          |           |  |        |          empty
          |           |  |        +--:(encrypted-symmetric-key)
```

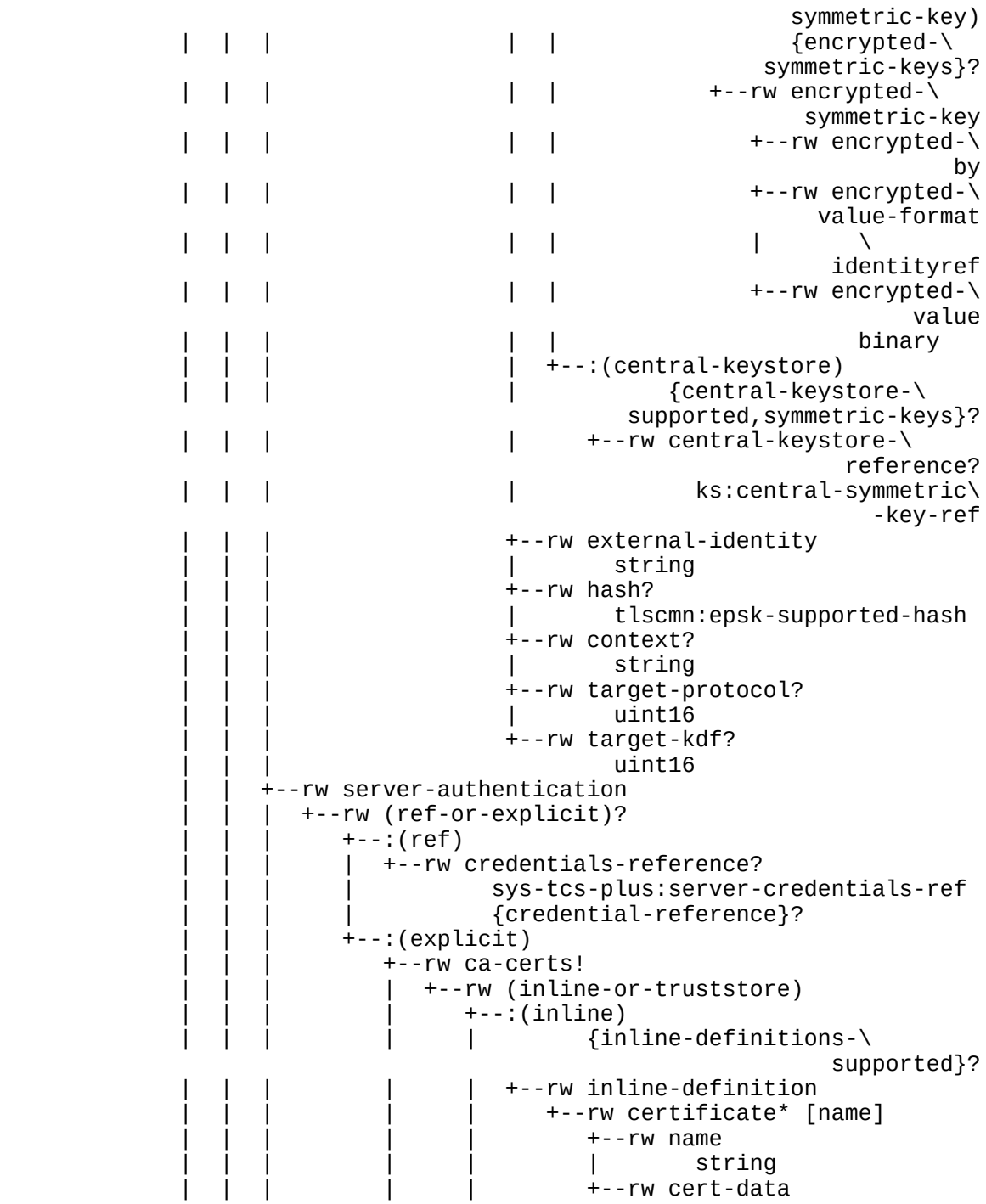
```
          |           |  |                 {encrypted-symmetric-keys}?
          |           |  |           +--rw encrypted-symmetric-key
          |           |  |              +--rw encrypted-by
          |           |  |              +--rw encrypted-value-format
          |           |  |              |       identityref
          |           |  |              +--rw encrypted-value
          |           |  |                      binary
          |           |  +--:(central-keystore)
          |           |           {central-keystore-supported,symmetric\
                                                              -keys}?
          |           |     +--rw central-keystore-reference?
          |           |             ks:central-symmetric-key-ref
          |           +--rw external-identity                   string
          |           +--rw hash?
          |           |       tlscmn:epsk-supported-hash
          |           +--rw context?                            string
          |           +--rw target-protocol?                    uint16
          |           +--rw target-kdf?                         uint16
          +--rw server-credentials* [id] {credential-reference}?
          |  +--rw id                 string
          |  +--rw ca-certs!
          |  |  +--rw (inline-or-truststore)
          |  |     +--:(inline) {inline-definitions-supported}?
          |  |     |  +--rw inline-definition
          |  |     |     +--rw certificate* [name]
          |  |     |        +--rw name                      string
          |  |     |        +--rw cert-data
          |  |     |        |       trust-anchor-cert-cms
          |  |     |        +---n certificate-expiration
          |  |     |                {certificate-expiration-\
                                                     notification}?
          |  |     |           +-- expiration-date    yang:date-and-time
          |  |     +--:(central-truststore)
          |  |              {central-truststore-supported,certificates}?
          |  |        +--rw central-truststore-reference?
          |  |                ts:central-certificate-bag-ref
          |  +--rw ee-certs!
          |  |  +--rw (inline-or-truststore)
          |  |     +--:(inline) {inline-definitions-supported}?
          |  |     |  +--rw inline-definition
          |  |     |     +--rw certificate* [name]
          |  |     |        +--rw name                      string
          |  |     |        +--rw cert-data
          |  |     |        |       trust-anchor-cert-cms
          |  |     |        +---n certificate-expiration
          |  |     |                {certificate-expiration-\
                                                     notification}?
          |  |     |           +-- expiration-date    yang:date-and-time
```

```
          |  |     +--:(central-truststore)
          |  |              {central-truststore-supported,certificates}?
          |  |        +--rw central-truststore-reference?
          |  |                 ts:central-certificate-bag-ref
          |  +--rw raw-public-keys! {tlsc:server-auth-raw-public-key}?
          |  |  +--rw (inline-or-truststore)
          |  |     +--:(inline) {inline-definitions-supported}?
          |  |     |  +--rw inline-definition
          |  |     |     +--rw public-key* [name]
          |  |     |        +--rw name                string
          |  |     |        +--rw public-key-format   identityref
          |  |     |        +--rw public-key          binary
          |  |     +--:(central-truststore)
          |  |              {central-truststore-supported,public-keys}?
          |  |        +--rw central-truststore-reference?
          |  |                 ts:central-public-key-bag-ref
          |  +--rw tls13-epsks?       empty
          |           {tlsc:server-auth-tls13-epsk}?
          +--rw server* [name]
             +--rw name                           string
             +--rw server-type
             |       tacacs-plus-server-type
             +--rw domain-name?                   inet:domain-name
             +--rw sni-enabled?                   boolean
             +--rw address                        inet:host
             +--rw port                           inet:port-number
             +--rw (security)
             |  +--:(tls)
             |  |  +--rw client-identity!
             |  |  |  +--rw (ref-or-explicit)?
             |  |  |     +--:(ref)
             |  |  |     |  +--rw credentials-reference?
             |  |  |     |          sys-tcs-plus:client-credentials-ref
             |  |  |     |          {credential-reference}?
             |  |  |     +--:(explicit)
             |  |  |        +--rw (auth-type)?
             |  |  |           +--:(certificate)
             |  |  |           |  +--rw certificate
             |  |  |           |     +--rw (inline-or-keystore)
             |  |  |           |        +--:(inline)
             |  |  |           |        |        {inline-definitions-\
                                                          supported}?
             |  |  |           |        |  +--rw inline-definition
             |  |  |           |        |     +--rw public-key-format?
             |  |  |           |        |     |       identityref
             |  |  |           |        |     +--rw public-key?
             |  |  |           |        |     |       binary
             |  |  |           |        |     +--rw private-key-format?
```


identityref
+--rw (private-key-type)
+--:(cleartext-private-key)
{cleartext-private-keys}?
+--rw cleartext-private-key?
binary
+--:(hidden-private-key)
{hidden-private-keys}?
+--rw hidden-private-key?
empty
+--:(encrypted-private-key)
{encrypted-private-keys}?
+--rw encrypted-private-key
+--rw encrypted-by
+--rw encrypted-value-format-identityref
+--rw encrypted-value
binary
+--rw cert-data?
end-entity-cert-cms
+---n certificate-expiration
{certificate-expiration-notification}?
+-- expiration-date
yang:date-and-time
+---x generate-csr
{csr-generation}?
+---w input
+---w csr-format
identityref
+---w csr-info
csr-info


+--ro output
+--ro (csr-type)
+--:(p10-csr)
+--ro p10-csr?
p10-csr
+--:(central-keystore)
{central-keystore-supported,asymmetric-keys}?
+--rw central-keystore-reference
+--rw asymmetric-key?
ks:central-asymmetric-key-ref
{central-keystore-supported,asymmetric-keys}?
+--rw certificate?
leafref
+--:(raw-public-key)
{tlsc:client-ident-raw-public-key}?
+--rw raw-private-key
+--rw (inline-or-keystore)
+--:(inline)
{inline-definitions-supported}?
+--rw inline-definition
+--rw public-key-format?
identityref
+--rw public-key?
binary
+--rw private-key-format?
identityref
+--rw (private-key-type)
+--:(cleartext-private-key)
{cleartext-private-keys}?
+--rw cleartext-private-key?
binary
+--:(hidden-private-key)
{hidden-private-keys}?
+--rw hidden-private-key?
empty


+--:(encrypted-private-key)
{encrypted-private-keys}?
+--rw encrypted-private-key
+--rw encrypted-by
+--rw encrypted-value-format
identityref
+--rw encrypted-value
binary
+--:(central-keystore)
{central-keystore-supported,asymmetric-keys}?
+--rw central-keystore-reference?
ks:central-asymmetric-key-ref
+--:(tls13-epsk)
{tlsc:client-ident-tls13-epsk}?
+--rw tls13-epsk
+--rw (inline-or-keystore)
+--:(inline)
{inline-definitions-supported}?
+--rw inline-definition
+--rw key-format?
identityref
+--rw (key-type)
+--:(cleartext-symmetric-key)
+--rw cleartext-symmetric-key?
binary
{cleartext-symmetric-keys}?
+--:(hidden-symmetric-key)
{hidden-symmetric-keys}?
+--rw hidden-symmetric-key?
empty
+--:(encrypted-


symmetric-key)
{encrypted-\
symmetric-keys}?
+--rw encrypted-\
symmetric-key
+--rw encrypted-\
by
+--rw encrypted-\
value-format
identityref
+--rw encrypted-\
value
binary
+--:(central-keystore)
{central-keystore-\
supported,symmetric-keys}?
+--rw central-keystore-\
reference?
ks:central-symmetric\
-key-ref
+--rw external-identity
string
+--rw hash?
tlscmn:epsk-supported-hash
+--rw context?
string
+--rw target-protocol?
uint16
+--rw target-kdf?
uint16
+--rw server-authentication
+--rw (ref-or-explicit)?
+--:(ref)
+--rw credentials-reference?
sys-tcs-plus:server-credentials-ref
{credential-reference}?
+--:(explicit)
+--rw ca-certs!
+--rw (inline-or-truststore)
+--:(inline)
{inline-definitions-\
supported}?
+--rw inline-definition
+--rw certificate* [name]
+--rw name
string
+--rw cert-data

```
|  |  |        |     |        |       trust-anchor-cert-cms
|  |  |        |     |        +---n certificate-expiration
|  |  |        |     |                {certificate-\
|  |  |        |     |                 expiration-notification}?
|  |  |        |     |                +-- expiration-date
|  |  |        |     |                       yang:date-and-time
|  |  |        |     +--:(central-truststore)
|  |  |        |     |                {central-truststore-\
|  |  |        |     |                     supported,certificates}?
|  |  |        |     |        +--rw central-truststore-reference?
|  |  |        |     |                  ts:central-certificate-bag\
|  |  |        |     |                                      -ref
|  |  |        |     +--rw ee-certs!
|  |  |        |     |  +--rw (inline-or-truststore)
|  |  |        |     |     +--:(inline)
|  |  |        |     |     |        {inline-definitions-\
|  |  |        |     |     |                              supported}?
|  |  |        |     |     |  +--rw inline-definition
|  |  |        |     |     |     +--rw certificate* [name]
|  |  |        |     |     |        +--rw name
|  |  |        |     |     |        |       string
|  |  |        |     |     |        +--rw cert-data
|  |  |        |     |     |        |       trust-anchor-cert-cms
|  |  |        |     |     |        +---n certificate-expiration
|  |  |        |     |     |                {certificate-\
|  |  |        |     |     |                 expiration-notification}?
|  |  |        |     |     |                +-- expiration-date
|  |  |        |     |     |                       yang:date-and-time
|  |  |        |     |     +--:(central-truststore)
|  |  |        |     |     |                {central-truststore-\
|  |  |        |     |     |                     supported,certificates}?
|  |  |        |     |     |        +--rw central-truststore-reference?
|  |  |        |     |     |                  ts:central-certificate-bag\
|  |  |        |     |     |                                      -ref
|  |  |        |     +--rw raw-public-keys!
|  |  |        |     |       {tlsc:server-auth-raw-public-key}?
|  |  |        |     |  +--rw (inline-or-truststore)
|  |  |        |     |     +--:(inline)
|  |  |        |     |     |        {inline-definitions-\
|  |  |        |     |     |                              supported}?
|  |  |        |     |     |  +--rw inline-definition
|  |  |        |     |     |     +--rw public-key* [name]
|  |  |        |     |     |        +--rw name
|  |  |        |     |     |        |       string
|  |  |        |     |     |        +--rw public-key-format
|  |  |        |     |     |        |       identityref
|  |  |        |     |     |        +--rw public-key
|  |  |        |     |     |                binary
```

```
|  |  |        |     +--:(central-truststore)
|  |  |        |              {central-truststore-\
                                    supported,public-keys}?
|  |  |        |        +--rw central-truststore-reference?
|  |  |        |                 ts:central-public-key-bag-\
                                                      ref
|  |  |        +--rw tls13-epsks?             empty
|  |  |                 {tlsc:server-auth-tls13-epsk}?
|  |  +--rw hello-params {tlscmn:hello-params}?
|  |     +--rw tls-versions
|  |     |  +--rw min?   identityref
|  |     |  +--rw max?   identityref
|  |     +--rw cipher-suites
|  |        +--rw cipher-suite*
|  |                tlscsa:tls-cipher-suite-algorithm
|  +--:(obfuscation)
|     +--rw shared-secret?           string
+--rw (source-type)?
|  +--:(source-ip)
|  |  +--rw source-ip?               inet:ip-address
|  +--:(source-interface)
|     +--rw source-interface?        if:interface-ref
+--rw vrf-instance?
|       -> /ni:network-instances/network-instance/name
+--rw single-connection?             boolean
+--rw timeout?                       uint16
+--ro statistics
   +--ro discontinuity-time?    yang:date-and-time
   +--ro connection-opens?      yang:counter64
   +--ro connection-closes?     yang:counter64
   +--ro connection-aborts?     yang:counter64
   +--ro connection-failures?   yang:counter64
   +--ro connection-timeouts?   yang:counter64
   +--ro messages-sent?         yang:counter64
   +--ro messages-received?     yang:counter64
   +--ro errors-received?       yang:counter64
   +--ro sessions?              yang:counter64
   +--ro cert-errors?           yang:counter64
   +--ro rpk-errors?            yang:counter64
           {tlsc:server-auth-raw-public-key}?
```

Acknowledgments

The document leverages data structures defined in [RFC9645].

Thanks to Joe Clarke and Tom Petch for the review and comments.

Thanks to Reshad Rahman for the yangdoctors review, Tina Tsou for the opsdir review, Ines Robles for the genart review, and Robert Sparks for the secdir review.

Thanks Mahesh Jethanandani for the AD review.

Thanks Erik Kline and テ詠ic Vyncke for the IESG review.

Authors of RFC 9105: Bo Wu

Guangying Zheng

Michael Wang

Acknowledgments from RFC 9105: The authors wish to thank Alex Campbell, John Heasley, Ebben Aries, Alan DeKok, Joe Clarke, Tom Petch, Robert Wilton, and many others for their helpful comments and suggestions.

Authors' Addresses

Mohamed Boucadair (editor)
Orange
Email: mohamed.boucadair@orange.com

Bo Wu
Huawei Technologies
Email: mlana.wubo@huawei.com