Stream: Internet Engineering Task Force (IETF)
RFC: 9645
Category: Standards Track
Published: October 2024
ISSN: 2070-1721
Author: K. Watsen
Watsen Networks

RFC 9645
YANG Groupings for TLS Clients and TLS Servers

Abstract

This document presents four YANG 1.1 modules -- three IETF modules and one supporting IANA module.

The three IETF modules are "ietf-tls-common", "ietf-tls-client", and "ietf-tls-server". The "ietf-tls-client" and "ietf-tls-server" modules are the primary productions of this work, supporting the configuration and monitoring of TLS clients and servers.

The IANA module is "iana-tls-cipher-suite-algs". This module defines YANG enumerations that provide support for an IANA-maintained algorithm registry.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc9645.

Copyright Notice

Table of Contents

1. Introduction

This document presents four YANG 1.1 [RFC7950] modules -- three IETF modules and one IANA module.

The three IETF modules are "ietf-tls-common" (Section 2), "ietf-tls-client" (Section 3), and "ietf-tls-server" (Section 4). The "ietf-tls-client" and "ietf-tls-server" modules are the primary productions of this work, supporting the configuration and monitoring of TLS clients and servers.

The groupings defined in this document are expected to be used in conjunction with the groupings defined in an underlying transport-level module, such as the groupings defined in [RFC9643]. The transport-level data model enables the configuration of transport-level values such as a remote address, a remote port, a local address, and a local port.

The IANA module is "iana-tls-cipher-suite-algs". This module defines YANG enumerations that provide support for an IANA-maintained algorithm registry.

IANA used the script in Appendix A to generate the "iana-tls-cipher-suite-algs" YANG module. This document does not publish the initial version of the module; it is published and maintained by IANA.

1.1. Regarding the Three IETF Modules

The three IETF modules define features and groupings to model "generic" TLS clients and TLS servers, where "generic" should be interpreted as "least common denominator" rather than "complete." Basic TLS protocol support is afforded by these modules, leaving configuration of advance features to augmentations made by consuming modules.

It is intended that the YANG groupings will be used by applications needing to configure TLS client and server protocol stacks. For instance, these groupings are used to help define the data model for HTTPS [RFC9110] and clients and servers based on the Network Configuration Protocol (NETCONF) over TLS [RFC7589] in [HTTP-CLIENT-SERVER] and [NETCONF-CLIENT-SERVER], respectively.

The "ietf-tls-client" and "ietf-tls-server" YANG modules each define one grouping, which is focused on just TLS-specific configuration, and specifically avoid any transport-level configuration, such as what ports to listen on or connect to. This affords applications the opportunity to define their own strategy for how the underlying TCP connection is established. For instance, applications supporting NETCONF Call Home [RFC8071] could use the "tls-server-grouping" grouping for the TLS parts it provides, while adding data nodes for the TCP-level call-home configuration.

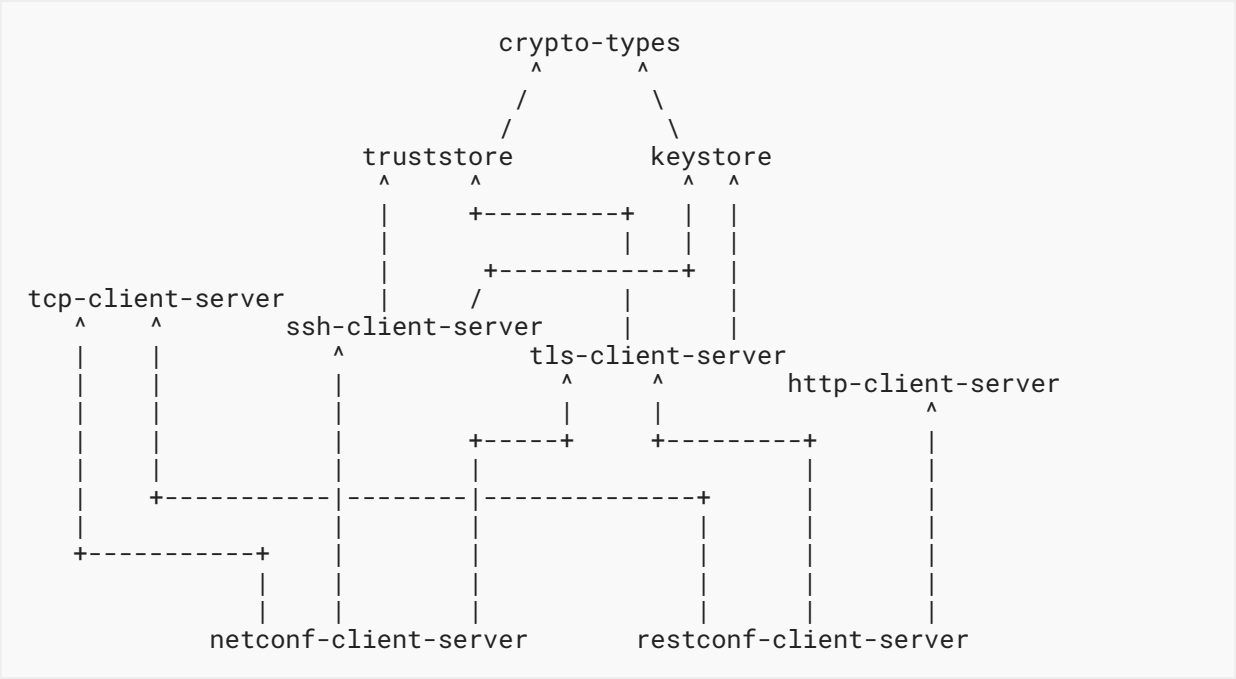
Both TLS 1.2 and TLS 1.3 may be configured. TLS 1.2 [RFC5246] is obsoleted by TLS 1.3 [RFC8446] but is still in common use, and hence its "feature" statement is marked "status deprecated".

1.2. Relation to Other RFCs

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

The dependency relationship between the primary YANG groupings defined in the various RFCs is presented in the diagram below. In some cases, a document may define secondary groupings that introduce dependencies not illustrated in the diagram. The labels in the diagram are shorthand names for the defining RFCs. The citation references for the shorthand names are provided below the diagram.

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



Label in Diagram	Originating RFC
crypto-types	[RFC9640]
truststore	[RFC9641]
keystore	[RFC9642]
tcp-client-server	[RFC9643]
ssh-client-server	[RFC9644]
tls-client-server	RFC 9645
http-client-server	[HTTP-CLIENT-SERVER]
netconf-client-server	[NETCONF-CLIENT-SERVER]
restconf-client-server	[RESTCONF-CLIENT-SERVER]

Table 1: Labels in Diagram to RFC Mapping

1.3. Specification Language

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

1.4. Adherence to the NMDA

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

1.5. Conventions

Various examples in this document use "BASE64VALUE=" as a placeholder value for binary data that has been base64 encoded (per Section 9.8 of [RFC7950]). This placeholder value is used because real base64-encoded structures are often many lines long and hence distracting to the example being presented.

Various examples in this document use the XML [W3C.REC-xml-20081126] encoding. Other encodings, such as JSON [RFC8259], could alternatively be used.

Various examples in this document contain long lines that may be folded, as described in [RFC8792].

2. The "ietf-tls-common" Module

The TLS common model presented in this section contains features and groupings common to both TLS clients and TLS servers. The "hello-params-grouping" grouping can be used to configure the list of TLS algorithms permitted by the TLS client or TLS server. The lists of algorithms are ordered such that, if multiple algorithms are permitted by the client, the algorithm that appears first in its list and that is also permitted by the server is used for the TLS transport layer connection. The ability to restrict the algorithms allowed is provided in this grouping for TLS clients and TLS servers that are capable of doing so and that may serve to make TLS clients and TLS servers compliant with local security policies. This model supports both TLS 1.2 [RFC5246] and TLS 1.3 [RFC8446].

Thus, in order to support both TLS 1.2 and TLS 1.3, the cipher suites part of the "hello-params-grouping" grouping should include the following three parameters for configuring its permitted TLS algorithms: TLS Cipher Suites, TLS SignatureScheme, and TLS Supported Groups.

2.1. Data Model Overview

This section provides an overview of the "ietf-tls-common" module in terms of its features, identities, and groupings.

2.1.1. Features

The following diagram lists all the "feature" statements defined in the "ietf-tls-common" module:

```
Features:
  +-- tls12
  +-- tls13
  +-- hello-params
  +-- asymmetric-key-pair-generation
  +-- supported-algorithms
```

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

Please refer to the YANG module for a description of each feature.

2.1.2. Identities

The following diagram illustrates the relationship amongst the "identity" statements defined in the "ietf-tls-common" module:

```
Identities:
  +-- tls-version-base
     +-- tls12
     +-- tls13
```

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

Comments:

- The diagram shows that there are two base identities.
- One base identity is used to specify TLS versions. This base identity is "abstract" in the object-oriented programming sense because it defines a "class" of things rather than a specific thing.
- These base identities are "abstract" in the object-oriented programming sense because they only define a "class" of things rather than a specific thing.

2.1.3. Groupings

The "ietf-tls-common" module defines the following "grouping" statement:

- hello-params-grouping

This grouping is presented in the following subsection.

2.1.3.1. The "hello-params-grouping" Grouping

The following tree diagram [RFC8340] illustrates the "hello-params-grouping" grouping:

```
  grouping hello-params-grouping:
    +-- tls-versions
    |  +-- min?   identityref
    |  +-- max?   identityref
    +-- cipher-suites
       +-- cipher-suite*   tlscsa:tls-cipher-suite-algorithm
```

Comments:

- This grouping is used by both the "tls-client-grouping" and the "tls-server-grouping" groupings defined in Sections 3.1.2.1 and 4.1.2.1, respectively.
- This grouping enables client and server configurations to specify the TLS versions and cipher suites that are to be used when establishing TLS sessions.
- The "cipher-suites" list is "ordered-by user".

2.1.4. Protocol-Accessible Nodes

The following tree diagram [RFC8340] lists all the protocol-accessible nodes defined in the "ietf-tls-common" module, without expanding the "grouping" statements:

```
module: ietf-tls-common
  +--ro supported-algorithms {algorithm-discovery}?
     +--ro supported-algorithm*   tlscsa:tls-cipher-suite-algorithm

  rpcs:
    +---x generate-asymmetric-key-pair
           {asymmetric-key-pair-generation}?
       +---w input
       |  +---w algorithm
       |  |       tlscsa:tls-cipher-suite-algorithm
       |  +---w num-bits?               uint16
       |  +---w private-key-encoding
       |     +---w (private-key-encoding)
       |        +--:(cleartext) {ct:cleartext-private-keys}?
       |        |  +---w cleartext?   empty
       |        +--:(encrypted) {ct:encrypted-private-keys}?
       |        |  +---w encrypted
       |        |     +---w ks:encrypted-by-grouping
       |        +--:(hidden) {ct:hidden-private-keys}?
       |           +---w hidden?      empty
       +--ro output
          +--ro (key-or-hidden)?
             +--:(key)
             |  +---u ct:asymmetric-key-pair-grouping
             +--:(hidden)
                +--ro location?
                        instance-identifier
```

Comments:

- Protocol-accessible nodes are nodes that are accessible when the module is "implemented", as described in Section 5.6.5 of [RFC7950].
- The protocol-accessible nodes for the "ietf-tls-common" module are limited to the "supported-algorithms" container, which is constrained by the "algorithm-discovery" feature, and the "generate-asymmetric-key-pair" RPC, which is constrained by the "asymmetric-key-pair-generation" feature.
- The "encrypted-by-grouping" grouping is discussed in Section 2.1.3.1 of [RFC9642].
- The "asymmetric-key-pair-grouping" grouping is discussed in Section 2.1.4.6 of [RFC9640].

2.2. Example Usage

The following example illustrates the "hello-params-grouping" grouping when populated with some data.

```
<!-- The outermost element below doesn't exist in the data model. -->
<!--  It simulates if the "grouping" were a "container" instead.  -->

<hello-params
   xmlns="urn:ietf:params:xml:ns:yang:ietf-tls-common"
   xmlns:tlscmn="urn:ietf:params:xml:ns:yang:ietf-tls-common">
  <tls-versions>
    <min>tlscmn:tls12</min>
    <max>tlscmn:tls13</max>
  </tls-versions>
  <cipher-suites>
    <cipher-suite>TLS_ECDHE_ECDSA_WITH_AES_256_CBC_SHA</cipher-suite>
    <cipher-suite>TLS_DHE_RSA_WITH_AES_128_CBC_SHA256</cipher-suite>
    <cipher-suite>TLS_RSA_WITH_3DES_EDE_CBC_SHA</cipher-suite>
  </cipher-suites>
</hello-params>
```

The following example illustrates operational state data indicating the TLS algorithms supported by the server.

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

<supported-algorithms
  xmlns="urn:ietf:params:xml:ns:yang:ietf-tls-common">
  <supported-algorithm>TLS_ECDHE_ECDSA_WITH_AES_256_CBC_SHA</support\
ed-algorithm>
  <supported-algorithm>TLS_ECDHE_ECDSA_WITH_AES_256_CBC_SHA384</supp\
orted-algorithm>
  <supported-algorithm>TLS_DHE_RSA_WITH_AES_128_CBC_SHA256</supporte\
d-algorithm>
  <supported-algorithm>TLS_RSA_WITH_3DES_EDE_CBC_SHA</supported-algo\
rithm>
  <supported-algorithm>TLS_ECDHE_PSK_WITH_AES_256_GCM_SHA384</suppor\
ted-algorithm>
  <supported-algorithm>TLS_DHE_PSK_WITH_CHACHA20_POLY1305_SHA256</su\
pported-algorithm>
  <supported-algorithm>TLS_ECCPWD_WITH_AES_256_GCM_SHA384</supported\
-algorithm>
  <supported-algorithm>TLS_PSK_WITH_AES_256_CCM</supported-algorithm>
  <supported-algorithm>TLS_PSK_WITH_AES_256_CCM_8</supported-algorit\
hm>
  <supported-algorithm>TLS_DHE_PSK_WITH_CAMELLIA_256_CBC_SHA384</sup\
ported-algorithm>
  <supported-algorithm>TLS_ECDH_RSA_WITH_AES_256_CBC_SHA384</support\
ed-algorithm>
  <supported-algorithm>TLS_ECDH_RSA_WITH_3DES_EDE_CBC_SHA</supported\
-algorithm>
  <supported-algorithm>TLS_DH_DSS_WITH_AES_128_GCM_SHA256</supported\
-algorithm>
</supported-algorithms>
```

The following example illustrates the "generate-asymmetric-key-pair" RPC.

REQUEST

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

<rpc message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <generate-asymmetric-key-pair
    xmlns="urn:ietf:params:xml:ns:yang:ietf-tls-common">
    <algorithm>TLS_ECDHE_PSK_WITH_AES_128_GCM_SHA256</algorithm>
    <num-bits>521</num-bits>
    <private-key-encoding>
      <encrypted>
        <asymmetric-key-ref>hidden-asymmetric-key</asymmetric-key-re\
f>
      </encrypted>
    </private-key-encoding>
  </generate-asymmetric-key-pair>
</rpc>
```

RESPONSE

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

<rpc-reply message-id="101"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
  xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-crypto-types"
  xmlns:tlscmn="urn:ietf:params:xml:ns:yang:ietf-tls-common">
  <tlscmn:public-key-format>ct:subject-public-key-info-format</tlscm\
n:public-key-format>
  <tlscmn:public-key>BASE64VALUE=</tlscmn:public-key>
  <tlscmn:private-key-format>ct:ec-private-key-format</tlscmn:privat\
e-key-format>
  <tlscmn:cleartext-private-key>BASE64VALUE=</tlscmn:cleartext-priva\
te-key>
</rpc-reply>
```

2.3. YANG Module

This YANG module has normative references to [RFC5288], [RFC5289], [RFC8422], [RFC9640], [RFC9642], [FIPS180-4], and [FIPS186-5].

This YANG module has informative references to [RFC5246] and [RFC8446].

```
<CODE BEGINS> file "ietf-tls-common@2024-10-10.yang"

module ietf-tls-common {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-tls-common";
  prefix tlscmn;

  import iana-tls-cipher-suite-algs {
    prefix tlscsa;
    reference
      "RFC 9645: YANG Groupings for TLS Clients and TLS Servers";
  }

  import ietf-crypto-types {
    prefix ct;
    reference
      "RFC 9640: YANG Data Types and Groupings for Cryptography";
  }

  import ietf-keystore {
    prefix ks;
    reference
      "RFC 9642: A YANG Data Model for a Keystore";
  }

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

  contact
    "WG List:  NETCONF WG list <mailto:netconf@ietf.org>
```

```
      WG Web:   https://datatracker.ietf.org/wg/netconf
      Author:   Kent Watsen <mailto:kent+ietf@watsen.net>
      Author:   Jeff Hartley <mailto:intensifysecurity@gmail.com>
      Author:   Gary Wu <mailto:garywu@cisco.com>";

    description
     "This module defines common features and groupings for
      Transport Layer Security (TLS).

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

      Copyright (c) 2024 IETF Trust and the persons identified
      as authors of the code. All rights reserved.

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

      This version of this YANG module is part of RFC 9645
      (https://www.rfc-editor.org/info/rfc9645); see the RFC
      itself for full legal notices.";

  revision 2024-10-10 {
    description
      "Initial version.";
    reference
      "RFC 9645: YANG Groupings for TLS Clients and TLS Servers";
  }

  // Features

  feature tls12 {
    description
      "TLS Protocol Version 1.2 is supported. TLS 1.2 is obsolete,
       and thus it is NOT RECOMMENDED to enable this feature.";
    reference
      "RFC 5246: The Transport Layer Security (TLS) Protocol
                 Version 1.2";
  }

  feature tls13 {
    description
      "TLS Protocol Version 1.3 is supported.";
    reference
      "RFC 8446: The Transport Layer Security (TLS)
                 Protocol Version 1.3";
  }

  feature hello-params {
    description
```

```
      "TLS hello message parameters are configurable.";
  }

  feature algorithm-discovery {
    description
      "Indicates that the server implements the
       'supported-algorithms' container.";
  }

  feature asymmetric-key-pair-generation {
    description
      "Indicates that the server implements the
       'generate-asymmetric-key-pair' RPC.";
  }

  // Identities

  identity tls-version-base {
    description
      "Base identity used to identify TLS protocol versions.";
  }

  identity tls12 {
    if-feature "tls12";
    base tls-version-base;
    description
      "TLS Protocol Version 1.2.";
    reference
      "RFC 5246: The Transport Layer Security (TLS) Protocol
                 Version 1.2";
  }

  identity tls13 {
    if-feature "tls13";
    base tls-version-base;
    description
      "TLS Protocol Version 1.3.";
    reference
      "RFC 8446: The Transport Layer Security (TLS)
                 Protocol Version 1.3";
  }

  // Typedefs

  typedef epsk-supported-hash {
    type enumeration {
      enum sha-256 {
        description
          "The SHA-256 hash.";
      }
      enum sha-384 {
        description
          "The SHA-384 hash.";
      }
    }
    description
      "As per Section 4.2.11 of RFC 8446, the hash algorithm
       supported by an instance of an External Pre-Shared
```

```
       Key (EPSK).";
    reference
      "RFC 8446: The Transport Layer Security (TLS)
                 Protocol Version 1.3";
  }


  // Groupings

  grouping hello-params-grouping {
    description
      "A reusable grouping for TLS hello message parameters.";
    reference
      "RFC 5246: The Transport Layer Security (TLS) Protocol
                 Version 1.2
       RFC 8446: The Transport Layer Security (TLS) Protocol
                 Version 1.3";
    container tls-versions {
      description
        "Parameters limiting which TLS versions, amongst
         those enabled by 'features', are presented during
         the TLS handshake.";
      leaf min {
        type identityref {
          base tls-version-base;
        }
        description
          "If not specified, then there is no configured
           minimum version.";
      }
      leaf max {
        type identityref {
          base tls-version-base;
        }
        description
          "If not specified, then there is no configured
           maximum version.";
      }
    }
    container cipher-suites {
      description
        "Parameters regarding cipher suites.";
      leaf-list cipher-suite {
        type tlscsa:tls-cipher-suite-algorithm;
        ordered-by user;
        description
          "Acceptable cipher suites in order of descending
           preference.  The configured host key algorithms should
           be compatible with the algorithm used by the configured
           private key.  Please see Section 5 of RFC 9645 for
           valid combinations.

           If this leaf-list is not configured (has zero elements),
           the acceptable cipher suites are implementation-
           defined.";
        reference
          "RFC 9645: YANG Groupings for TLS Clients and TLS Servers";
      }
```

```
    }
  } // hello-params-grouping


  // Protocol-accessible Nodes

  container supported-algorithms {
    if-feature "algorithm-discovery";
    config false;
    description
      "A container for a list of cipher suite algorithms supported
       by the server.";
    leaf-list supported-algorithm {
      type tlscsa:tls-cipher-suite-algorithm;
      description
        "A cipher suite algorithm supported by the server.";
    }
  }

  rpc generate-asymmetric-key-pair {
    if-feature "asymmetric-key-pair-generation";
    description
      "Requests the device to generate an 'asymmetric-key-pair'
       key using the specified key algorithm.";
    input {
      leaf algorithm {
        type tlscsa:tls-cipher-suite-algorithm;
        mandatory true;
        description
          "The cipher suite algorithm that the generated key
           works with.  Implementations derive the public key
           algorithm from the cipher suite algorithm.  For
           example, cipher suite
           'tls-rsa-with-aes-256-cbc-sha256' maps to the RSA
           public key.";
      }
      leaf num-bits {
        type uint16;
        description
          "Specifies the number of bits to create in the key.
           For RSA keys, the minimum size is 1024 bits, and
           the default is 3072 bits.  Generally, 3072 bits is
           considered sufficient.  DSA keys must be exactly
           1024 bits as specified by FIPS 186-2.  For
           elliptical keys, the 'num-bits' value determines
           the key length of the curve (e.g., 256, 384, or 521),
           where valid values supported by the server are
           conveyed via an unspecified mechanism.  For some
           public algorithms, the keys have a fixed length, and
           thus the 'num-bits' value is not specified.";
      }
      container private-key-encoding {
        description
          "Indicates how the private key is to be encoded.";
        choice private-key-encoding {
          mandatory true;
          description
            "A choice amongst optional private key handling.";
```

```
          case cleartext {
            if-feature "ct:cleartext-private-keys";
            leaf cleartext {
              type empty;
              description
                "Indicates that the private key is to be returned
                 as a cleartext value.";
            }
          }
          case encrypted {
            if-feature "ct:encrypted-private-keys";
            container encrypted {
              description
                "Indicates that the key is to be encrypted using
                 the specified symmetric or asymmetric key.";
              uses ks:encrypted-by-grouping;
            }
          }
          case hidden {
            if-feature "ct:hidden-private-keys";
            leaf hidden {
              type empty;
              description
                "Indicates that the private key is to be hidden.

                 Unlike the 'cleartext' and 'encrypt' options, the
                 key returned is a placeholder for an internally
                 stored key.  See Section 3 of RFC 9642 ('Support
                 for Built-In Keys') for information about hidden
                 keys.";
            }
          }
        }
      }
    }
    output {
      choice key-or-hidden {
        case key {
          uses ct:asymmetric-key-pair-grouping;
        }
        case hidden {
          leaf location {
            type instance-identifier;
            description
              "The location to where a hidden key was created.";
          }
        }
        description
          "The output can be either a key (for cleartext and
           encrypted keys) or the location to where the key
           was created (for hidden keys).";
      }
    }
  } // end generate-asymmetric-key-pair

}
```

```
<CODE ENDS>
```

3. The "ietf-tls-client" Module

This section defines a YANG 1.1 [RFC7950] module called "ietf-tls-client". A high-level overview of the module is provided in Section 3.1. Examples illustrating the module's use are provided in Section 3.2 ("Example Usage"). The YANG module itself is defined in Section 3.3.

3.1. Data Model Overview

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

3.1.1. Features

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

```
Features:
  +-- tls-client-keepalives
  +-- client-ident-x509-cert
  +-- client-ident-raw-public-key
  +-- client-ident-psk
  +-- server-auth-x509-cert
  +-- server-auth-raw-public-key
  +-- server-auth-psk
```

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

Please refer to the YANG module for a description of each feature.

3.1.2. Groupings

The "ietf-tls-client" module defines the following "grouping" statement:

- tls-client-grouping

This grouping is presented in the following subsection.

3.1.2.1. The "tls-client-grouping" Grouping

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

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

  grouping tls-client-grouping:
    +-- client-identity!
    |  +-- (auth-type)
    |     +--:(certificate) {client-ident-x509-cert}?
    |     |  +-- certificate
    |     |     +---u ks:inline-or-keystore-end-entity-cert-with-key\
-grouping
    |     +--:(raw-public-key) {client-ident-raw-public-key}?
    |     |  +-- raw-private-key
    |     |     +---u ks:inline-or-keystore-asymmetric-key-grouping
    |     +--:(tls12-psk) {client-ident-tls12-psk}?
    |     |  +-- tls12-psk
    |     |     +---u ks:inline-or-keystore-symmetric-key-grouping
    |     |     +-- id?
    |     |             string
    |     +--:(tls13-epsk) {client-ident-tls13-epsk}?
    |        +-- tls13-epsk
    |           +---u ks:inline-or-keystore-symmetric-key-grouping
    |           +-- external-identity
    |           |       string
    |           +-- hash?
    |           |       tlscmn:epsk-supported-hash
    |           +-- context?
    |           |       string
    |           +-- target-protocol?
    |           |       uint16
    |           +-- target-kdf?
    |                   uint16
    +-- server-authentication
    |  +-- ca-certs! {server-auth-x509-cert}?
    |  |  +---u ts:inline-or-truststore-certs-grouping
    |  +-- ee-certs! {server-auth-x509-cert}?
    |  |  +---u ts:inline-or-truststore-certs-grouping
    |  +-- raw-public-keys! {server-auth-raw-public-key}?
    |  |  +---u ts:inline-or-truststore-public-keys-grouping
    |  +-- tls12-psks?        empty {server-auth-tls12-psk}?
    |  +-- tls13-epsks?       empty {server-auth-tls13-epsk}?
    +-- hello-params {tlscmn:hello-params}?
    |  +---u tlscmn:hello-params-grouping
    +-- keepalives {tls-client-keepalives}?
       +-- peer-allowed-to-send?   empty
       +-- test-peer-aliveness!
          +-- max-wait?       uint16
          +-- max-attempts?   uint8
```

Comments:

- The "client-identity" node, which is optionally configured (as client authentication **MAY** occur at a higher protocol layer), configures identity credentials, each enabled by a "feature" statement defined in Section 3.1.1.
- The "server-authentication" node configures trust anchors for authenticating the TLS server, with each option enabled by a "feature" statement.

- The "hello-params" node, which must be enabled by a feature, configures parameters for the TLS sessions established by this configuration.
- The "keepalives" node, which must be enabled by a feature, configures a "presence" container to test the aliveness of the TLS server. The aliveness-test occurs at the TLS protocol layer.
- For the referenced grouping statement(s):
  - The "inline-or-keystore-end-entity-cert-with-key-grouping" grouping is discussed in Section 2.1.3.6 of [RFC9642].
  - The "inline-or-keystore-asymmetric-key-grouping" grouping is discussed in Section 2.1.3.4 of [RFC9642].
  - The "inline-or-keystore-symmetric-key-grouping" grouping is discussed in Section 2.1.3.3 of [RFC9642].
  - The "inline-or-truststore-certs-grouping" grouping is discussed in Section 2.1.3.3 of [RFC9641].
  - The "inline-or-truststore-public-keys-grouping" grouping is discussed in Section 2.1.3.4 of [RFC9641].
  - The "hello-params-grouping" grouping is discussed in Section 2.1.3.1 in this document.

3.1.3. Protocol-Accessible Nodes

The "ietf-tls-client" module defines only "grouping" statements that are used by other modules to instantiate protocol-accessible nodes. Thus, this module does not itself define any protocol-accessible nodes when implemented.

3.2. Example Usage

This section presents two examples showing the "tls-client-grouping" grouping populated with some data. These examples are effectively the same except the first configures the client identity using a local key while the second uses a key configured in a keystore. Both examples are consistent with the examples presented in Section 2.2.1 of [RFC9641] and Section 2.2.1 of [RFC9642].

The following configuration example uses inline-definitions for the client identity and server authentication:

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

<!-- The outermost element below doesn't exist in the data model. -->
<!--  It simulates if the "grouping" were a "container" instead.  -->

<tls-client
  xmlns="urn:ietf:params:xml:ns:yang:ietf-tls-client"
  xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-crypto-types">

    <!-- how this client will authenticate itself to the server  -->
    <client-identity>
        <certificate>
            <inline-definition>
```

```
                <private-key-format>ct:rsa-private-key-format</priva\
te-key-format>
                <cleartext-private-key>BASE64VALUE=</cleartext-priva\
te-key>
                <cert-data>BASE64VALUE=</cert-data>
            </inline-definition>
        </certificate>
    </client-identity>

    <!-- which certificates will this client trust -->
    <server-authentication>
        <ca-certs>
            <inline-definition>
                <certificate>
                    <name>Server Cert Issuer #1</name>
                    <cert-data>BASE64VALUE=</cert-data>
                </certificate>
                <certificate>
                    <name>Server Cert Issuer #2</name>
                    <cert-data>BASE64VALUE=</cert-data>
                </certificate>
            </inline-definition>
        </ca-certs>
        <ee-certs>
            <inline-definition>
                <certificate>
                    <name>My Application #1</name>
                    <cert-data>BASE64VALUE=</cert-data>
                </certificate>
                <certificate>
                    <name>My Application #2</name>
                    <cert-data>BASE64VALUE=</cert-data>
                </certificate>
            </inline-definition>
        </ee-certs>
        <raw-public-keys>
            <inline-definition>
                <public-key>
                    <name>corp-fw1</name>
                    <public-key-format>ct:subject-public-key-info-fo\
rmat</public-key-format>
                    <public-key>BASE64VALUE=</public-key>
                </public-key>
                <public-key>
                    <name>corp-fw2</name>
                    <public-key-format>ct:subject-public-key-info-fo\
rmat</public-key-format>
                    <public-key>BASE64VALUE=</public-key>
                </public-key>
            </inline-definition>
        </raw-public-keys>
        <tls12-psks/>
        <tls13-epsks/>
    </server-authentication>

    <keepalives>
        <test-peer-aliveness>
            <max-wait>30</max-wait>
```

```
            <max-attempts>3</max-attempts>
        </test-peer-aliveness>
    </keepalives>

</tls-client>
```

The following configuration example uses central-keystore-references for the client identity and central-truststore-references for server authentication from the keystore:

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

<!-- The outermost element below doesn't exist in the data model. -->
<!--  It simulates if the "grouping" were a "container" instead.  -->

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

    <!-- how this client will authenticate itself to the server -->
    <client-identity>
        <certificate>
            <central-keystore-reference>
                <asymmetric-key>rsa-asymmetric-key</asymmetric-key>
                <certificate>ex-rsa-cert</certificate>
            </central-keystore-reference>
        </certificate>
    </client-identity>

    <!-- which certificates will this client trust -->
    <server-authentication>
        <ca-certs>
            <central-truststore-reference>trusted-server-ca-certs</c\
entral-truststore-reference>
        </ca-certs>
        <ee-certs>
            <central-truststore-reference>trusted-server-ee-certs</c\
entral-truststore-reference>
        </ee-certs>
        <raw-public-keys>
            <central-truststore-reference>Raw Public Keys for TLS Se\
rvers</central-truststore-reference>
        </raw-public-keys>
        <tls12-psks/>
        <tls13-epsks/>
    </server-authentication>

    <keepalives>
        <test-peer-aliveness>
            <max-wait>30</max-wait>
            <max-attempts>3</max-attempts>
        </test-peer-aliveness>
    </keepalives>

</tls-client>
```

3.3. YANG Module

This YANG module has normative references to [RFC4279], [RFC5280], [RFC6520], [RFC7250], [RFC9640], [RFC9641], and [RFC9642] and informative references to [RFC5056], [RFC5246], [RFC8446], [RFC9258], and [RFC9257].

```
<CODE BEGINS> file "ietf-tls-client@2024-10-10.yang"
module ietf-tls-client {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-tls-client";
  prefix tlsc;

  import ietf-netconf-acm {
    prefix nacm;
    reference
      "RFC 8341: Network Configuration Access Control Model";
  }
  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";
  }

  organization
    "IETF NETCONF (Network Configuration) Working Group";
  contact
    "WG List:  NETCONF WG list <mailto:netconf@ietf.org>
     WG Web:   https://datatracker.ietf.org/wg/netconf
     Author:   Kent Watsen <mailto:kent+ietf@watsen.net>
     Author:   Jeff Hartley <mailto:intensifysecurity@gmail.com>";
  description
    "This module defines reusable groupings for TLS clients that
     can be used as a basis for specific TLS client instances.

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

```
     Copyright (c) 2024 IETF Trust and the persons identified
     as authors of the code. All rights reserved.

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

     This version of this YANG module is part of RFC 9645
     (https://www.rfc-editor.org/info/rfc9645); see the RFC
     itself for full legal notices.";

  revision 2024-10-10 {
    description
      "Initial version";
    reference
      "RFC 9645: YANG Groupings for TLS Clients and TLS Servers";
  }

  // Features

  feature tls-client-keepalives {
    description
      "Per-socket TLS keepalive parameters are configurable for
       TLS clients on the server implementing this feature.";
  }

  feature client-ident-x509-cert {
    description
      "Indicates that the client supports identifying itself
       using X.509 certificates.";
    reference
      "RFC 5280:
         Internet X.509 Public Key Infrastructure Certificate
         and Certificate Revocation List (CRL) Profile";
  }

  feature client-ident-raw-public-key {
    description
      "Indicates that the client supports identifying itself
       using raw public keys.";
    reference
      "RFC 7250:
         Using Raw Public Keys in Transport Layer Security (TLS)
         and Datagram Transport Layer Security (DTLS)";
  }

  feature client-ident-tls12-psk {
    if-feature "tlscmn:tls12";
    description
      "Indicates that the client supports identifying itself
       using TLS 1.2 PSKs (pre-shared or pairwise symmetric keys).";
    reference
      "RFC 4279:
         Pre-Shared Key Ciphersuites for Transport Layer Security
```

```
        (TLS)";
  }

  feature client-ident-tls13-epsk {
    if-feature "tlscmn:tls13";
    description
      "Indicates that the client supports identifying itself
       using TLS 1.3 External PSKs (pre-shared keys).";
    reference
      "RFC 8446:
         The Transport Layer Security (TLS) Protocol Version 1.3";
  }

  feature server-auth-x509-cert {
    description
      "Indicates that the client supports authenticating servers
       using X.509 certificates.";
    reference
      "RFC 5280:
         Internet X.509 Public Key Infrastructure Certificate
         and Certificate Revocation List (CRL) Profile";
  }

  feature server-auth-raw-public-key {
    description
      "Indicates that the client supports authenticating servers
       using raw public keys.";
    reference
      "RFC 7250:
         Using Raw Public Keys in Transport Layer Security (TLS)
         and Datagram Transport Layer Security (DTLS)";
  }

  feature server-auth-tls12-psk {
    description
      "Indicates that the client supports authenticating servers
       using PSKs (pre-shared or pairwise symmetric keys).";
    reference
      "RFC 4279:
         Pre-Shared Key Ciphersuites for Transport Layer Security
         (TLS)";
  }

  feature server-auth-tls13-epsk {
    description
      "Indicates that the client supports authenticating servers
       using TLS 1.3 External PSKs (pre-shared keys).";
    reference
      "RFC 8446:
         The Transport Layer Security (TLS) Protocol Version 1.3";
  }

  // Groupings

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

```
        established.

        Note that this grouping uses fairly typical descendant
        node names such that a stack of 'uses' statements will
        have name conflicts.  It is intended that the consuming
        data model will resolve the issue (e.g., by wrapping
        the 'uses' statement in a container called
        'tls-client-parameters').  This model purposely does
        not do this itself so as to provide maximum flexibility
        to consuming models.";
      container client-identity {
        nacm:default-deny-write;
        presence "Indicates that a TLS-level client identity has been
                  configured.  This statement is present so the
                  mandatory descendant nodes do not imply that this
                  node must be configured.";
        description
          "Identity credentials the TLS client MAY present when
           establishing a connection to a TLS server.  If not
           configured, then client authentication is presumed to
           occur in a protocol layer above TLS.  When configured,
           and requested by the TLS server when establishing a
           TLS session, these credentials are passed in the
           Certificate message defined in Section 7.4.2 of
           RFC 5246 and Section 4.4.2 of RFC 8446.";
        reference
          "RFC 5246: The Transport Layer Security (TLS)
                     Protocol Version 1.2
           RFC 8446: The Transport Layer Security (TLS)
                     Protocol Version 1.3
           RFC 9642: A YANG Data Model for a Keystore";
        choice auth-type {
          mandatory true;
          description
            "A choice amongst authentication types, of which one must
             be enabled (via its associated 'feature') and selected.";
          case certificate {
            if-feature "client-ident-x509-cert";
            container certificate {
              description
                "Specifies the client identity using a certificate.";
              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")';
                }
              }
            }
          }
        }
```

```
        case raw-public-key {
          if-feature "client-ident-raw-public-key";
          container raw-private-key {
            description
              "Specifies the client identity using a raw
               private key.";
            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")';
              }
            }
          }
        }
        case tls12-psk {
          if-feature "client-ident-tls12-psk";
          container tls12-psk {
            description
              "Specifies the client identity using a PSK (pre-shared
               or pairwise symmetric key).";
            uses ks:inline-or-keystore-symmetric-key-grouping;
            leaf id {
              type string;
              description
                "The key 'psk_identity' value used in the TLS
                 'ClientKeyExchange' message.";
              reference
                "RFC 4279: Pre-Shared Key Ciphersuites for
                           Transport Layer Security (TLS)";
            }
          }
        }
        case tls13-epsk {
          if-feature "client-ident-tls13-epsk";
          container 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).  EPSKs MUST NOT be
               imported for (D)TLS 1.2 or prior versions.  When
               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.

               The structure of this container is designed to satisfy
               the requirements in Section 4.2.11 of RFC 8446, the
               recommendations from Section 6 of RFC 9257, and the
               EPSK input fields detailed in Section 5.1 of RFC 9258.
               The base-key is based upon
```

```
              'ks:inline-or-keystore-symmetric-key-grouping' in
              order to provide users with flexible and secure
              storage options.";
            reference
              "RFC 8446: The Transport Layer Security (TLS)
                         Protocol Version 1.3
               RFC 9257: Guidance for External Pre-Shared Key
                         (PSK) Usage in TLS
               RFC 9258: Importing External Pre-Shared Keys
                         (PSKs) for TLS 1.3";
            uses ks:inline-or-keystore-symmetric-key-grouping;
            leaf external-identity {
              type string;
              mandatory true;
              description
                "As per Section 4.2.11 of RFC 8446 and Section 4.1
                 of RFC 9257, 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
                 RFC 9257: Guidance for External Pre-Shared Key
                           (PSK) Usage in TLS";
            }
            leaf hash {
              type tlscmn:epsk-supported-hash;
              default "sha-256";
              description
                "As per Section 4.2.11 of RFC 8446, for EPSKs,
                 the hash algorithm MUST be set when the PSK is
                 established; otherwise, default to SHA-256 if
                 no such algorithm is defined.  The server MUST
                 ensure that it selects a compatible PSK (if any)
                 and cipher suite.  Each PSK MUST only be used
                 with a single hash function.";
              reference
                "RFC 8446: The Transport Layer Security (TLS)
                           Protocol Version 1.3";
            }
            leaf context {
              type string;
              description
                "As per Section 5.1 of RFC 9258, context MUST
                 include 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.
                 Since the EPSK is a key derived from an external
                 protocol or a sequence of protocols, context MUST
                 include a channel binding for the deriving
                 protocols (see RFC 5056).  The details of this
                 binding are protocol specific and out of scope
                 for this document.";
              reference
                "RFC 9258: Importing External Pre-Shared Keys
                           (PSKs) for TLS 1.3";
            }
```

```
            leaf target-protocol {
              type uint16;
              description
                "As per Section 3 of RFC 9258, the protocol
                 for which a PSK is imported for use.";
              reference
                "RFC 9258: Importing External Pre-Shared Keys
                           (PSKs) for TLS 1.3";
            }
            leaf target-kdf {
              type uint16;
              description
                "As per Section 3 of RFC 9258, the Key Derivation
                 Function (KDF) for which a PSK is imported for
                 use.";
              reference
                "RFC 9258: Importing External Pre-Shared Keys
                           (PSKs) for TLS 1.3";
            }
          }
        }
      }
    } // container client-identity
    container server-authentication {
      nacm:default-deny-write;
      must "ca-certs or ee-certs or raw-public-keys or tls12-psks
                    or tls13-epsks";
      description
        "Specifies how the TLS client can authenticate TLS servers.
         Any combination of credentials is additive and unordered.

         Note that no configuration is required for authentication
         based on PSK (pre-shared or pairwise symmetric key) as
         the key is necessarily the same as configured in the
         '../client-identity' node.";
      container ca-certs {
        if-feature "server-auth-x509-cert";
        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 {
        if-feature "server-auth-x509-cert";
        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., EE certificates) used
           by the 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 "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 the 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 tls12-psks {
        if-feature "server-auth-tls12-psk";
        type empty;
        description
          "Indicates that the TLS client can authenticate TLS servers
           using configured PSKs (pre-shared or pairwise symmetric
           keys).

           No configuration is required since the PSK value is the
           same as the PSK value configured in the 'client-identity'
           node.";
      }
      leaf tls13-epsks {
        if-feature "server-auth-tls13-epsk";
        type empty;
        description
          "Indicates that the TLS client can authenticate TLS servers
           using configured External PSKs (pre-shared keys).

           No configuration is required since the PSK value is the
           same as the PSK value configured in the 'client-identity'
           node.";
      }
```

```
    } // container server-authentication
    container hello-params {
      nacm:default-deny-write;
      if-feature "tlscmn:hello-params";
      uses tlscmn:hello-params-grouping;
      description
        "Configurable parameters for the TLS hello message.";
    } // container hello-params
    container keepalives {
      nacm:default-deny-write;
      if-feature "tls-client-keepalives";
      description
        "Configures the keepalive policy for the TLS client.";
      leaf peer-allowed-to-send {
        type empty;
        description
          "Indicates that the remote TLS server is allowed to send
           HeartbeatRequest messages, as defined by RFC 6520,
           to this TLS client.";
        reference
          "RFC 6520: Transport Layer Security (TLS) and Datagram
           Transport Layer Security (DTLS) Heartbeat Extension";
      }
      container test-peer-aliveness {
        presence "Indicates that the TLS client proactively tests the
                  aliveness of the remote TLS server.";
        description
          "Configures the keepalive policy to proactively test
           the aliveness of the TLS server.  An unresponsive
           TLS server is dropped after approximately max-wait
           * max-attempts seconds.  The TLS client MUST send
           HeartbeatRequest messages, as defined in RFC 6520.";
        reference
          "RFC 6520: Transport Layer Security (TLS) and Datagram
           Transport Layer Security (DTLS) Heartbeat Extension";
        leaf max-wait {
          type uint16 {
            range "1..max";
          }
          units "seconds";
          default "30";
          description
            "Sets the amount of time in seconds, after which a
             TLS-level message will be sent to test the
             aliveness of the TLS server if no data has been
             received from the TLS server.";
        }
        leaf max-attempts {
          type uint8;
          default "3";
          description
            "Sets the maximum number of sequential keepalive
             messages that can fail to obtain a response from
             the TLS server before assuming the TLS server is
             no longer alive.";
        }
      }
    }
```

```
  } // grouping tls-client-grouping

}

<CODE ENDS>
```

4. The "ietf-tls-server" Module

This section defines a YANG 1.1 module called "ietf-tls-server". A high-level overview of the module is provided in Section 4.1. Examples illustrating the module's use are provided in Section 4.2 ("Example Usage"). The YANG module itself is defined in Section 4.3.

4.1. Data Model Overview

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

4.1.1. Features

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

```
Features:
  +-- tls-server-keepalives
  +-- server-ident-x509-cert
  +-- server-ident-raw-public-key
  +-- server-ident-psk
  +-- client-auth-supported
  +-- client-auth-x509-cert
  +-- client-auth-raw-public-key
  +-- client-auth-psk
```

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

Please refer to the YANG module for a description of each feature.

4.1.2. Groupings

The "ietf-tls-server" module defines the following "grouping" statement:

- tls-server-grouping

This grouping is presented in the following subsection.

4.1.2.1. The "tls-server-grouping" Grouping

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

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

  grouping tls-server-grouping:
    +-- server-identity
    |  +-- (auth-type)
    |     +--:(certificate) {server-ident-x509-cert}?
    |     |  +-- certificate
    |     |     +---u ks:inline-or-keystore-end-entity-cert-with-key\
-grouping
    |     +--:(raw-private-key) {server-ident-raw-public-key}?
    |     |  +-- raw-private-key
    |     |     +---u ks:inline-or-keystore-asymmetric-key-grouping
    |     +--:(tls12-psk) {server-ident-tls12-psk}?
    |     |  +-- tls12-psk
    |     |     +---u ks:inline-or-keystore-symmetric-key-grouping
    |     |     +-- id-hint?
    |     |             string
    |     +--:(tls13-epsk) {server-ident-tls13-epsk}?
    |        +-- tls13-epsk
    |           +---u ks:inline-or-keystore-symmetric-key-grouping
    |           +-- external-identity
    |           |       string
    |           +-- hash?
    |           |       tlscmn:epsk-supported-hash
    |           +-- context?
    |           |       string
    |           +-- target-protocol?
    |           |       uint16
    |           +-- target-kdf?
    |                   uint16
    +-- client-authentication! {client-auth-supported}?
    |  +-- ca-certs! {client-auth-x509-cert}?
    |  |  +---u ts:inline-or-truststore-certs-grouping
    |  +-- ee-certs! {client-auth-x509-cert}?
    |  |  +---u ts:inline-or-truststore-certs-grouping
    |  +-- raw-public-keys! {client-auth-raw-public-key}?
    |  |  +---u ts:inline-or-truststore-public-keys-grouping
    |  +-- tls12-psks?        empty {client-auth-tls12-psk}?
    |  +-- tls13-epsks?       empty {client-auth-tls13-epsk}?
    +-- hello-params {tlscmn:hello-params}?
    |  +---u tlscmn:hello-params-grouping
    +-- keepalives {tls-server-keepalives}?
       +-- peer-allowed-to-send?   empty
       +-- test-peer-aliveness!
          +-- max-wait?       uint16
          +-- max-attempts?   uint8
```

Comments:

- The "server-identity" node configures identity credentials, each of which is enabled by a "feature".
- The "client-authentication" node, which is optionally configured (as client authentication **MAY** occur at a higher protocol layer), configures trust anchors for authenticating the TLS client, with each option enabled by a "feature" statement.

- The "hello-params" node, which must be enabled by a feature, configures parameters for the TLS sessions established by this configuration.
- The "keepalives" node, which must be enabled by a feature, configures a flag enabling the TLS client to test the aliveness of the TLS server as well as a "presence" container to test the aliveness of the TLS client. The aliveness-tests occur at the TLS protocol layer.
- For the referenced grouping statement(s):
  - The "inline-or-keystore-end-entity-cert-with-key-grouping" grouping is discussed in Section 2.1.3.6 of [RFC9642].
  - The "inline-or-keystore-asymmetric-key-grouping" grouping is discussed in Section 2.1.3.4 of [RFC9642].
  - The "inline-or-keystore-symmetric-key-grouping" grouping is discussed in Section 2.1.3.3 of [RFC9642].
  - The "inline-or-truststore-public-keys-grouping" grouping is discussed in Section 2.1.3.4 of [RFC9641].
  - The "inline-or-truststore-certs-grouping" grouping is discussed in Section 2.1.3.3 of [RFC9641].
  - The "hello-params-grouping" grouping is discussed in Section 2.1.3.1 in this document.

4.1.3. Protocol-Accessible Nodes

The "ietf-tls-server" module defines only "grouping" statements that are used by other modules to instantiate protocol-accessible nodes. Thus, this module does not itself define any protocol-accessible nodes when implemented.

4.2. Example Usage

This section presents two examples showing the "tls-server-grouping" grouping populated with some data. These examples are effectively the same except the first configures the server identity using a local key while the second uses a key configured in a keystore. Both examples are consistent with the examples presented in Section 2.2.1 of [RFC9641] and Section 2.2.1 of [RFC9642].

The following configuration example uses inline-definitions for the server identity and client authentication:

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

<!-- The outermost element below doesn't exist in the data model. -->
<!--  It simulates if the "grouping" were a "container" instead.  -->

<tls-server
  xmlns="urn:ietf:params:xml:ns:yang:ietf-tls-server"
  xmlns:ct="urn:ietf:params:xml:ns:yang:ietf-crypto-types">

    <!-- how this server will authenticate itself to the client -->
    <server-identity>
        <certificate>
          <inline-definition>
```

```
              <private-key-format>ct:rsa-private-key-format</private\
-key-format>
              <cleartext-private-key>BASE64VALUE=</cleartext-private\
-key>
              <cert-data>BASE64VALUE=</cert-data>
            </inline-definition>
        </certificate>
    </server-identity>

    <!-- which certificates will this server trust -->
    <client-authentication>
        <ca-certs>
            <inline-definition>
                <certificate>
                    <name>Identity Cert Issuer #1</name>
                    <cert-data>BASE64VALUE=</cert-data>
                </certificate>
                <certificate>
                    <name>Identity Cert Issuer #2</name>
                    <cert-data>BASE64VALUE=</cert-data>
                </certificate>
            </inline-definition>
        </ca-certs>
        <ee-certs>
            <inline-definition>
                <certificate>
                    <name>Application #1</name>
                    <cert-data>BASE64VALUE=</cert-data>
                </certificate>
                <certificate>
                    <name>Application #2</name>
                    <cert-data>BASE64VALUE=</cert-data>
                </certificate>
            </inline-definition>
        </ee-certs>
        <raw-public-keys>
            <inline-definition>
                <public-key>
                    <name>User A</name>
                    <public-key-format>ct:subject-public-key-info-fo\
rmat</public-key-format>
                    <public-key>BASE64VALUE=</public-key>
                </public-key>
                <public-key>
                    <name>User B</name>
                    <public-key-format>ct:subject-public-key-info-fo\
rmat</public-key-format>
                    <public-key>BASE64VALUE=</public-key>
                </public-key>
            </inline-definition>
        </raw-public-keys>
        <tls12-psks/>
        <tls13-epsks/>
    </client-authentication>

    <keepalives>
        <peer-allowed-to-send/>
    </keepalives>
```

```
</tls-server>
```

The following configuration example uses central-keystore-references for the server identity and central-truststore-references for client authentication from the keystore:

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

<!-- The outermost element below doesn't exist in the data model. -->
<!--  It simulates if the "grouping" were a "container" instead.  -->

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

    <!-- how this server will authenticate itself to the client -->
    <server-identity>
        <certificate>
            <central-keystore-reference>
                <asymmetric-key>rsa-asymmetric-key</asymmetric-key>
                <certificate>ex-rsa-cert</certificate>
            </central-keystore-reference>
        </certificate>
    </server-identity>

    <!-- which certificates will this server trust -->
    <client-authentication>
        <ca-certs>
            <central-truststore-reference>trusted-client-ca-certs</c\
entral-truststore-reference>
        </ca-certs>
        <ee-certs>
            <central-truststore-reference>trusted-client-ee-certs</c\
entral-truststore-reference>
        </ee-certs>
        <raw-public-keys>
            <central-truststore-reference>Raw Public Keys for TLS Cl\
ients</central-truststore-reference>
        </raw-public-keys>
        <tls12-psks/>
        <tls13-epsks/>
    </client-authentication>

    <keepalives>
        <peer-allowed-to-send/>
    </keepalives>

</tls-server>
```

4.3. YANG Module

This YANG module has normative references to [RFC4279], [RFC5280], [RFC6520], [RFC7250], [RFC9640], [RFC9641], and [RFC9642] and informative references to [RFC5056], [RFC5246], [RFC8446], [RFC9258], and [RFC9257].

```
<CODE BEGINS> file "ietf-tls-server@2024-10-10.yang"

module ietf-tls-server {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-tls-server";
  prefix tlss;

  import ietf-netconf-acm {
    prefix nacm;
    reference
      "RFC 8341: Network Configuration Access Control Model";
  }
  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";
  }

  organization
    "IETF NETCONF (Network Configuration) Working Group";
  contact
    "WG List:  NETCONF WG list <mailto:netconf@ietf.org>
     WG Web:   https://datatracker.ietf.org/wg/netconf
     Author:   Kent Watsen <mailto:kent+ietf@watsen.net>
     Author:   Jeff Hartley <mailto:intensifysecurity@gmail.com>";
  description
    "This module defines reusable groupings for TLS servers that
     can be used as a basis for specific TLS server instances.

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

     Copyright (c) 2024 IETF Trust and the persons identified
     as authors of the code. All rights reserved.

     Redistribution and use in source and binary forms, with
     or without modification, is permitted pursuant to, and
     subject to the license terms contained in, the Revised
```

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

      This version of this YANG module is part of RFC 9645
      (https://www.rfc-editor.org/info/rfc9645); see the RFC
      itself for full legal notices.";

    revision 2024-10-10 {
      description
        "Initial version.";
      reference
        "RFC 9645: YANG Groupings for TLS Clients and TLS Servers";
    }

    // Features

    feature tls-server-keepalives {
      description
        "Per-socket TLS keepalive parameters are configurable for
         TLS servers on the server implementing this feature.";
    }

    feature server-ident-x509-cert {
      description
        "Indicates that the server supports identifying itself
         using X.509 certificates.";
      reference
        "RFC 5280:
           Internet X.509 Public Key Infrastructure Certificate
           and Certificate Revocation List (CRL) Profile";
    }

    feature server-ident-raw-public-key {
      description
        "Indicates that the server supports identifying itself
         using raw public keys.";
      reference
        "RFC 7250:
           Using Raw Public Keys in Transport Layer Security (TLS)
           and Datagram Transport Layer Security (DTLS)";
    }

    feature server-ident-tls12-psk {
      if-feature "tlscmn:tls12";
      description
        "Indicates that the server supports identifying itself
         using TLS 1.2 PSKs (pre-shared or pairwise symmetric keys).";
      reference
        "RFC 4279:
           Pre-Shared Key Ciphersuites for Transport Layer Security
           (TLS)";
    }

    feature server-ident-tls13-epsk {
      if-feature "tlscmn:tls13";
      description
        "Indicates that the server supports identifying itself
```

```
       using TLS 1.3 External PSKs (pre-shared keys).";
    reference
      "RFC 8446:
         The Transport Layer Security (TLS) Protocol Version 1.3";
  }

  feature client-auth-supported {
    description
      "Indicates that the configuration for how to authenticate
       clients can be configured herein.  TLS-level client
       authentication may not be needed when client authentication
       is expected to occur only at another protocol layer.";
  }

  feature client-auth-x509-cert {
    description
      "Indicates that the server supports authenticating clients
       using X.509 certificates.";
    reference
      "RFC 5280:
         Internet X.509 Public Key Infrastructure Certificate
         and Certificate Revocation List (CRL) Profile";
  }

  feature client-auth-raw-public-key {
    description
      "Indicates that the server supports authenticating clients
       using raw public keys.";
    reference
      "RFC 7250:
         Using Raw Public Keys in Transport Layer Security (TLS)
         and Datagram Transport Layer Security (DTLS)";
  }

  feature client-auth-tls12-psk {
    description
      "Indicates that the server supports authenticating clients
       using PSKs (pre-shared or pairwise symmetric keys).";
    reference
      "RFC 4279:
         Pre-Shared Key Ciphersuites for Transport Layer Security
         (TLS)";
  }

  feature client-auth-tls13-epsk {
    description
      "Indicates that the server supports authenticating clients
       using TLS 1.3 External PSKs (pre-shared keys).";
    reference
      "RFC 8446:
         The Transport Layer Security (TLS) Protocol Version 1.3";
  }

  // Groupings

  grouping tls-server-grouping {
    description
      "A reusable grouping for configuring a TLS server without
```

```
        any consideration for how underlying TCP sessions are
        established.

        Note that this grouping uses fairly typical descendant
        node names such that a stack of 'uses' statements will
        have name conflicts.  It is intended that the consuming
        data model will resolve the issue (e.g., by wrapping
        the 'uses' statement in a container called
        'tls-server-parameters').  This model purposely does
        not do this itself so as to provide maximum flexibility
        to consuming models.";
      container server-identity {
        nacm:default-deny-write;
        description
          "A locally defined or referenced End-Entity (EE) certificate,
           including any configured intermediate certificates, that
           the TLS server will present when establishing a TLS
           connection in its Certificate message, as defined in
           Section 7.4.2 of RFC 5246 and Section 4.4.2 of RFC 8446.";
        reference
          "RFC 5246: The Transport Layer Security (TLS) Protocol
                     Version 1.2
           RFC 8446: The Transport Layer Security (TLS) Protocol
                     Version 1.3
           RFC 9642: A YANG Data Model for a Keystore";
        choice auth-type {
          mandatory true;
          description
            "A choice amongst authentication types, of which one must
             be enabled (via its associated 'feature') and selected.";
          case certificate {
            if-feature "server-ident-x509-cert";
            container certificate {
              description
                "Specifies the server identity using a certificate.";
              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")';
                }
              }
            }
          }
          case raw-private-key {
            if-feature "server-ident-raw-public-key";
            container raw-private-key {
              description
                "Specifies the server identity using a raw
                 private key.";
```

```
            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")';
              }
            }
          }
          case tls12-psk {
            if-feature "server-ident-tls12-psk";
            container tls12-psk {
              description
                "Specifies the server identity using a PSK (pre-shared
                 or pairwise symmetric key).";
              uses ks:inline-or-keystore-symmetric-key-grouping;
              leaf id-hint {
                type string;
                description
                  "The key 'psk_identity_hint' value used in the TLS
                   'ServerKeyExchange' message.";
                reference
                  "RFC 4279: Pre-Shared Key Ciphersuites for
                             Transport Layer Security (TLS)";
              }
            }
          }
          case tls13-epsk {
            if-feature "server-ident-tls13-epsk";
            container 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).  EPSKs MUST NOT be
                 imported for (D)TLS 1.2 or prior versions.
                 When PSKs are provisioned out of band, the PSK
                 identity and the KDF hash algorithm to be used
                 with the PSK MUST also be provisioned.

                 The structure of this container is designed to
                 satisfy the requirements in Section 4.2.11 of
                 RFC 8446, the recommendations from Section 6 of
                 RFC 9257, and the EPSK input fields detailed in
                 Section 5.1 of RFC 9258.  The base-key is based
                 upon 'ks:inline-or-keystore-symmetric-key-grouping'
                 in order to provide users with flexible and
                 secure storage options.";
              reference
                "RFC 8446: The Transport Layer Security (TLS)
                           Protocol Version 1.3
```

```
                RFC 9257: Guidance for External Pre-Shared Key
                          (PSK) Usage in TLS
                RFC 9258: Importing External Pre-Shared Keys
                          (PSKs) for TLS 1.3";
            uses ks:inline-or-keystore-symmetric-key-grouping;
            leaf external-identity {
              type string;
              mandatory true;
              description
                "As per Section 4.2.11 of RFC 8446 and Section 4.1
                 of RFC 9257, 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
                 RFC 9257: Guidance for External Pre-Shared Key
                           (PSK) Usage in TLS";
            }
            leaf hash {
              type tlscmn:epsk-supported-hash;
              default "sha-256";
              description
                "As per Section 4.2.11 of RFC 8446, for EPSKs,
                 the hash algorithm MUST be set when the PSK is
                 established; otherwise, default to SHA-256 if
                 no such algorithm is defined.  The server MUST
                 ensure that it selects a compatible PSK (if any)
                 and cipher suite.  Each PSK MUST only be used
                 with a single hash function.";
              reference
                "RFC 8446: The Transport Layer Security (TLS)
                           Protocol Version 1.3";
            }
            leaf context {
              type string;
              description
                "As per Section 5.1 of RFC 9258, context MUST
                 include 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.
                 Since the EPSK is a key derived from an external
                 protocol or sequence of protocols, context MUST
                 include a channel binding for the deriving
                 protocols (see RFC 5056).  The details of this
                 binding are protocol specific and out of scope
                 for this document.";
              reference
                "RFC 9258: Importing External Pre-Shared Keys
                           (PSKs) for TLS 1.3";
            }
            leaf target-protocol {
              type uint16;
              description
                "As per Section 3.1 of RFC 9258, the protocol
                 for which a PSK is imported for use.";
              reference
```

```
                "RFC 9258: Importing External Pre-Shared Keys
                           (PSKs) for TLS 1.3";
            }
            leaf target-kdf {
              type uint16;
              description
                "As per Section 3 of RFC 9258, the KDF for
                 which a PSK is imported for use.";
              reference
                "RFC 9258: Importing External Pre-Shared Keys
                           (PSKs) for TLS 1.3";
            }
          }
        }
      }
    } // container server-identity
    container client-authentication {
      if-feature "client-auth-supported";
      nacm:default-deny-write;
      must "ca-certs or ee-certs or raw-public-keys or tls12-psks
                    or tls13-epsks";
      presence "Indicates that client authentication is supported
                (i.e., that the server will request clients send
                certificates).  If not configured, the TLS server
                SHOULD NOT request that TLS clients provide
                authentication credentials.";
      description
        "Specifies how the TLS server can authenticate TLS clients.
         Any combination of credentials is additive and unordered.

         Note that no configuration is required for authentication
         based on PSK (pre-shared or pairwise symmetric key) as the
         the key is necessarily the same as configured in the
         '../server-identity' node.";
      container ca-certs {
        if-feature "client-auth-x509-cert";
        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 server to
           authenticate TLS client certificates.  A client
           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 {
        if-feature "client-auth-x509-cert";
        presence "Indicates that 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 client certificates (i.e., EE certificates)
```

```
           used by the TLS server to authenticate
           certificates presented by TLS clients.  A client
           certificate is authenticated if it is an exact
           match to a configured client certificate.";
        reference
          "RFC 9641: A YANG Data Model for a Truststore";
        uses ts:inline-or-truststore-certs-grouping;
      }
      container raw-public-keys {
        if-feature "client-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 the TLS server to
           authenticate raw public keys presented by the TLS
           client.  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 tls12-psks {
        if-feature "client-auth-tls12-psk";
        type empty;
        description
          "Indicates that the TLS server can authenticate TLS clients
           using configured PSKs (pre-shared or pairwise symmetric
           keys).

           No configuration is required since the PSK value is the
           same as PSK value configured in the 'server-identity'
           node.";
      }
      leaf tls13-epsks {
        if-feature "client-auth-tls13-epsk";
        type empty;
        description
          "Indicates that the TLS 1.3 server can authenticate TLS
           clients using configured External PSKs (pre-shared keys).

           No configuration is required since the PSK value is the
           same as PSK value configured in the 'server-identity'
           node.";
      }
```

```
    } // container client-authentication
    container hello-params {
      nacm:default-deny-write;
      if-feature "tlscmn:hello-params";
      uses tlscmn:hello-params-grouping;
      description
        "Configurable parameters for the TLS hello message.";
    } // container hello-params
    container keepalives {
      nacm:default-deny-write;
      if-feature "tls-server-keepalives";
      description
        "Configures the keepalive policy for the TLS server.";
      leaf peer-allowed-to-send {
        type empty;
        description
          "Indicates that the remote TLS client is allowed to send
           HeartbeatRequest messages, as defined by RFC 6520,
           to this TLS server.";
        reference
          "RFC 6520: Transport Layer Security (TLS) and Datagram
           Transport Layer Security (DTLS) Heartbeat Extension";
      }
      container test-peer-aliveness {
        presence "Indicates that the TLS server proactively tests the
                  aliveness of the remote TLS client.";
        description
          "Configures the keepalive policy to proactively test
           the aliveness of the TLS client.  An unresponsive
           TLS client is dropped after approximately max-wait
           * max-attempts seconds.";
        leaf max-wait {
          type uint16 {
            range "1..max";
          }
          units "seconds";
          default "30";
          description
            "Sets the amount of time in seconds, after which a
             TLS-level message will be sent to test the
             aliveness of the TLS client if no data has been
             received from the TLS client.";
        }
        leaf max-attempts {
          type uint8;
          default "3";
          description
            "Sets the maximum number of sequential keepalive
             messages that can fail to obtain a response from
             the TLS client before assuming the TLS client is
             no longer alive.";
        }
      }
    } // container keepalives
  } // grouping tls-server-grouping

}
```

```
<CODE ENDS>
```

5. Security Considerations

The three IETF YANG modules in this document define groupings and will not be deployed as standalone modules. Their security implications may be context dependent based on their use in other modules. The designers of modules that import these grouping must conduct their own analysis of the security considerations.

5.1. Considerations for the "iana-tls-cipher-suite-algs" YANG Module

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

The "iana-tls-cipher-suite-algs" 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 protocols have mandatory-to-implement secure transport layers (e.g., Secure Shell (SSH) [RFC4252], TLS [RFC8446], and QUIC [RFC9000]) and mandatory-to-implement mutual authentication.

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular users to a preconfigured subset of all available protocol operations and content.

This YANG module defines YANG enumerations, for a public IANA-maintained registry.

YANG enumerations are not security-sensitive, as they are statically defined in the publicly accessible YANG module. IANA **MAY** deprecate and/or obsolete enumerations over time as needed to address security issues found in the algorithms.

This module does not define any writable nodes, RPCs, actions, or notifications, and thus the security considerations for such are not provided here.

5.2. Considerations for the "ietf-tls-common" YANG Module

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

The "ietf-tls-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 protocols have mandatory-to-implement secure transport layers (e.g., Secure Shell (SSH) [RFC4252], TLS [RFC8446], and QUIC [RFC9000]) and mandatory-to-implement mutual authentication.

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular users to a preconfigured subset of all available protocol operations and content.

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

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

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

This module defines the "generate-asymmetric-key-pair" RPC that may, if the "ct:cleartext-private-keys" feature is enabled and the client requests it, return the private clear in cleartext form. It is **NOT RECOMMENDED** for private keys to pass the server's security perimeter.

This module does not define any actions or notifications, and thus the security considerations for such are not provided here.

5.3. Considerations for the "ietf-tls-client" YANG Module

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

The "ietf-tls-client" 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 protocols have mandatory-to-implement secure transport layers (e.g., Secure Shell (SSH) [RFC4252], TLS [RFC8446], and QUIC [RFC9000]) and mandatory-to-implement mutual authentication.

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular users to a preconfigured subset of all available protocol operations and content.

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

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

All the writable data nodes defined by this module may be considered sensitive or vulnerable in some network environments. For instance, 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 for all data nodes defined in this module.

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

5.4. Considerations for the "ietf-tls-server" YANG Module

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

The "ietf-tls-server" 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 protocols have mandatory-to-implement secure transport layers (e.g., Secure Shell (SSH) [RFC4252], TLS [RFC8446], and QUIC [RFC9000]) and mandatory-to-implement mutual authentication.

The Network Configuration Access Control Model (NACM) [RFC8341] provides the means to restrict access for particular users to a preconfigured subset of all available protocol operations and content.

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

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

Please be aware that this module uses the "key" and "private-key" nodes from the "ietf-crypto-types" module [RFC9640], where said nodes have the NACM extension "default-deny-all" set, thus preventing unrestricted read access to the cleartext key values.

All the writable data nodes defined by this module may be considered sensitive or vulnerable in some network environments. For instance, 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 for all data nodes defined in this module.

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

6. IANA Considerations

6.1. The IETF XML Registry

IANA has registered the following four URIs in the "ns" registry of the "IETF XML Registry" [RFC3688].

URI: urn:ietf:params:xml:ns:yang:iana-tls-cipher-suite-algs
Registrant Contact: The IESG

XML: N/A; the requested URI is an XML namespace.

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

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

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

6.2. The YANG Module Names Registry

IANA has registered the following four YANG modules in the "YANG Module Names" registry [RFC6020].

name: iana-tls-cipher-suite-algs
Maintained by IANA: Y
namespace: urn:ietf:params:xml:ns:yang:iana-tls-cipher-suite-algs
prefix: tlscsa
reference: RFC 9645

name: ietf-tls-common
Maintained by IANA: N
namespace: urn:ietf:params:xml:ns:yang:ietf-tls-common
prefix: tlscmn
reference: RFC 9645

name: ietf-tls-client
Maintained by IANA: N
namespace: urn:ietf:params:xml:ns:yang:ietf-tls-client
prefix: tlsc
reference: RFC 9645

name: ietf-tls-server
Maintained by IANA: N
namespace: urn:ietf:params:xml:ns:yang:ietf-tls-server
prefix: tlss
reference: RFC 9645

6.3. Considerations for the "iana-tls-cipher-suite-algs" YANG Module

This section follows the template defined in Section 4.30.3.1 of [RFC8407BIS].

IANA used the script in Appendix A to generate the IANA-maintained "iana-tls-cipher-suite-algs" YANG module. The YANG module is available from the "YANG Parameters" registry [IANA-YANG-PARAMETERS].

IANA has added the following note to the registry:

> New values must not be directly added to the "iana-tls-cipher-suite-algs" YANG module. They must instead be added to the "TLS Cipher Suites" registry in the "Transport Layer Security (TLS) Parameters" registry group [IANA-CIPHER-ALGS].

When a value is added to the "TLS Cipher Suites" registry, a new "enum" statement must be added to the "iana-tls-cipher-suite-algs" YANG module. The "enum" statement, and substatements thereof, should be defined as follows:

enum
: Replicates a name from the registry.

value
: Contains the decimal value of the IANA-assigned value.

status
: Include only if a registration has been deprecated or obsoleted. An IANA "Recommended" value "N" maps to YANG status "deprecated". Since the registry is unable to express a logical "**MUST NOT**" recommendation, there is no mapping to YANG status "obsolete", which is unfortunate given the moving of single-DES and International Data Encryption Algorithm (IDEA) TLS cipher suites to Historic [RFC8996].

description
: Contains "Enumeration for the 'TLS_FOO' algorithm", where "TLS_FOO" is a placeholder for the algorithm's name (e.g., "TLS_PSK_WITH_AES_256_CBC_SHA").

reference
: Replicates the reference(s) from the registry with the title of the document(s) added.

Unassigned or reserved values are not present in the module.

When the "iana-tls-cipher-suite-algs" YANG module is updated, a new "revision" statement with a unique revision date must be added in front of the existing revision statements. The "revision" must have a "description" statement explaining why the the update occurred and must have a "reference" substatement that points to the document defining the registry update that resulted in this change. For instance:

```
revision 2024-10-10 {
    description
        "This update reflects the update made to the underlying
         'Foo Bar' registry per RFC XXXX.";
    reference
        "RFC XXXX: Extend the Foo Bar Registry
                   to Support Something Important";
}
```

IANA has added the following note to the "TLS Cipher Suites" registry under the "Transport Layer Security (TLS) Parameters" registry group [IANA-CIPHER-ALGS].

> When this registry is modified, the YANG module "iana-tls-cipher-suite-algs" [IANA-YANG-PARAMETERS] must be updated as defined in RFC 9645.

7. References

7.1. Normative References

[FIPS180-4] National Institute of Standards and Technology (NIST), "Secure Hash Standard (SHS)", FIPS PUB 180-4, DOI 10.6028/NIST.FIPS.180-4, August 2015, <https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.180-4.pdf>.

[FIPS186-5] National Institute of Standards and Technology (NIST), "Digital Signature Standard (DSS)", FIPS 186-5, DOI 10.6028/NIST.FIPS.186-5, February 2023, <https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.186-5.pdf>.

[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>.

[RFC4252] Ylonen, T. and C. Lonvick, Ed., "The Secure Shell (SSH) Authentication Protocol", RFC 4252, DOI 10.17487/RFC4252, January 2006, <https://www.rfc-editor.org/info/rfc4252>.

[RFC4279] Eronen, P., Ed. and H. Tschofenig, Ed., "Pre-Shared Key Ciphersuites for Transport Layer Security (TLS)", RFC 4279, DOI 10.17487/RFC4279, December 2005, <https://www.rfc-editor.org/info/rfc4279>.

[RFC5280] Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", RFC 5280, DOI 10.17487/RFC5280, May 2008, <https://www.rfc-editor.org/info/rfc5280>.

[RFC5288] Salowey, J., Choudhury, A., and D. McGrew, "AES Galois Counter Mode (GCM) Cipher Suites for TLS", RFC 5288, DOI 10.17487/RFC5288, August 2008, <https://www.rfc-editor.org/info/rfc5288>.

[RFC5289] Rescorla, E., "TLS Elliptic Curve Cipher Suites with SHA-256/384 and AES Galois Counter Mode (GCM)", RFC 5289, DOI 10.17487/RFC5289, August 2008, <https://www.rfc-editor.org/info/rfc5289>.

[RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <https://www.rfc-editor.org/info/rfc6020>.

[RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <https://www.rfc-editor.org/info/rfc6241>.

[RFC6520] Seggelmann, R., Tuexen, M., and M. Williams, "Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS) Heartbeat Extension", RFC 6520, DOI 10.17487/RFC6520, February 2012, <https://www.rfc-editor.org/info/rfc6520>.

[RFC7250] Wouters, P., Ed., Tschofenig, H., Ed., Gilmore, J., Weiler, S., and T. Kivinen, "Using Raw Public Keys in Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS)", RFC 7250, DOI 10.17487/RFC7250, June 2014, <https://www.rfc-editor.org/info/rfc7250>.

[RFC7589] Badra, M., Luchuk, A., and J. Schoenwaelder, "Using the NETCONF Protocol over Transport Layer Security (TLS) with Mutual X.509 Authentication", RFC 7589, DOI 10.17487/RFC7589, June 2015, <https://www.rfc-editor.org/info/rfc7589>.

[RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, DOI 10.17487/RFC7950, August 2016, <https://www.rfc-editor.org/info/rfc7950>.

[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>.

[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>.

[RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", STD 91, RFC 8341, DOI 10.17487/RFC8341, March 2018, <https://www.rfc-editor.org/info/rfc8341>.

[RFC8422] Nir, Y., Josefsson, S., and M. Pegourie-Gonnard, "Elliptic Curve Cryptography (ECC) Cipher Suites for Transport Layer Security (TLS) Versions 1.2 and Earlier", RFC 8422, DOI 10.17487/RFC8422, August 2018, <https://www.rfc-editor.org/info/rfc8422>.

[RFC8446] Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <https://www.rfc-editor.org/info/rfc8446>.

[RFC9000] Iyengar, J., Ed. and M. Thomson, Ed., "QUIC: A UDP-Based Multiplexed and Secure Transport", RFC 9000, DOI 10.17487/RFC9000, May 2021, <https://www.rfc-editor.org/info/rfc9000>.

[RFC9640] Watsen, K., "YANG Data Types and Groupings for Cryptography", RFC 9640, DOI 10.17487/RFC9640, October 2024, <https://www.rfc-editor.org/info/rfc9640>.

[RFC9641] Watsen, K., "A YANG Data Model for a Truststore", RFC 9641, DOI 10.17487/RFC9641, October 2024, <https://www.rfc-editor.org/info/rfc9641>.

[RFC9642] Watsen, K., "A YANG Data Model for a Keystore", RFC 9642, DOI 10.17487/RFC9642, October 2024, <https://www.rfc-editor.org/info/rfc9642>.

7.2. Informative References

[HTTP-CLIENT-SERVER] Watsen, K., "YANG Groupings for HTTP Clients and HTTP Servers", Work in Progress, Internet-Draft, draft-ietf-netconf-http-client-server-23, 15 August 2024, <https://datatracker.ietf.org/doc/html/draft-ietf-netconf-http-client-server-23>.

[IANA-CIPHER-ALGS] IANA, "TLS Cipher Suites", <https://www.iana.org/assignments/tls-parameters/>.

[IANA-YANG-PARAMETERS] IANA, "YANG Parameters", <https://www.iana.org/assignments/yang-parameters>.

[NETCONF-CLIENT-SERVER] Watsen, K., "NETCONF Client and Server Models", Work in Progress, Internet-Draft, draft-ietf-netconf-netconf-client-server-37, 14 August 2024, <https://datatracker.ietf.org/doc/html/draft-ietf-netconf-netconf-client-server-37>.

[RESTCONF-CLIENT-SERVER] Watsen, K., "RESTCONF Client and Server Models", Work in Progress, Internet-Draft, draft-ietf-netconf-restconf-client-server-38, 14 August 2024, <https://datatracker.ietf.org/doc/html/draft-ietf-netconf-restconf-client-server-38>.

[RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <https://www.rfc-editor.org/info/rfc3688>.

[RFC5056] Williams, N., "On the Use of Channel Bindings to Secure Channels", RFC 5056, DOI 10.17487/RFC5056, November 2007, <https://www.rfc-editor.org/info/rfc5056>.

[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>.

[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>.

[RFC8259] Bray, T., Ed., "The JavaScript Object Notation (JSON) Data Interchange Format", STD 90, RFC 8259, DOI 10.17487/RFC8259, December 2017, <https://www.rfc-editor.org/info/rfc8259>.

[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>.

[RFC8342] Bjorklund, M., Schoenwaelder, J., Shafer, P., Watsen, K., and R. Wilton, "Network Management Datastore Architecture (NMDA)", RFC 8342, DOI 10.17487/RFC8342, March 2018, <https://www.rfc-editor.org/info/rfc8342>.

[RFC8407] Bierman, A., "Guidelines for Authors and Reviewers of Documents Containing YANG Data Models", BCP 216, RFC 8407, DOI 10.17487/RFC8407, October 2018, <https://www.rfc-editor.org/info/rfc8407>.

[RFC8407BIS] Bierman, A., Boucadair, M., and Q. Wu, "Guidelines for Authors and Reviewers of Documents Containing YANG Data Models", Work in Progress, Internet-Draft, draft-ietf-netmod-rfc8407bis-17, 27 September 2024, <https://datatracker.ietf.org/doc/html/draft-ietf-netmod-rfc8407bis-17>.

[RFC8996] Moriarty, K. and S. Farrell, "Deprecating TLS 1.0 and TLS 1.1", BCP 195, RFC 8996, DOI 10.17487/RFC8996, March 2021, <https://www.rfc-editor.org/info/rfc8996>.

[RFC9110] Fielding, R., Ed., Nottingham, M., Ed., and J. Reschke, Ed., "HTTP Semantics", STD 97, RFC 9110, DOI 10.17487/RFC9110, June 2022, <https://www.rfc-editor.org/info/rfc9110>.

[RFC9257] Housley, R., Hoyland, J., Sethi, M., and C. A. Wood, "Guidance for External Pre-Shared Key (PSK) Usage in TLS", RFC 9257, DOI 10.17487/RFC9257, July 2022, <https://www.rfc-editor.org/info/rfc9257>.

[RFC9258] Benjamin, D. and C. A. Wood, "Importing External Pre-Shared Keys (PSKs) for TLS 1.3", RFC 9258, DOI 10.17487/RFC9258, July 2022, <https://www.rfc-editor.org/info/rfc9258>.

[RFC9643] Watsen, K. and M. Scharf, "YANG Groupings for TCP Clients and TCP Servers", RFC 9643, DOI 10.17487/RFC9643, October 2024, <https://www.rfc-editor.org/info/rfc9643>.

[RFC9644] Watsen, K., "YANG Groupings for SSH Clients and SSH Servers", RFC 9644, DOI 10.17487/RFC9644, October 2024, <https://www.rfc-editor.org/info/rfc9644>.

[SYSTEM-CONFIG] Ma, Q., Wu, Q., and C. Feng, "System-defined Configuration", Work in Progress, Internet-Draft, draft-ietf-netmod-system-config-09, 29 September 2024, <https://datatracker.ietf.org/doc/html/draft-ietf-netmod-system-config-09>.

[W3C.REC-xml-20081126] Bray, T., Paoli, J., Sperberg-McQueen, C. M., Maler, E., and F. Yergeau, "Extensible Markup Language (XML) 1.0 (Fifth Edition)", W3C Recommendation REC-xml-20081126, November 2008, <https://www.w3.org/TR/xml/>.

Appendix A. Script to Generate IANA-Maintained YANG Modules

This section is not normative.

The Python <https://www.python.org> script contained in this section was used to create the initial IANA-maintained "iana-tls-cipher-suite-algs" YANG module maintained at [IANA-YANG-PARAMETERS].

Run the script using the command 'python gen-yang-modules.py' to produce the YANG module file in the current directory.

Be aware that the script does not attempt to copy the "revision" statements from the previous/current YANG module. Copying the revision statements must be done manually.

```
<CODE BEGINS>
=============== NOTE: '\\' line wrapping per RFC 8792 ===============

import re
import csv
import requests
import textwrap
import requests_cache
from io import StringIO
from datetime import datetime

# Metadata for the one YANG module produced by this script
MODULES = [
    {
        "csv_url": "https://www.iana.org/assignments/tls-parameters/\
\tls-parameters-4.csv",
        "spaced_name": "cipher-suite",
        "hyphenated_name": "cipher-suite",
        "prefix": "tlscsa",
    }
]


def create_module_begin(module, f):

    # Define template for all four modules
    PREAMBLE_TEMPLATE="""
module iana-tls-HNAME-algs {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:iana-tls-HNAME-algs";
  prefix PREFIX;

  organization
    "Internet Assigned Numbers Authority (IANA)";
```

```
  contact
    "Postal: ICANN
             12025 Waterfront Drive, Suite 300
             Los Angeles, CA  90094-2536
             United States of America
     Tel:    +1 310 301 5800
     Email:  <iana@iana.org>";

  description
    "This module defines enumerations for the cipher suite
     algorithms defined in the 'TLS Cipher Suites' registry
     under the 'Transport Layer Security (TLS) Parameters'
     registry group maintained by IANA.

     Copyright (c) 2024 IETF Trust and the persons identified as
     authors of the code. All rights reserved.

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

     The initial version of this YANG module is part of RFC 9645
     (https://www.rfc-editor.org/info/rfc9645); see the RFC
     itself for full legal notices.

     All versions of this module are published by IANA
     (https://www.iana.org/assignments/yang-parameters).";

  revision DATE {
    description
      "This initial version of the module was created using
       the script defined in RFC 9645 to reflect the contents
       of the SNAME algorithms registry maintained by IANA.";
    reference
      "RFC 9645: YANG Groupings for TLS Clients and TLS Servers";
  }

  typedef tls-HNAME-algorithm {
    type enumeration {
"""
    # Replacements
    rep = {
      "DATE": datetime.today().strftime('%Y-%m-%d'),
      "YEAR": datetime.today().strftime('%Y'),
      "SNAME": module["spaced_name"],
      "HNAME": module["hyphenated_name"],
      "PREFIX": module["prefix"]
    }

    # Do the replacement
    rep = dict((re.escape(k), v) for k, v in rep.items())
    pattern = re.compile("|".join(rep.keys()))
    text = pattern.sub(lambda m: rep[re.escape(m.group(0))], PREAMBL\
\E_TEMPLATE)
```

```
    # Write preamble into the file
    f.write(text)


def create_module_body(module, f):

    # Fetch the current CSV file from IANA
    r = requests.get(module["csv_url"])
    assert r.status_code == 200, "Could not get " + module["csv_url"]

    # Parse each CSV line
    with StringIO(r.text) as csv_file:
        csv_reader = csv.DictReader(csv_file)
        for row in csv_reader:

            # Skip reserved algs
            if row["Description"].startswith("Unassigned"):
                continue

            # Skip unassigned algs
            if row["Description"].startswith("Reserved"):
                continue

            # Ensure this is the TLS line
            assert row["Description"].startswith("TLS_"), "Unrecogni\
\zed description: '" + row["Description"] + "'"

            # Set the 'refs' and 'titles' lists
            if row["Reference"] == "":
                pass # skip when the Reference field is empty

            else:

                # There may be more than one ref
                refs = row["Reference"][1:-1]  # remove the '[' and \
\']' chars
                refs = refs.split("][")
                titles = []
                for ref in refs:

                    # Ascertain the ref's title
                    if ref.startswith("RFC"):

                        # Fetch the current BIBTEX entry
                        bibtex_url="https://datatracker.ietf.org/doc\
\/"+ ref.lower() + "/bibtex/"
                        r = requests.get(bibtex_url)
                        assert r.status_code == 200, "Could not GET \
\" + bibtex_url

                        # Append to 'titles' value from the "title" \
\line
                        for item in r.text.split("\n"):
                            if "title =" in item:
                                title = re.sub('.*{{(.*)}}.*', r'\g<\
\1>', item)
                                if title.startswith("ECDHE\_PSK"):
```

```
                                    title = re.sub("ECDHE\\\\_PSK", \
\"ECDHE_PSK", title)
                                titles.append(re.sub('.*{{(.*)}}.*',\
\ r'\g<1>', title))
                                break
                        else:
                            raise Exception("RFC title not found")


                        # Insert a space: "RFC9645" --> "RFC 9645"
                        index = refs.index(ref)
                        refs[index] = "RFC " + ref[3:]

                    elif ref == "IESG Action 2018-08-16":

                        # Rewrite the ref value
                        index = refs.index(ref)
                        refs[index] = "IESG Action"

                        # Let title be something descriptive
                        titles.append("IESG Action 2018-08-16")

                    elif ref == "draft-irtf-cfrg-aegis-aead-08":

                        # Manually set the document's title
                        titles.append("The AEGIS Family of Authentic\
\ated Encryption Algorithms")

                    elif ref:
                        raise Exception(f'ref "{ref}" not found')

                    else:
                        raise Exception(f'ref missing: {row}')

            # Write out the enum
            f.write(f'      enum {row["Description"]} {{\n');
            if row["Recommended"] == 'N':
                f.write(f'        status deprecated;\n')
            f.write(f'        description\n')
            description = f'          "Enumeration for the \'{row["D\
\escription"]}\' algorithm.";'
            description = textwrap.fill(description, width=69, subse\
\quent_indent="           ")
            f.write(f'{description}\n')
            f.write('        reference\n')
            f.write('          "')
            if row["Reference"] == "":
                f.write('Missing in IANA registry.')
            else:
                ref_len = len(refs)
                for i in range(ref_len):
                    ref = refs[i]
                    f.write(f'{ref}:\n')
                    title = "            " + titles[i]
                    if i == ref_len - 1:
                        title += '";'
                    title = textwrap.fill(title, width=69, subsequen\
\t_indent="            ")
```

```
                    f.write(f'{title}')
                    if i != ref_len - 1:
                        f.write('\n           ')
            f.write('\n')
            f.write('      }\n')



def create_module_end(module, f):

    # Close out the enumeration, typedef, and module
    f.write("    }\n")
    f.write("    description\n")
    f.write(f'      "An enumeration for TLS {module["spaced_name"]} \
\algorithms.";\n')
    f.write("  }\n")
    f.write('\n')
    f.write('}\n')


def create_module(module):

    # Install cache for 8x speedup
    requests_cache.install_cache()

    # Ascertain the yang module's name
    yang_module_name = "iana-tls-" + module["hyphenated_name"] + "-a\
\lgs.yang"

    # Create yang module file
    with open(yang_module_name, "w") as f:
        create_module_begin(module, f)
        create_module_body(module, f)
        create_module_end(module, f)


def main():
    for module in MODULES:
        create_module(module)


if __name__ == "__main__":
    main()

<CODE ENDS>
```

Acknowledgements

The authors would like to thank the following for lively discussions on list and in the halls (ordered by first name): Alan Luchuk, Andy Bierman, Balázs Kovács, Benoit Claise, Bert Wijnen, David Lamparter, Dhruv Dhody, Éric Vyncke, Gary Wu, Henk Birkholz, Jeff Hartley, Jürgen Schönwälder, Ladislav Lhotka, Liang Xia, Martin Björklund, Martin Thomson, Mehmet Ersue, Michal Vaško, Murray Kucherawy, Paul Wouters, Phil Shafer, Qin Wu, Radek Krejci, Rob Wilton, Roman Danyliw, Russ Housley, Sean Turner, Thomas Martin, and Tom Petch.

Contributors

Special acknowledgement goes to Gary Wu who contributed the "ietf-tls-common" module and Tom Petch who carefully ensured that references were set correctly throughout.

Author's Address

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