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Two-Way Active Measurement Protocol (TWAMP) Data Model
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Abstract

This document specifies a data model for client and server implementations of the Two-Way Active Measurement Protocol (TWAMP). We define the TWAMP data model through Unified Modeling Language (UML) class diagrams and formally specify it using YANG.

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1. Introduction

The Two-Way Active Measurement Protocol (TWAMP) [[RFC5357](#)] is used to measure network performance parameters such as latency, bandwidth, and packet loss by sending probe packets and measuring their experience in the network. To date, TWAMP implementations do not come with a standard management framework and, as such, configuration depends on proprietary mechanisms developed by the corresponding TWAMP vendor. This document addresses this gap by formally specifying the TWAMP data model using YANG.

1.1. Motivation

In current TWAMP deployments the lack of a standardized data model limits the flexibility to dynamically instantiate TWAMP-based measurements across equipment from different vendors. In large, virtualized, and dynamically instantiated infrastructures where network functions are placed according to orchestration algorithms as discussed in [[I-D.unify-nfvrg-challenges](#)][[I-D.unify-nfvrg-devops](#)], proprietary mechanisms for managing TWAMP measurements pose severe limitations with respect to programmability.

Two major trends call for revisiting the standardization on TWAMP management aspects. First, we expect that in the coming years large-scale and multi-vendor TWAMP deployments will become the norm. From an operations perspective, dealing with several vendor-specific TWAMP configuration mechanisms is simply unsustainable in this context. Second, the increasingly software-defined and virtualized nature of network infrastructures, based on dynamic service chains [[NSC](#)] and programmable control and management planes [[RFC7426](#)] requires a well-defined data model for TWAMP implementations. This document defines such a TWAMP data model and specifies it formally using the YANG data modeling language [[RFC6020](#)].

1.2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [[RFC2119](#)].

1.3. Document Organization

The rest of this document is organized as follows. [Section 2](#) presents the scope and applicability of this document. [Section 3](#) provides a high-level overview of the TWAMP data model. [Section 4](#) details the configuration parameters of the data model and [Section 5](#) specifies in YANG the TWAMP data model. [Section 6](#) lists illustrative

examples which conform to the YANG data model specified in this document. [Appendix A](#) elaborates these examples further.

2. Scope, Model, and Applicability

The purpose of this document is the specification of a vendor-independent data model for TWAMP implementations.

Figure 1 illustrates a redrawn version of the TWAMP logical model found in [Section 1.2 of \[RFC5357\]](#). The figure is annotated with pointers to the UML diagrams provided in this document and associated with the data model of the four logical entities in a TWAMP deployment, namely the TWAMP Control-Client, Server, Session-Sender and Session-Reflector.

As per [\[RFC5357\]](#), unlabeled links in Figure 1 are left unspecified and may be proprietary protocols.

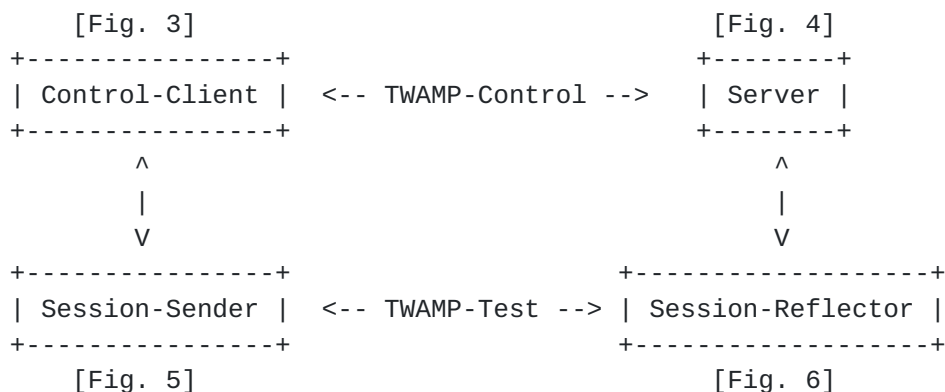


Figure 1: Annotated TWAMP logical model

As per [\[RFC5357\]](#), a TWAMP implementation may follow a simplified logical model, in which the same node acts both as Control-Client and Session-Sender, while another node acts at the same time as TWAMP Server and Session-Reflector. Figure 2 illustrates this simplified logical model and indicates the interaction between the TWAMP configuration client and server using, for instance, NETCONF [\[RFC6241\]](#) or RESTCONF [\[I-D.ietf-netconf-restconf\]](#).

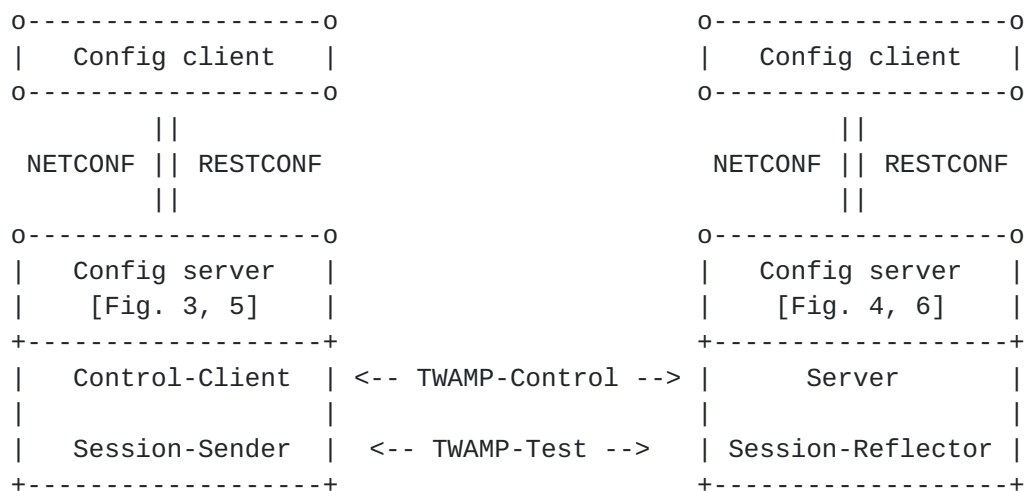


Figure 2: Simplified TWAMP model and protocols

We note that the data model defined in this document is orthogonal to the specific protocol used between the Config client and Config server to communicate the TWAMP configuration parameters.

Operational actions such as how TWAMP-Test sessions are started and stopped, how performance measurement results are retrieved, or how stored results are cleared, and so on, are not addressed by the configuration model defined in this document. As noted above, such operational actions are not part of the TWAMP specification [RFC5357] and hence are out of scope of this document. See also [Appendix B](#).

3. Data Model Overview

The TWAMP data model includes four categories of configuration items.

Global configuration items relate to parameters that are set on a per device level. For example, the administrative status of the device with respect to whether it allows TWAMP sessions and, if so, in what capacity (e.g. Control-Client, Server or both), are typical instances of global configuration items.

A second category includes attributes that can be configured on a per TWAMP-Control connection basis, such as the Server IP address.

A third category includes attributes related to per TWAMP-Test session attributes, for instance setting different values in the Differentiated Services Code Point (DSCP) field.

Finally, the data model includes attributes that relate to the operational state of the TWAMP implementation.

As we describe the TWAMP data model in the remaining sections of this document, readers should keep in mind the functional entity grouping illustrated in Figure 1.

3.1. Control-Client

A TWAMP Control-Client has an administrative status field set at the device level that indicates whether the node is enabled to function as such.

Each TWAMP Control-Client is associated with zero or more TWAMP-Control connections. The main configuration parameters of each control connection are:

- o A name which can be used to uniquely identify at the Control-Client a particular control connection. This name is necessary for programmability reasons because at the time of creation of a TWAMP-Control connection not all IP and TCP port number information needed to uniquely identify the connection is available.
- o The IP address of the interface the Control-Client will use for connections.
- o The IP address of the remote TWAMP Server.
- o Authentication and Encryption attributes such as KeyID, Token and the Client Initialization Vector (Client-IV); see also the last paragraph of [Section 6 in \[RFC4656\]](#) and [\[RFC4086\]](#).

Each TWAMP-Control connection, in turn, is associated with zero or more TWAMP-Test sessions. For each test session we note the following configuration items:

- o The test session name that uniquely identifies a particular test session at the Control-Client and Session-Sender. Similarly to the control connections above, this unique test session name is needed because at the time of creation of a TWAMP-Test session, for example, the source UDP port number is not known to uniquely identify the test session.
- o The IP address and UDP port number of the Session-Sender on the path under test by TWAMP.
- o The IP address and UDP port number of the Session-Reflector on said path.

- o Information pertaining to the test packet stream, such as the test starting time, which performance metric is to be used [[I-D.ietf-ippm-metric-registry](#)], or whether the test should be repeated.

[3.2.](#) Server

Each TWAMP Server has an administrative status field set at the device level to indicate whether the node is enabled to function as a TWAMP Server.

Each Server is associated with zero or more TWAMP-Control connections. Each control connection is uniquely identified by the 4-tuple {Control-Client IP address, Control-Client TCP port number, Server IP address, Server TCP port}. Control connection configuration items on a TWAMP Server are read-only.

[3.3.](#) Session-Sender

There is one Session-Sender instance for each TWAMP-Test session that is initiated from the sending device. Primary configuration fields include:

- o The test session name that MUST be identical with the corresponding test session name on the TWAMP Control-Client ([Section 3.1](#))
- o The control connection name, which along with the test session name uniquely identify the TWAMP Session-Sender instance
- o Information pertaining to the test packet stream, such as, for example, the number of test packets and the packet distribution to be employed; see also [[RFC3432](#)].

[3.4.](#) Session-Reflector

Each Session-Reflector is associated with zero or more TWAMP-Test sessions. For each test session, the REFWAIT parameter ([Section 4.2](#) of [[RFC5357](#)]) can be configured.

Read-only access to other data model parameters, such as the Sender IP address is foreseen. Each test session can be uniquely identified by the 4-tuple mentioned in [Section 3.2](#).

4. Data Model Parameters

This section defines the TWAMP data model using UML and introduces selected parameters associated with the four TWAMP logical entities. The complete TWAMP data model specification is provided in the YANG module presented in [Section 5.2](#).

4.1. Control-Client

The client container (see Figure 3) holds items that are related to the configuration of the TWAMP Control-Client logical entity (recall Figure 1).

The client container includes an administrative configuration parameter (client/admin-state) that indicates whether the device is allowed to initiate TWAMP-Control connections.

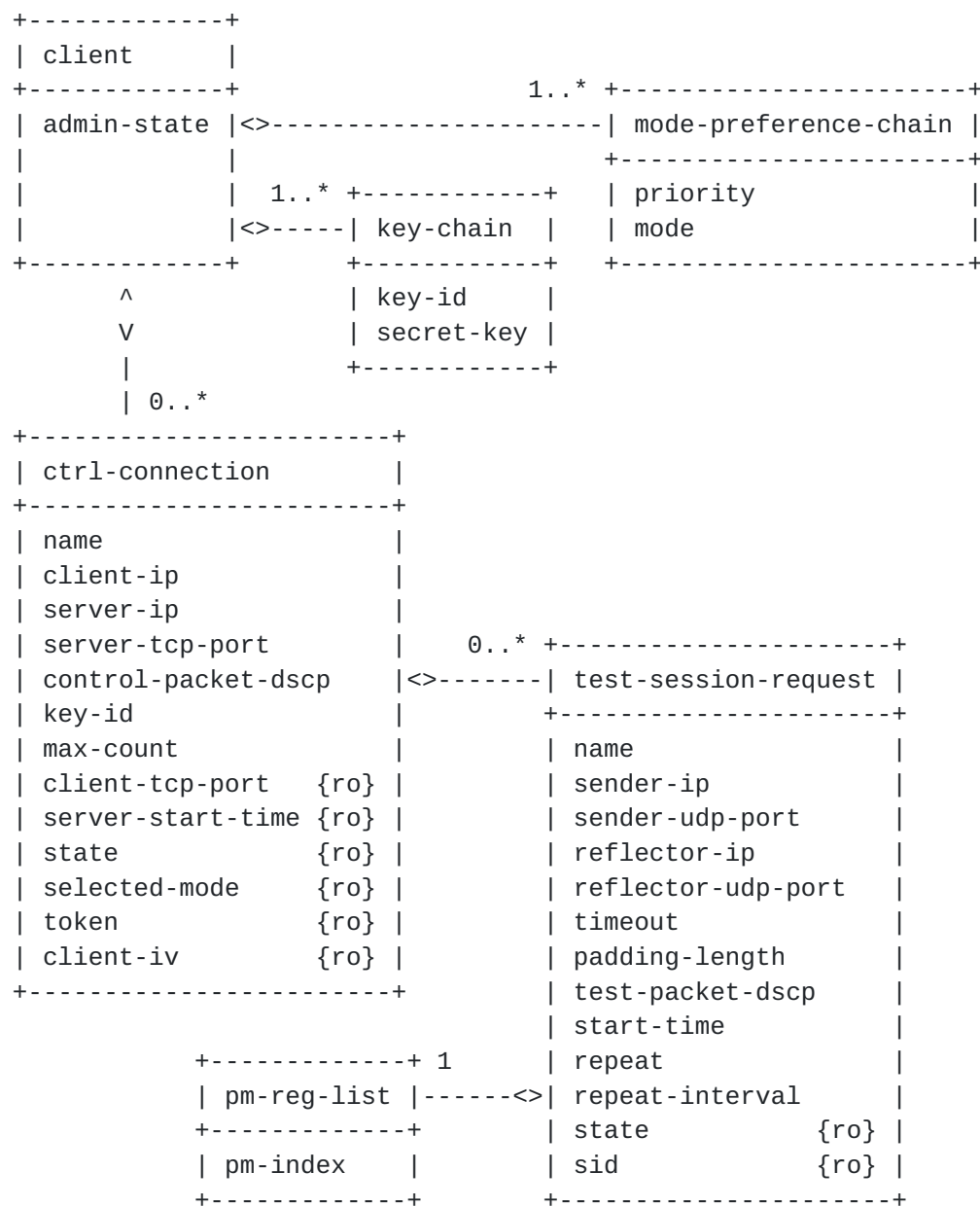


Figure 3: TWAMP Control-Client UML class diagram

The client container holds a list (mode-preference-chain) which specifies the Mode values according to their preferred order of use by the operator of this Control-Client, including the authentication and encryption Modes. Specifically, mode-preference-chain lists each priority (expressed as a 16-bit unsigned integer, where zero is the highest priority and subsequent values monotonically increasing) with their corresponding mode (expressed as a 32-bit Hexadecimal value).

Depending on the Modes available in the Server Greeting, the Control-Client MUST choose the highest priority Mode from the configured mode-preference-chain list.

Note that the list of preferred Modes may set bit position combinations when necessary, such as when referring to the extended TWAMP features in [[RFC5618](#)], [[RFC5938](#)], [[RFC6038](#)], and [[RFC7717](#)]. If the Control-Client cannot determine an acceptable Mode, it MUST respond with zero Mode bits set in the Set-up Response message, indicating it will not continue with the control connection.

In addition, the client container holds a list named key-chain which relates KeyIDs with the respective secret keys. Both the Server and the Control-Client use the same mappings from KeyIDs to shared secrets (key-id and secret-key in Figure 3, respectively). The Server, being prepared to conduct sessions with more than one Control-Client, uses KeyIDs to choose the appropriate secret-key; a Control-Client would typically have different secret keys for different Servers. The secret-key is the shared secret, an octet string of arbitrary length whose interpretation as a text string is unspecified. The key-id and secret-key encoding should follow [Section 9.4 of \[RFC6020\]](#). The derived key length (dkLen in [[RFC2898](#)]) MUST be 128-bits for the AES Session-key used for encryption and a 256-bit HMAC-SHA1 Session-key used for authentication (see [Section 6.10 of \[RFC4656\]](#)).

Each client container also holds a list of ctrl-connections, where each item in the list describes a TWAMP control connection that will be initiated by this Control-Client. There SHALL be one instance of ctrl-connection per TWAMP-Control (TCP) connection that is to be initiated from this device.

Each ctrl-connection holds a list of test-session-request. test-session-request holds information associated with the Control-Client for this test session. This includes information that is associated with the Request-TW-Session/Accept-Session message exchange (see [Section 3.5 of \[RFC5357\]](#)).

There SHALL be one instance of test-session-request for each TWAMP-Test session that is to be negotiated by this TWAMP-Control connection via a Request-TW-Session/Accept-Session exchange.

The Control-Client is also responsible for scheduling and results collection for TWAMP-Test sessions, so test-session-request will also hold information related to these actions (e.g. pm-index, repeat-interval).

4.2. Server

The server container (see Figure 4) holds items that are related to the configuration of the TWAMP Server logical entity (recall Figure 1).

The server container includes an administrative configuration parameter (server/admin-state) that indicates whether the device is allowed to receive TWAMP-Control connections.

A device operating in the Server role cannot configure attributes on a per TWAMP-Control connection basis, as it has no foreknowledge of the incoming TWAMP-Control connections to be received. As such, any parameter that the Server might want to apply to an incoming control connection must be configured at the overall Server level, and will then be applied to all incoming TWAMP-Control connections.

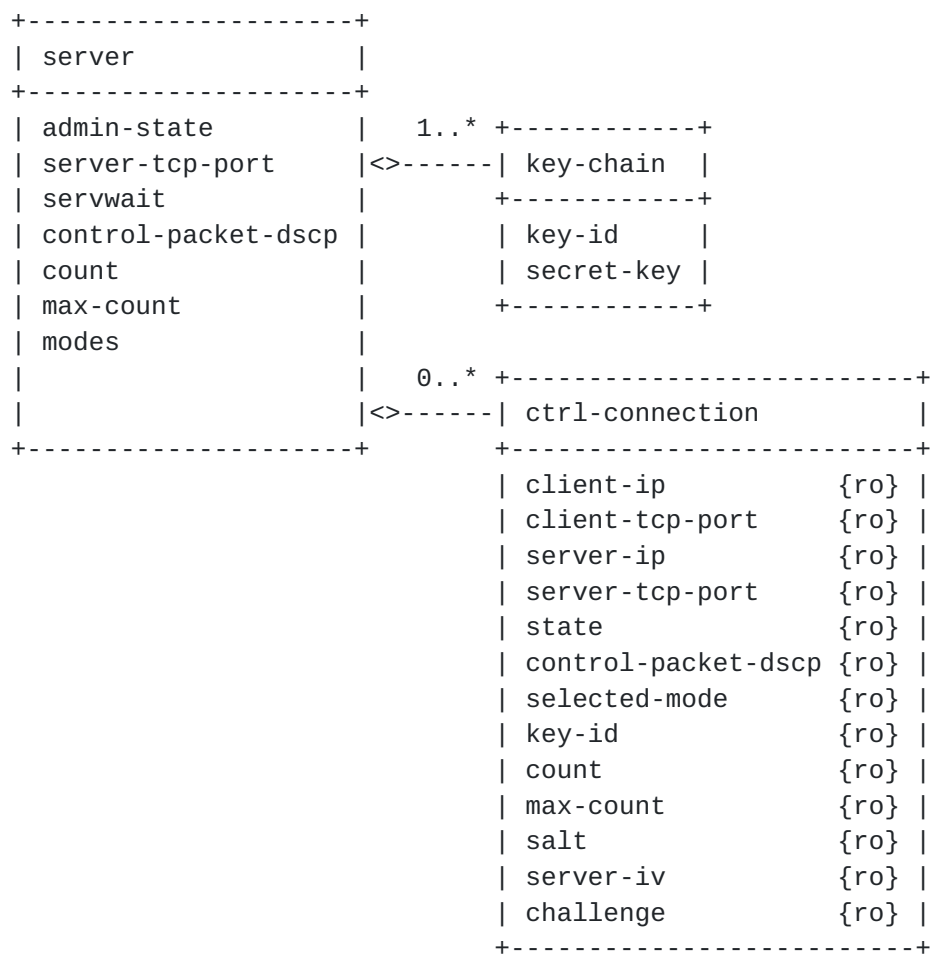


Figure 4: TWAMP Server UML class diagram

Each server container holds a list named `key-chain` which relates KeyIDs with the respective secret keys. As mentioned in [Section 4.1](#), both the Server and the Control-Client use the same mappings from KeyIDs to shared secrets. The Server, being prepared to conduct sessions with more than one Control-Client, uses KeyIDs to choose the appropriate secret-key; a Control-Client would typically have different secret keys for different Servers. `key-id` tells the Server which shared-secret the Control-Client wishes to use for authentication or encryption.

Each incoming control connection that is active on the Server will be represented by an instance of a `ctrl-connection` object. There SHALL be one instance of `ctrl-connection` per incoming TWAMP-Control (TCP) connection that is received and active on the Server device.

All items in the `ctrl-connection` object are read-only. Each instance of `ctrl-connection` can be uniquely identified by the 4-tuple {`client-ip`, `client-tcp-port`, `server-ip`, `server-tcp-port`}.

4.3. Session-Sender

The `session-sender` container, illustrated in Figure 5, holds items that are related to the configuration of the TWAMP Session-Sender logical entity.

The `session-sender` container includes an administrative parameter (`session-sender/admin-state`) that controls whether the device is allowed to initiate TWAMP-Test sessions.

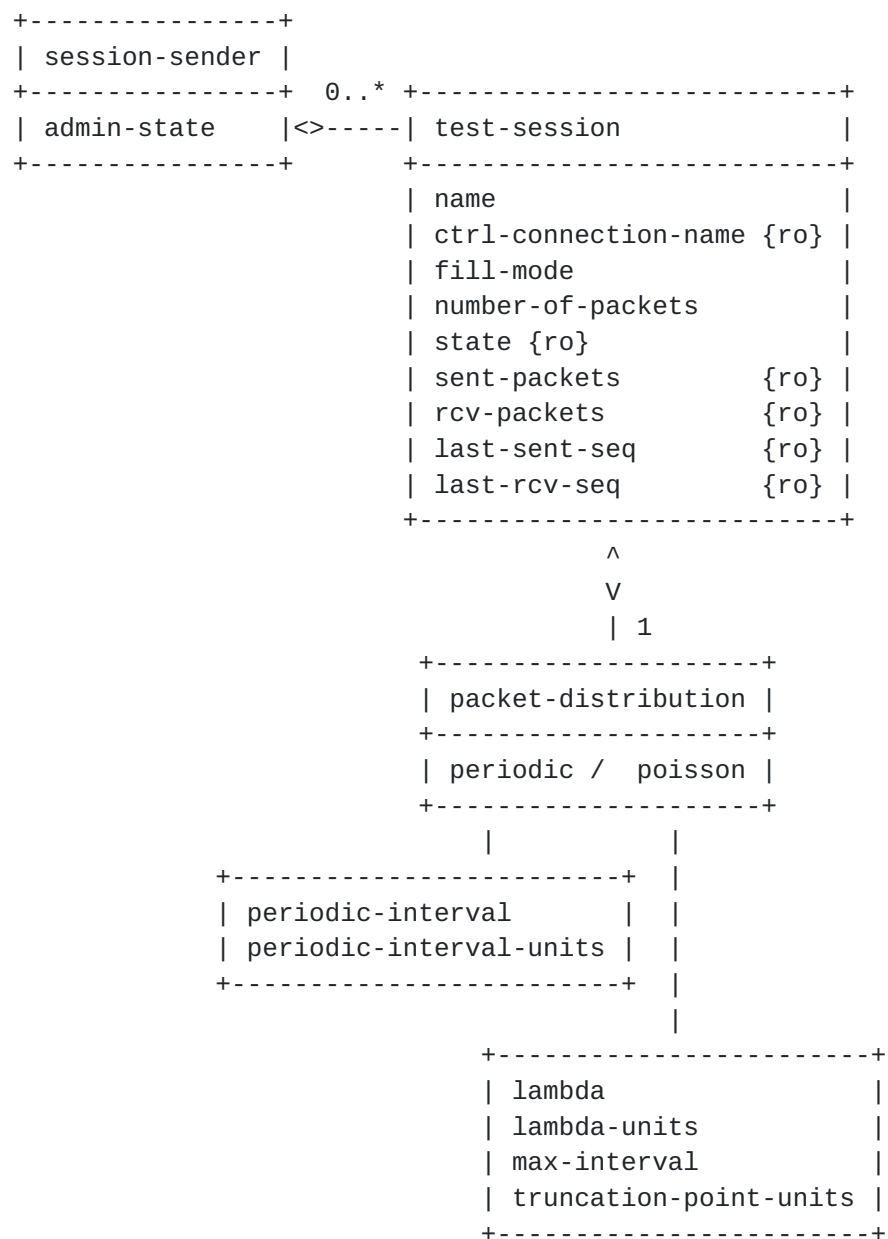


Figure 5: TWAMP Session-Sender UML class diagram

Each TWAMP-Test session initiated by the Session-Sender will be represented by an instance of a test-session object. There SHALL be one instance of test-session for each TWAMP-Test session for which packets are being sent.

4.4. Session-Reflector

The session-reflector container, illustrated in Figure 6, holds items that are related to the configuration of the TWAMP Session-Reflector logical entity.

The session-reflector container includes an administrative parameter (session-reflector/admin-state) that controls whether the device is allowed to respond to incoming TWAMP test sessions.

A device operating in the Session-Reflector role cannot configure attributes on a per-session basis, as it has no foreknowledge of what incoming sessions it will receive. As such, any parameter that the Session-Reflector might want to apply to an incoming TWAMP-Test session must be configured at the overall Session-Reflector level, and will then be applied to all incoming sessions.

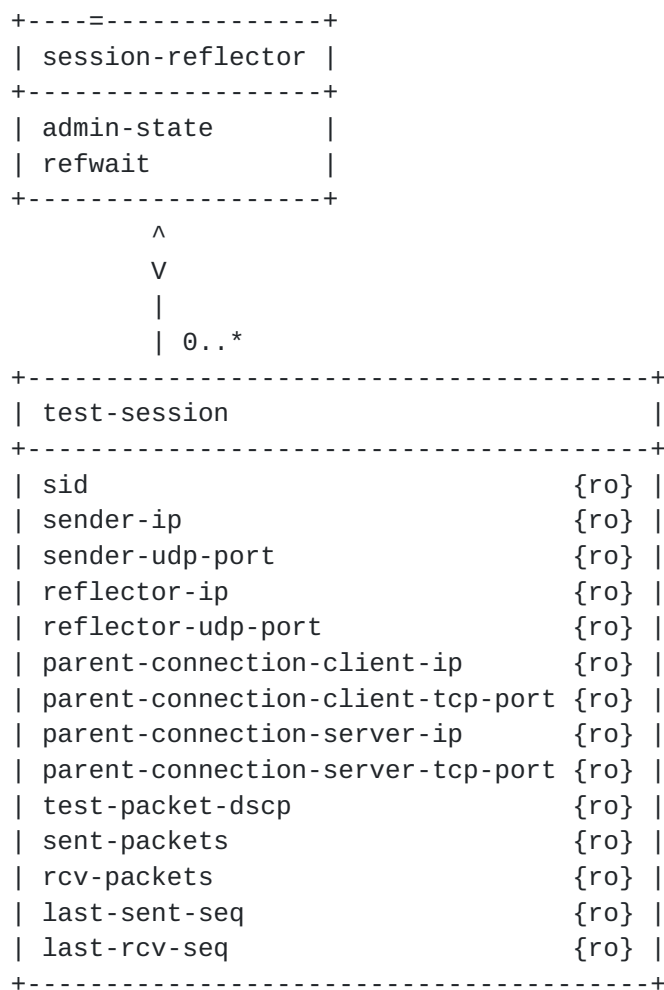


Figure 6: TWAMP Session-Reflector UML class diagram

Each incoming TWAMP-Test session that is active on the Session-Reflector SHALL be represented by an instance of a test-session object. All items in the test-session object are read-only.

Instances of test-session are indexed by a session identifier (sid). This value is auto-allocated by the TWAMP Server as test session

requests are received, and communicated back to the Control-Client in the SID field of the Accept-Session message; see [Section 4.3 of \[RFC6038\]](#).

When attempting to retrieve operational data for active test sessions from a Session-Reflector device, the user will not know what sessions are currently active on that device, or what SIDs have been auto-allocated for these test sessions. If the user has network access to the Control-Client device, then it is possible to read the data for this session under `client/ctrl-connection/test-session-request/sid` and obtain the SID (see Figure 3). The user may then use this SID value as an index to retrieve an individual session-reflector/test-session instance on the Session-Reflector device.

If the user has no network access to the Control-Client device, then the only option is to retrieve all test-session instances from the Session-Reflector device. This could be problematic if a large number of test sessions are currently active on that device.

Each Session-Reflector TWAMP-Test session contains the following 4-tuple: {parent-connection-client-ip, parent-connection-client-tcp-port, parent-connection-server-ip, parent-connection-server-tcp-port}. This 4-tuple MUST correspond to the equivalent 4-tuple {client-ip, client-tcp-port, server-ip, server-tcp-port} in the server/ctrl-connection object. This 4-tuple allows the user to trace back from the TWAMP-Test session to the (parent) TWAMP-Control connection that negotiated this test session.

5. Data Model

This section formally specifies the TWAMP data model using YANG.

5.1. YANG Tree Diagram

This section presents a simplified graphical representation of the TWAMP data model using a YANG tree diagram. Readers should keep in mind that the limit of 72 characters per line forces us to introduce artificial line breaks in some tree diagram nodes.

```
module: ietf-twamp
  +--rw twamp
    +--rw client! {control-client}?
      | +--rw admin-state          boolean
      | +--rw mode-preference-chain* [priority]
      | | +--rw priority          uint16
      | | +--rw mode?             twamp-modes
      | +--rw key-chain* [key-id]
      | | +--rw key-id            string
```



```

| | +--rw secret-key?  string
| +--rw ctrl-connection* [name]
|   +--rw name          string
|   +--rw client-ip?    inet:ip-address
|   +--rw server-ip     inet:ip-address
|   +--rw server-tcp-port? inet:port-number
|   +--rw control-packet-dscp? inet:dscp
|   +--rw key-id?       string
|   +--rw max-count?    uint32
|   +--ro client-tcp-port? inet:port-number
|   +--ro server-start-time? uint64
|   +--ro state? \
|       control-client-connection-state
|   +--ro selected-mode? twamp-modes
|   +--ro token?         binary
|   +--ro client-iv?     binary
|   +--rw test-session-request* [name]
|     +--rw name          string
|     +--rw sender-ip?    inet:ip-address
|     +--rw sender-udp-port? dynamic-port-number
|     +--rw reflector-ip  inet:ip-address
|     +--rw reflector-udp-port? dynamic-port-number
|     +--rw timeout?      uint64
|     +--rw padding-length? uint32
|     +--rw test-packet-dscp? inet:dscp
|     +--rw start-time?   uint64
|     +--rw repeat?       uint32
|     +--rw repeat-interval? uint32
|     +--rw pm-reg-list* [pm-index]
|       | +--rw pm-index  uint16
|       +--ro state?      test-session-state
|       +--ro sid?        string
+--rw server! {server}?
|   +--rw admin-state      boolean
|   +--rw server-tcp-port? inet:port-number
|   +--rw servwait?        uint32
|   +--rw control-packet-dscp? inet:dscp
|   +--rw count?           uint32
|   +--rw max-count?       uint32
|   +--rw modes?           twamp-modes
|   +--rw key-chain* [key-id]
|     | +--rw key-id      string
|     | +--rw secret-key? string
|   +--ro ctrl-connection* \
|       [client-ip client-tcp-port server-ip server-tcp-port]
|   +--ro client-ip        inet:ip-address
|   +--ro client-tcp-port  inet:port-number
|   +--ro server-ip        inet:ip-address

```



```

|   +---ro server-tcp-port      inet:port-number
|   +---ro state?               server-ctrl-connection-state
|   +---ro control-packet-dscp? inet:dscp
|   +---ro selected-mode?       twamp-modes
|   +---ro key-id?              string
|   +---ro count?               uint32
|   +---ro max-count?           uint32
|   +---ro salt?                binary
|   +---ro server-iv?           binary
|   +---ro challenge?           binary
+---rw session-sender! {session-sender}?
|   +---rw admin-state          boolean
|   +---rw test-session* [name]
|       +---rw name              string
|       +---ro ctrl-connection-name? string
|       +---rw fill-mode?        padding-fill-mode
|       +---rw number-of-packets? uint32
|       +---rw (packet-distribution)?
|           | +---:(periodic)
|           | | +---rw periodic-interval?      uint32
|           | | +---rw periodic-interval-units? time-units
|           | +---:(poisson)
|           | | +---rw lambda?                  uint32
|           | | +---rw lambda-units?            uint32
|           | | +---rw max-interval?            uint32
|           | | +---rw truncation-point-units?  time-units
|       +---ro state?                  sender-session-state
|       +---ro sent-packets?           uint32
|       +---ro rcv-packets?           uint32
|       +---ro last-sent-seq?         uint32
|       +---ro last-rcv-seq?         uint32
+---rw session-reflector! {session-reflector}?
|   +---rw admin-state          boolean
|   +---rw refwait?             uint32
|   +---ro test-session* \
|       [sender-ip sender-udp-port \
|       reflector-ip reflector-udp-port]
|       +---ro sid?                  string
|       +---ro sender-ip              \
|                                       inet:ip-address
|       +---ro sender-udp-port        \
|                                       dynamic-port-number
|       +---ro reflector-ip           \
|                                       inet:ip-address
|       +---ro reflector-udp-port     \
|                                       dynamic-port-number
|       +---ro parent-connection-client-ip?\
|                                       inet:ip-address
|       +---ro parent-connection-client-tcp-port? \

```



```

                                inet:port-number
+--ro parent-connection-server-ip? \
                                inet:ip-address
+--ro parent-connection-server-tcp-port? \
                                inet:port-number
+--ro test-packet-dscp?         inet:dscp
+--ro sent-packets?            uint32
+--ro rcv-packets?             uint32
+--ro last-sent-seq?           uint32
+--ro last-rcv-seq?           uint32
```

5.2. YANG Module

This section presents the YANG module for the TWAMP data model defined in this document.

<CODE BEGINS> file "ietf-twamp@2016-07-07.yang"

```
module ietf-twamp {
  //namespace need to be assigned by IANA
  namespace
    urn:ietf:params:xml:ns:yang:ietf-twamp;
  prefix
    ietf-twamp;

  import ietf-inet-types {
    prefix inet;
  }

  organization
    "IETF IPPM (IP Performance Metrics) Working Group";

  contact
    draft-ietf-ippm-twamp-yang@tools.ietf.org;

  description
    "This YANG module specifies a vendor-independent data
    model for the Two-Way Active Measurement Protocol (TWAMP).

    The data model covers four TWAMP logical entities:
    Control-Client, Server, Session-Sender, and Session-Reflector.
    See Fig. 1 of draft-ietf-ippm-twamp-yang for an illustration
    of the annotated TWAMP logical model.

    The YANG module uses features to indicate which of the four
    logical entities are supported by an implementation.";
```



```
revision 2016-07-07 {
  description
    "Revision appearing in draft-ietf-ippm-twamp-yang-01.
    Covers RFC 5357, RFC 5618, RFC 5938, RFC 6038, RFC 7717,
    and draft-ietf-ippm-metric-registry";
  reference
    draft-ietf-ippm-twamp-yang;
}

/*
 * Typedefs
 */

typedef twamp-modes {
  type bits {
    bit unauthenticated {
      position 0;
      description
        "Unauthenticated mode. See RFC 7717 Section 7.";
    }
    bit authenticated {
      position 1;
      description
        "Authenticated mode. See RFC 7717 Section 7.";
    }
    bit encrypted {
      position 2;
      description
        "Encrypted mode. See RFC 7717 Section 7.";
    }
    bit unauth-test-encrpyt-control {
      position 3;
      description
        "Mixed Security Mode: TWAMP-Test protocol security
        mode in Unauthenticated mode, TWAMP-Control protocol
        in Encrypted mode.";
      reference
        "RFC 5618: Mixed Security Mode for the Two-Way Active
        Measurement Protocol (TWAMP)";
    }
    bit individual-session-control {
      position 4;
      description
        "Individual Session Control.";
      reference
        "RFC 5938: Individual Session Control Feature
        for the Two-Way Active Measurement Protocol (TWAMP)";
    }
  }
}
```



```
    }
    bit reflect-octets {
      position 5;
      description
        "Reflect Octets Capability.";
      reference
        "RFC 6038: Two-Way Active Measurement Protocol (TWAMP)
        Reflect Octets and Symmetrical Size Features";
    }
    bit symmetrical-size {
      position 6;
      description
        "Symmetrical Size Sender Test Packet Format.";
      reference
        "RFC 6038: Two-Way Active Measurement Protocol (TWAMP)
        Reflect Octets and Symmetrical Size Features";
    }
    bit IKEv2Derived {
      position 7;
      description
        "IKEv2Derived Mode Capability.";
      reference
        "RFC 7717: IKEv2-Derived Shared Secret Key for
        the One-Way Active Measurement Protocol (OWAMP)
        and Two-Way Active Measurement Protocol (TWAMP)";
    }
  }
  description
    "Specifies the configurable TWAMP-Modes used during a
    TWAMP-Control Connection setup between a Control-Client
    and a Server. RFC 7717 Section 7 summarizes the
    TWAMP-Modes registry.";
}

typedef control-client-connection-state {
  type enumeration {
    enum active {
      description
        "Indicates an active TWAMP-Control connection to Server.";
    }
    enum idle {
      description
        "Indicates an idle TWAMP-Control connection to Server.";
    }
  }
  description "Control-Client control connection state";
}
```



```
typedef test-session-state {
  type enumeration {
    enum accepted {
      value 0;
      description
        "Indicates that the TWAMP-Test session request
        is accepted.";
    }
    enum failed {
      value 1;
      description
        "Indicates a TWAMP-Test session failure due to
        some unspecified reason (catch-all).";
    }
    enum internal-error {
      value 2;
      description
        "Indicates a TWAMP-Test session failure due to
        an internal error.";
    }
    enum not-supported {
      value 3;
      description
        "Indicates a TWAMP-Test session failure because
        some aspect of the TWAMP-Test session request
        is not supported.";
    }
    enum permanent-resource-limit {
      value 4;
      description
        "Indicates a TWAMP-Test session failure due to
        permanent resource limitations.";
    }
    enum temp-resource-limit {
      value 5;
      description
        "Indicates a TWAMP-Test session failure due to
        temporary resource limitations.";
    }
  }
  description "TWAMP-Test session state";
}

typedef server-ctrl-connection-state {
  type enumeration {
    enum active {
      description "Indicates an active TWAMP-Control connection
        to the Control-Client.";
    }
  }
}
```



```
    }
    enum servwait {
      description "Indicates that the TWAMP-Control connection
        to the Control-Client is in SERVWAIT according to RFC 5357
        (Section 3.1): [a] Server MAY discontinue any established
        control connection when no packet associated with that
        connection has been received within SERVWAIT seconds.";
    }
  }
  description "Server control connection state";
}

typedef sender-session-state {
  type enumeration {
    enum active {
      description
        "Indicates that the TWAMP-Test session is active.";
    }
    enum failure {
      description
        "Indicates that the TWAMP-Test session has failed.";
    }
  }
  description "Session-Sender session state.";
}

typedef padding-fill-mode {
  type enumeration {
    enum zero {
      description "Packets will be padded with
        all zeros";
    }
    enum random {
      description "Packets will be padded with
        pseudo-random numbers";
    }
  }
  description "Indicates what type of packet padding is
    to be used for the UDP TWAMP-Test packets.";
}

typedef time-units {
  type enumeration {
    enum s {
      description "Seconds.";
    }
    enum ms {
      description "Milliseconds.";
    }
  }
}
```



```
    }
    enum us {
        description "Microseconds.";
    }
    enum ns {
        description "Nanoseconds.";
    }
}
description "TWAMP configuration parameters time units.";
}

typedef dynamic-port-number {
type inet:port-number {
    range 49152..65535;
}
description "Dynamic range for port numbers";
}

/*
 * Features
 */

feature control-client {
    description
        "Indicates that the device supports configuration
        of the TWAMP Control-Client.";
}

feature server {
    description
        "Indicates that the device supports configuration
        of the TWAMP Server.";
}

feature session-sender {
    description
        "Indicates that the device supports configuration
        of the TWAMP Session-Sender.";
}

feature session-reflector {
    description
        "Indicates that the device supports configuration
        of the TWAMP Session-Reflector.";
}

/*
```



```
* Reusable node groups
*/

grouping key-management {

  list key-chain {
    key key-id;
    leaf key-id {
      type string {
        length 1..80;
      }
      description
        "KeyID to be used for a TWAMP-Control connection.";
    }

    leaf secret-key {
      type string;
      description
        "The corresponding secret key for the
        TWAMP-Control connection.";
    }
    description
      "Relates KeyIDs with the respective secret keys
      for a TWAMP-Control connection.";
  }
  description "TWAMP-Control key management.";
}

grouping maintenance-statistics {

  leaf sent-packets {
    type uint32;
    config false;
    description "Packets sent";
  }

  leaf rcv-packets {
    type uint32;
    config false;
    description "Packets received";
  }

  leaf last-sent-seq {
    type uint32;
    config false;
    description "Last sent sequence number";
  }
}
```



```
    leaf last-rcv-seq {
      type uint32;
      config false;
      description "Last received sequence number";
    }
    description "TWAMP-Test maintenance statistics";
  }

/*
 * Configuration data nodes
 */

container twamp {
  description
    "TWAMP logical entity configuration grouping.";

  container client {
    if-feature control-client;
    presence client;
    description
      "Configuration of the TWAMP Control-Client logical entity.";

    leaf admin-state {
      type boolean;
      mandatory true;
      description
        "Indicates whether the device is allowed to operate
         as a TWAMP Control-Client.";
    }

    list mode-preference-chain {
      key priority;
      unique mode;
      leaf priority {
        type uint16;
        description "Priority.";
      }
      leaf mode {
        type twamp-modes;
        description "Supported TWAMP Mode.";
      }
    }
    description
      "Indicates the preferred order of use for the
       corresponding supported TWAMP Modes";
  }
}
```



```
uses key-management;

list ctrl-connection {
  key name;
  description
    "List of TWAMP Control-Client control connections.
    Each item in the list describes a control connection
    that will be initiated by this Control-Client";

  leaf name {
    type string;
    description
      "A unique name used as a key to identify this individual
      TWAMP control connection on the Control-Client device.";
  }
  leaf client-ip {
    type inet:ip-address;
    description
      "The IP address of the local Control-Client device,
      to be placed in the source IP address field of the
      IP header in TWAMP-Control (TCP) packets belonging
      to this control connection. If not configured, the
      device SHALL choose its own source IP address.";
  }
  leaf server-ip {
    type inet:ip-address;
    mandatory true;
    description
      "The IP address belonging to the remote Server device,
      which the TWAMP-Control connection will be
      initiated to.";
  }
}

leaf server-tcp-port {
  type inet:port-number;
  default 862;
  description
    "This parameter defines the TCP port number that is
    to be used by this outgoing TWAMP-Control connection.
    Typically, this is the well-known TWAMP port number (862)
    as per RFC 5357. However, there are known
    realizations of TWAMP in the field that were implemented
    before this well-known port number was allocated. These
    early implementations allowed the port number to be
    configured. This parameter is therefore provided for
    backward compatibility reasons.";
}
```



```
leaf control-packet-dscp {
  type inet:dscp;
  default 0;
  description
    "The DSCP value to be placed in the IP header of
    TWAMP-Control (TCP) packets generated by this
    Control-Client.";
}

leaf key-id {
  type string {
    length 1..80;
  }
  description
    "The KeyID value that is selected
    for this TWAMP-Control connection.";
}

leaf max-count {
  type uint32 {
    range 1024..4294967295;
  }
  default 32768;
  description
    "This parameter limits the maximum Count value.

    If an attacking system sets the maximum value in
    Count (2**32), then the system under attack would stall
    for a significant period of time while it attempts to
    generate keys.";
}

leaf client-tcp-port {
  type inet:port-number;
  config false;
  description
    "The source TCP port number used in the TWAMP-Control
    packets belonging to this control connection.";
}

leaf server-start-time {
  type uint64;
  config false;
  description
    "The Start-Time advertized by the Server in the
    Server-Start message (RFC 4656, Section 3.1). This is
    a timestamp representing the time when the current
```



```
        instantiation of the Server started operating.";
    }

    leaf state {
        type control-client-connection-state;
        config false;
        description
            "Indicates the current state of the TWAMP-Control
            connection state.";
    }

    leaf selected-mode {
        type twamp-modes;
        config false;
        description
            "The TWAMP Mode that the Control-Client has chosen for
            this control connection as set in the Mode field of the
            Set-Up-Response message (RFC 4656, Section 3.1).";
    }

    leaf token {
        type binary {
            length 64;
        }
        config false;
        description
            "This parameter holds the 64 octets containing the
            concatenation of a 16-octet Challenge, a 16-octet AES
            Session-key used for encryption, and a 32-octet
            HMAC-SHA1 Session-key used for authentication.

            AES Session-key and HMAC Session-key are generated
            randomly by the Control-Client. AES Session-key and
            HMAC Session-key MUST be generated with sufficient
            entropy not to reduce the security of the underlying
            cipher. The token itself is encrypted
            using the AES (Advanced Encryption Standard) in
            Cipher Block Chaining (CBC). Encryption MUST be
            performed using an Initialization Vector (IV)
            of zero and a key derived from the shared secret
            associated with KeyID. Challenge is the same as
            transmitted by the Server in the clear; see also the
            last paragraph of Section 6 in RFC 4656.";
        reference
            "RFC 4086: Randomness Requirements for Security";
    }

    leaf client-iv {
```



```
type binary {
  length 16;
}
config false;
description
  "The Control-Client Initialization Vector (Client-IV)
  is generated randomly by the Control-Client.

  Client-IV merely needs to be unique (i.e., it MUST
  never be repeated for different sessions using the
  same secret key; a simple way to achieve that without
  the use of cumbersome state is to generate the
  Client-IV values using a cryptographically secure
  pseudo-random number source.";
}

list test-session-request {
  key name;
  description
    "Information associated with the Control-Client
    for this test session";

  leaf name {
    type string;
    description
      "A unique name to be used for identification of
      this TWAMP-Test session on the Control-Client.";
  }

  leaf sender-ip {
    type inet:ip-address;
    description
      "The IP address of the Session-Sender device,
      which is to be placed in the source IP address
      field of the IP header in TWAMP-Test (UDP) packets
      belonging to this test session. This value will be
      used to populate the sender address field of the
      Request-TW-Session message. If not configured,
      the device SHALL choose its own source IP address.";
  }

  leaf sender-udp-port {
    type dynamic-port-number;
    description
      "The UDP port number that is to be used by
      the Session-Sender for this TWAMP-Test session.
      The number is restricted to the dynamic port range.
      A value of zero indicates that the Control-Client
```



```
    SHALL auto-allocate a UDP port number for this
    TWAMP-Test session. The configured
    (or auto-allocated) value is advertized in the
    Sender Port field of the Request-TW-session message
    (see also Section 3.5 of RFC 5357. Note that in the
    scenario where a device auto-allocates a UDP port
    number for a session, and the repeat parameter
    for that session indicates that it should be
    repeated, the device is free to auto-allocate a
    different UDP port number when it negotiates the
    next (repeated) iteration of this session.";
}

leaf reflector-ip {
    type inet:ip-address;
    mandatory true;
    description
        "The IP address belonging to the remote
        Session-Reflector device to which the TWAMP-Test
        session will be initiated. This value will be
        used to populate the receiver address field of
        the Request-TW-Session message.";
}

leaf reflector-udp-port {
    type dynamic-port-number;
    description
        "This parameter defines the UDP port number that
        will be used by the Session-Reflector for
        this TWAMP-Test session. The number is restricted
        to the dynamic port range and is to be placed in
        the Receiver Port field of the Request-TW-Session
        message. If this value is not set, the device SHALL
        use the same port number as defined in the
        server-tcp-port parameter of this
        test-session-request's parent
        twamp/client/ctrl-connection.";
}

leaf timeout {
    type uint64;
    default 2;
    description
        "The length of time (in seconds) that the
        Session-Reflector should continue to respond to
        packets belonging to this TWAMP-Test session after
        a Stop-Sessions TWAMP-Control message has been
        received (RFC 5357, Section 3.8)."
```



```
        This value will be placed in the Timeout field of
        the Request-TW-Session message.";
    }

    leaf padding-length {
        type uint32 {
            range 64..4096;
        }
        description
            "The number of padding bytes to be added to the
            TWAMP-Test (UDP) packets generated by the
            Session-Sender.

            This value will be placed in the Padding Length
            field of the Request-TW-Session message
            (RFC 4656, Section 3.5).";
    }

    leaf test-packet-dscp {
        type inet:dscp;
        description
            "The DSCP value to be placed in the IP header
            of TWAMP-Test packets generated by the
            Session-Sender, and in the UDP header of the
            TWAMP-Test response packets generated by the
            Session-Reflector for this test session.

            This value will be placed in the Type-P Descriptor
            field of the Request-TW-Session message (RFC 5357).";
    }

    leaf start-time {
        type uint64;
        default 0;
        description
            "Time when the session is to be started
            (but not before the TWAMP Start-Sessions command
            is issued; see RFC 5357, Section 3.4).

            The start-time value is placed in the Start Time
            field of the Request-TW-Session message.

            The default value of 0 indicates that the session
            will be started as soon as the Start-Sessions message
            is received.";
    }

    leaf repeat {
```



```
type uint32;
default 0;
description
    "This value determines if the TWAMP-Test session must
    be repeated. When a test session has completed, the
    repeat parameter is checked.

    The value of 0 indicates that the session MUST NOT be
    repeated.

    If the value is 1 through 4,294,967,294 then the test
    session SHALL be repeated using the information in
    repeat-interval parameter, and the parent
    TWAMP-Control connection for this test session is
    restarted to negotiate a new instance of this
    TWAMP-Test session. The implementation MUST decrement
    the value of repeat after determining a repeated
    session is expected.

    The value of 4,294,967,295 indicates that the test
    session SHALL be repeated *forever* using the
    information in repeat-interval parameter, and
    SHALL NOT decrement the value."
}

leaf repeat-interval {
    when "../repeat!='0'" {
        description
            "This parameter determines the timing of repeated
            test sessions when repeat is more than 0.

            When the value of repeat-interval is 0, the
            negotiation of a new test session SHALL begin
            immediately after the previous test session
            completes. Otherwise, the Control-Client will
            wait for the number of minutes specified in the
            repeat-interval parameter before negotiating the
            new instance of this TWAMP-Test session."
    }
    type uint32;
    default 0;
    description "Repeat interval (in minutes)";
}

list pm-reg-list {
    key pm-index;
    leaf pm-index {
        type uint16;
```



```
        description
            "Numerical index value of a Registered Metric
            in the Performance Metric Registry
            (see ietf-ippm-metric-registry). Output statistics
            are specified in the corresponding Registry entry.";
    }
    description
        "A list of one or more Performance Metric Registry
        Index values, which communicate packet stream
        characteristics along with one or more metrics
        to be measured.

        All members of the pm-reg-list MUST have the same
        stream characteristics, such that they combine
        to specify all metrics that shall be measured on
        a single stream.";
    reference
        "ietf-ippm-metric-registry:
        Registry for Performance Metrics";
    }
    leaf state {
        type test-session-state;
        config false;
        description
            "Indicates the TWAMP-Test session state (accepted or
            indication of an error); see Section 3.5 of RFC 5357.";
    }
    leaf sid {
        type string;
        config false;
        description
            "The SID allocated by the Server for this TWAMP-Test
            session, and communicated back to the Control-Client
            in the SID field of the Accept-Session message;
            see Section 4.3 of RFC 6038.";
    }
    }
}

container server {
    if-feature server;
    presence server;
    description
        "Configuration of the TWAMP Server logical entity.";

    leaf admin-state {
```



```
    type boolean;
    mandatory true;
    description
        "Indicates whether the device is allowed to operate
        as a TWAMP Server.";
}

leaf server-tcp-port {
    type inet:port-number;
    default 862;
    description
        "This parameter defines the well known TCP port number
        that is used by TWAMP-Control. The Server will listen
        on this port number for incoming TWAMP-Control
        connections. Although this is defined as a fixed value
        (862) in RFC 5357, there are several realizations of
        TWAMP in the field that were implemented before this
        well-known port number was allocated. These early
        implementations allowed the port number to be
        configured. This parameter is therefore provided for
        backward compatibility reasons.";
}

leaf servwait {
    type uint32 {
        range 1..604800;
    }
    default 900;
    description
        "TWAMP-Control (TCP) session timeout, in seconds
        (RFC 5357, Section 3.1).";
}

leaf control-packet-dscp {
    type inet:dscp;
    description
        "The DSCP value to be placed in the IP header of
        TWAMP-Control (TCP) packets generated by the Server.

        Section 3.1 of RFC 5357 specifies that the server
        SHOULD use the DSCP value from the Control-Client's
        TCP SYN. However, for practical purposes TWAMP will
        typically be implemented using a general purpose TCP
        stack provided by the underlying operating system,
        and such a stack may not provide this information to the
        user. Consequently, it is not always possible to
        implement the behavior described in RFC 5357 in an
        OS-portable version of TWAMP. The default behavior if
```



```
    this item is not set is to use the DSCP value from
    the Control-Client's TCP SYN, as per Section 3.1
    of RFC 5357.";
}

leaf count {
    type uint32 {
        range 1024..4294967295;
    }
    description
        "Parameter used in deriving a key from a shared
        secret as described in Section 3.1 of RFC 4656,
        and are communicated to the Control-Client as part
        of the Server Greeting message.

        count MUST be a power of 2.

        count MUST be at least 1024.

        count SHOULD be increased as more computing power
        becomes common.";
}

leaf max-count {
    type uint32 {
        range 1024..4294967295;
    }
    default 32768;
    description
        "This parameter limits the maximum Count value.

        If an attacking system sets the maximum value in
        Count ( $2^{32}$ ), then the system under attack would stall
        for a significant period of time while it attempts to
        generate keys.

        TWAMP-compliant systems SHOULD have a configuration
        control to limit the maximum count value. The
        default max-count value SHOULD be 32768.";
}

leaf modes {
    type twamp-modes;
    description
        "The bit mask of TWAMP Modes this Server instance
        is willing to support; see IANA TWAMP Modes Registry.";
}

uses key-management;
```



```
list ctrl-connection {
  key
    "client-ip client-tcp-port server-ip server-tcp-port";
  config false;
  description
    "List of all incoming TWAMP-Control (TCP) connections";

  leaf client-ip {
    type inet:ip-address;
    description
      "The IP address on the remote Control-Client device,
      which is the source IP address used in the
      TWAMP-Control (TCP) packets belonging to this control
      connection.";
  }

  leaf client-tcp-port {
    type inet:port-number;
    description
      "The source TCP port number used in the TWAMP-Control
      (TCP) packets belonging to this control connection.";
  }

  leaf server-ip {
    type inet:ip-address;
    description
      "The IP address of the local Server device, which is
      the destination IP address used in the
      TWAMP-Control (TCP) packets belonging to this control
      connection.";
  }

  leaf server-tcp-port {
    type inet:port-number;
    description
      "The destination TCP port number used in the
      TWAMP-Control (TCP) packets belonging to this
      control connection. This will usually be the
      same value as the server-tcp-port configured
      under twamp/server. However, in the event that
      the user re-configured server/server-tcp-port
      after this control connection was initiated, this
      value will indicate the server-tcp-port that is
      actually in use for this control connection.";
  }

  leaf state {
    type server-ctrl-connection-state;
```



```
    description
      "Indicates the Server TWAMP-Control connection state.";
  }

  leaf control-packet-dscp {
    type inet:dscp;
    description
      "The DSCP value used in the IP header of the
      TWAMP-Control (TCP) packets sent by the Server
      for this control connection. This will usually
      be the same value as is configured in the
      control-packet-dscp parameter under the twamp/server
      container. However, in the event that the user
      re-configures server/dscp after this control
      connection is already in progress, this read-only
      value will show the actual dscp value in use by this
      TWAMP-Control connection.";
  }

  leaf selected-mode {
    type twamp-modes;
    description
      "The Mode that was chosen for this TWAMP-Control
      connection as set in the Mode field of the
      Set-Up-Response message.";
  }

  leaf key-id {
    type string {
      length 1..80;
    }
    description
      "The KeyID value that is in use by this TWAMP-Control
      connection as selected by Control-Client.";
  }

  leaf count {
    type uint32 {
      range 1024..4294967295;
    }
    description
      "The count value that is in use by this TWAMP-Control
      connection. This will usually be the same value
      as is configured under twamp/server. However, in the
      event that the user re-configured server/count
      after this control connection is already in progress,
      this read-only value will show the actual count that
      is in use for this TWAMP-Control connection.";
```



```
}

leaf max-count {
  type uint32 {
    range 1024..4294967295;
  }
  description
    "The max-count value that is in use by this
    TWAMP-Control connection. This will usually be the
    same value as is configured under twamp/server. However,
    in the event that the user re-configured
    server/max-count after this control connection is
    already in progress, this read-only value will show the
    actual max-count that is in use for this
    control connection.";
}

leaf salt {
  type binary {
    length 16;
  }
  description
    "A parameter used in deriving a key from a
    shared secret as described in Section 3.1 of RFC 4656.
    Salt MUST be generated pseudo-randomly (independently
    of anything else in the RFC) and is communicated to
    the Control-Client as part of the Server Greeting
    message.";
}

leaf server-iv {
  type binary {
    length 16;
  }
  description
    "The Server Initialization Vector
    (IV) is generated randomly by the Server.";
}

leaf challenge {
  type binary {
    length 16;
  }
  description
    "A random sequence of octets generated by the Server.
    As described in client/token, Challenge is used
    by the Control-Client to prove possession of a
    shared secret.";
```



```
    }
  }
}

container session-sender {
  if-feature session-sender;
  presence session-sender;
  description
    "Configuration of the TWAMP Session-Sender
    logical entity";
  leaf admin-state {
    type boolean;
    mandatory true;
    description
      "Indicates whether the device is allowed to operate
      as a TWAMP Session-Sender.";
  }

  list test-session{
    key name;
    description
      "TWAMP Session-Sender test sessions.";

    leaf name {
      type string;
      description
        "A unique name for this TWAMP-Test session to be used
        for identifying this test session by the Session-Sender
        logical entity.";
    }

    leaf ctrl-connection-name {
      type string;
      config false;
      description
        "The name of the parent TWAMP-Control connection that
        is responsible for negotiating this TWAMP-Test session.";
    }

    leaf fill-mode {
      type padding-fill-mode;
      default zero;
      description
        "Indicates whether the padding added to the
        TWAMP-Test (UDP) packets will contain pseudo-random
        numbers, or whether it should consist of all zeroes,
        as per Section 4.2.1 of RFC 5357.";
    }
  }
}
```



```
leaf number-of-packets {
  type uint32;
  description
    "The overall number of TWAMP-Test (UDP) packets to
    be transmitted by the Session-Sender
    for this test session.";
}

choice packet-distribution {
  description
    "Indicates the distribution to be used for transmitting
    the TWAMP-Test (UDP) packets.";
  case periodic {
    leaf periodic-interval {
      type uint32;
      description
        "Indicates the period to wait between the first bits
        of TWAMP-Test (UDP) packet transmissions for
        this test session";
    }
    leaf periodic-interval-units {
      type time-units;
      description "Periodic interval time unit.";
      reference
        "RFC 3432: Network performance measurement
        with periodic streams";
    }
  }
}

case poisson {
  leaf lambda {
    type uint32;
    description
      "Indicates the average packet transmission rate.";
  }
  leaf lambda-units {
    type uint32;
    description
      "Indicates the units of lambda in
      reciprocal seconds.";
    reference
      "RFC 3432: Network performance measurement
      with periodic streams";
  }
}

leaf max-interval {
  type uint32;
  description
    "Indicates the maximum time between packet
    transmissions.";
```



```
    }
    leaf truncation-point-units {
        type time-units;
        description "Time units to truncate.";
    }
}

leaf state {
    type sender-session-state;
    config false;
    description
        "Indicates the Session-Sender test session state.";
}

uses maintenance-statistics;
}
}

container session-reflector {
    if-feature session-reflector;
    presence session-reflector;
    description
        "Configuration of the TWAMP Session-Reflector
        logical entity";

    leaf admin-state {
        type boolean;
        mandatory true;
        description
            "Indicates whether the device is allowed to operate
            as a TWAMP Session-Reflector.";
    }

    leaf refwait {
        type uint32 {
            range 1..604800;
        }
        default 900;
        description
            "The Session-Reflector MAY discontinue any session
            that has been started when no packet associated with
            that session has been received for REFWAIT seconds.

            The default value of REFWAIT SHALL be 900 seconds, and
            this waiting time MAY be configurable. This timeout
            allows a Session-Reflector to free up resources in
            case of failure.";
```



```
}

list test-session {
  key
    "sender-ip sender-udp-port
    reflector-ip reflector-udp-port";
  config false;
  description
    "TWAMP Session-Reflector test sessions.";

  leaf sid {
    type string;
    description
      "An auto-allocated identifier for this TWAMP-Test
      session, that is unique within the context of this
      Server/Session-Reflector device only. This value
      will be communicated to the Control-Client that
      requested the test session in the SID field of the
      Accept-Session message.";
  }

  leaf sender-ip {
    type inet:ip-address;
    description
      "The IP address on the remote device, which is the
      source IP address used in the TWAMP-Test
      (UDP) packets belonging to this test session.";
  }

  leaf sender-udp-port {
    type dynamic-port-number;
    description
      "The source UDP port used in the TWAMP-Test packets
      belonging to this test session.";
  }

  leaf reflector-ip {
    type inet:ip-address;
    description
      "The IP address of the local Session-Reflector
      device, which is the destination IP address used
      in the TWAMP-Test (UDP) packets belonging to this test
      session.";
  }

  leaf reflector-udp-port {
    type dynamic-port-number;
    description
```



```
        "The destination UDP port number used in the
        TWAMP-Test (UDP) test packets belonging to this
        test session.";
    }

    leaf parent-connection-client-ip {
        type inet:ip-address;
        description
            "The IP address on the Control-Client device, which
            is the source IP address used in the TWAMP-Control
            (TCP) packets belonging to the parent control
            connection that negotiated this test session.";
    }

    leaf parent-connection-client-tcp-port {
        type inet:port-number;
        description
            "The source TCP port number used in the TWAMP-Control
            (TCP) packets belonging to the parent control connection
            that negotiated this test session.";
    }

    leaf parent-connection-server-ip {
        type inet:ip-address;
        description
            "The IP address of the Server device, which is the
            destination IP address used in the TWAMP-Control
            (TCP) packets belonging to the parent control
            connection that negotiated this test session.";
    }

    leaf parent-connection-server-tcp-port {
        type inet:port-number;
        description
            "The destination TCP port number used in the TWAMP-Control
            (TCP) packets belonging to the parent control connection
            that negotiated this test session.";
    }

    leaf test-packet-dscp {
        type inet:dscp;
        description
            "The DSCP value present in the IP header of
            TWAMP-Test (UDP) packets belonging to this test
            session.";
    }

    uses maintenance-statistics;
```



```

    }
  }
}

```

<CODE ENDS>

6. Data Model Examples

This section presents a simple but complete example of configuring all four entities in Figure 1, based on the YANG module specified in [Section 5](#). The example is illustrative in nature, but aims to be self-contained, i.e. were it to be executed in a real TWAMP implementation it would lead to a correctly configured test session. For completeness, examples are provided for both IPv4 and IPv6.

A more elaborated example, which also includes authentication parameters, is provided in [Appendix A](#).

6.1. Control-Client

The following configuration example shows a Control-Client with client/admin-state enabled. In a real implementation following Figure 2 this would permit the initiation of TWAMP-Control connections and TWAMP-Test sessions.

```

<?xml version="1.0" encoding="utf-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <client>
      <admin-state>true</admin-state>
    </client>
  </twamp>
</config>

```

The following configuration example shows a Control-Client with two instances of client/ctrl-connection, one called "RouterA" and another called "RouterB".

Each TWAMP-Control connection is to a different Server. The control connection named "RouterA" has two test session requests. The TWAMP-Control connection named "RouterB" has no TWAMP-Test session requests.

```

<?xml version="1.0" encoding="utf-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">

```



```
<client>
  <admin-state>true</admin-state>
  <ctrl-connection>
    <name>RouterA</name>
    <client-ip>203.0.113.1</client-ip>
    <server-ip>203.0.113.2</server-ip>
    <test-session-request>
      <name>Test1</name>
      <sender-ip>10.1.1.1</sender-ip>
      <sender-udp-port>50000</sender-udp-port>
      <reflector-ip>10.1.1.2</reflector-ip>
      <reflector-udp-port>500001</reflector-udp-port>
      <start-time>0</start-time>
    </test-session-request>
    <test-session-request>
      <name>Test2</name>
      <sender-ip>203.0.113.1</sender-ip>
      <sender-udp-port>4001</sender-udp-port>
      <reflector-ip>203.0.113.2</reflector-ip>
      <reflector-udp-port>50001</reflector-udp-port>
      <start-time>0</start-time>
    </test-session-request>
  </ctrl-connection>
  <ctrl-connection>
    <name>RouterB</name>
    <client-ip>203.0.113.1</client-ip>
    <server-ip>203.0.113.3</server-ip>
  </ctrl-connection>
</client>
</twamp>
</config>

<?xml version="1.0" encoding="utf-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <client>
      <admin-state>true</admin-state>
      <ctrl-connection>
        <name>RouterA</name>
        <client-ip>2001:DB8:203:0:113::1</client-ip>
        <server-ip>2001:DB8:203:0:113::2</server-ip>
        <test-session-request>
          <name>Test1</name>
          <sender-ip>2001:DB8:10:1:1::1</sender-ip>
          <sender-udp-port>4000</sender-udp-port>
          <reflector-ip>2001:DB8:10:1:1::2</reflector-ip>
          <reflector-udp-port>5000</reflector-udp-port>
          <start-time>0</start-time>
        </test-session-request>
      </ctrl-connection>
    </client>
  </twamp>
</config>
```



```
    </test-session-request>
    <test-session-request>
      <name>Test2</name>
      <sender-ip>2001:DB8:203:0:113::1</sender-ip>
      <sender-udp-port>4001</sender-udp-port>
      <reflector-ip>2001:DB8:203:0:113::2</reflector-ip>
      <reflector-udp-port>5001</reflector-udp-port>
      <start-time>0</start-time>
    </test-session-request>
  </ctrl-connection>
  <ctrl-connection>
    <name>RouterB</name>
    <client-ip>2001:DB8:203:0:113::1</client-ip>
    <server-ip>2001:DB8:203:0:113::3</server-ip>
  </ctrl-connection>
</client>
</twamp>
</config>
```

6.2. Server

This configuration example shows a Server with server/admin-state enabled, which permits a device following Figure 2 to respond to TWAMP-Control connections and TWAMP-Test sessions.

```
<?xml version="1.0" encoding="utf-8"?>
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <server>
      <admin-state>true</admin-state>
    </server>
  </twamp>
</config>
```

The following example presents a Server with the TWAMP-Control connection corresponding to the control connection name (client/ctrl-connection/name) "RouterA" presented in [Section 6.1](#).


```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <server>
      <admin-state>true</admin-state>
      <ctrl-connection>
        <client-ip>203.0.113.1</client-ip>
        <client-tcp-port>16341</client-tcp-port>
        <server-ip>203.0.113.2</server-ip>
        <server-tcp-port>862</server-tcp-port>
        <state>
          active
        </state>
      </ctrl-connection>
    </server>
  </twamp>
</data>
```

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <server>
      <admin-state>true</admin-state>
      <ctrl-connection>
        <client-ip>2001:DB8:203:0:113::1</client-ip>
        <client-tcp-port>16341</client-tcp-port>
        <server-ip>2001:DB8:203:0:113::2</server-ip>
        <server-tcp-port>862</server-tcp-port>
        <state>
          active
        </state>
      </ctrl-connection>
    </server>
  </twamp>
</data>
```

6.3. Session-Sender

The following configuration example shows a Session-Sender with the two TWAMP-Test sessions presented in [Section 6.1](#).


```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <session-sender>
      <admin-state>true</admin-state>
      <test-session>
        <name>Test1</name>
        <ctrl-connection-name>RouterA</ctrl-connection-name>
        <number-of-packets>900</number-of-packets>
        <periodic-interval>1</periodic-interval>
        <periodic-interval-units>seconds</periodic-interval-units>
        <state>setup</state>
      </test-session>
      <test-session>
        <name>Test2</name>
        <ctrl-connection-name>
          RouterA
        </ctrl-connection-name>
        <number-of-packets>900</number-of-packets>
        <lambda>1</lambda>
        <lambda-units>1</lambda-units>
        <max-interval>2</max-interval>
        <truncation-point-units>seconds</truncation-point-units>
        <state>setup</state>
      </test-session>
    </session-sender>
  </twamp>
</data>
```

6.4. Session-Reflector

The following example shows the two Session-Reflector TWAMP-Test sessions corresponding to the test sessions presented in [Section 6.3](#).

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <session-reflector>
      <admin-state>
        true
      </admin-state>
      <test-session>
        <sender-ip>10.1.1.1</sender-ip>
        <sender-udp-port>4000</sender-udp-port>
        <reflector-ip>10.1.1.2</reflector-ip>
        <reflector-udp-port>50001</reflector-udp-port>
        <sid>1232</sid>
        <parent-connection-client-ip>
```



```
        203.0.113.1
      </parent-connection-client-ip>
    <parent-connection-client-tcp-port>
      16341
    </parent-connection-client-tcp-port>
    <parent-connection-server-ip>
      203.0.113.2
    </parent-connection-server-ip>
    <parent-connection-server-tcp-port>
      862
    </parent-connection-server-tcp-port>
    <sent-packets>2</sent-packets>
    <rcv-packets>2</rcv-packets>
    <last-sent-seq>1</last-sent-seq>
    <last-rcv-seq>1</last-rcv-seq>
  </test-session>
<test-session>
  <sender-ip>203.0.113.1</sender-ip>
  <sender-udp-port>50000</sender-udp-port>
  <reflector-ip>192.68.0.2</reflector-ip>
  <reflector-udp-port>50001</reflector-udp-port>
  <sid>178943</sid>
  <parent-connection-client-ip>
    203.0.113.1
  </parent-connection-client-ip>
  <parent-connection-client-tcp-port>
    16341
  </parent-connection-client-tcp-port>
  <parent-connection-server-ip>
    203.0.113.2
  </parent-connection-server-ip>
  <parent-connection-server-tcp-port>
    862
  </parent-connection-server-tcp-port>
  <sent-packets>21</sent-packets>
  <rcv-packets>21</rcv-packets>
  <last-sent-seq>20</last-sent-seq>
  <last-rcv-seq>20</last-rcv-seq>
</test-session>
</session-reflector>
</twamp>
</data>

<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <session-reflector>
      <admin-state>true</admin-state>
```



```
<test-session>
  <sender-ip>10.1.1.1</sender-ip>
  <sender-udp-port>4000</sender-udp-port>
  <reflector-ip>10.1.1.2</reflector-ip>
  <reflector-udp-port>5000</reflector-udp-port>
  <sid>1232</sid>
  <parent-connection-client-ip>
    203.0.113.1
  </parent-connection-client-ip>
  <parent-connection-client-tcp-port>
    16341
  </parent-connection-client-tcp-port>
  <parent-connection-server-ip>
    203.0.113.2
  </parent-connection-server-ip>
  <parent-connection-server-tcp-port>
    862
  </parent-connection-server-tcp-port>
  <sent-packets>2</sent-packets>
  <rcv-packets>2</rcv-packets>
  <last-sent-seq>1</last-sent-seq>
  <last-rcv-seq>1</last-rcv-seq>
</test-session>
<test-session>
  <sender-ip>203.0.113.1</sender-ip>
  <sender-udp-port>4001</sender-udp-port>
  <reflector-ip>192.68.0.2</reflector-ip>
  <reflector-udp-port>5001</reflector-udp-port>
  <sid>178943</sid>
  <parent-connection-client-ip>
    203.0.113.1
  </parent-connection-client-ip>
  <parent-connection-client-tcp-port>
    16341
  </parent-connection-client-tcp-port>
  <parent-connection-server-ip>
    203.0.113.2
  </parent-connection-server-ip>
  <parent-connection-server-tcp-port>
    862
  </parent-connection-server-tcp-port>
  <sent-packets>21</sent-packets>
  <rcv-packets>21</rcv-packets>
  <last-sent-seq>20</last-sent-seq>
  <last-rcv-seq>20</last-rcv-seq>
</test-session>
</session-reflector>
</twamp>
```


</data>

7. Security Considerations

The YANG module defined in [Section 5](#) is designed to be accessed, among other protocols, via NETCONF [[RFC6241](#)]. Protocols like NETCONF use a secure transport layer like SSH that is mandatory to implement. The NETCONF Access Control Module (NACM) [[RFC6536](#)] provides the means to restrict access for particular users to a pre-configured set of NETCONF protocol operations and attributes.

There are a number of nodes defined in this YANG module which are writeable. These data nodes may be considered sensitive and vulnerable to attacks in some network environments. Ability to write into these nodes without proper protection can have a negative effect on the devices that support this feature.

Examples of nodes that are particularly vulnerable include several timeout values put in the protocol to protect against sessions that are not active but are consuming resources.

8. IANA Considerations

This document registers a URI in the IETF XML registry [[RFC3688](#)]. Following the format in [[RFC3688](#)], the following registration is requested to be made.

URI: urn:ietf:params:xml:ns:yang:ietf-twamp

Registrant Contact: The IPPM WG of the IETF.

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

This document registers a YANG module in the YANG Module Names registry [[RFC6020](#)].

name: ietf-twamp

namespace: urn:ietf:params:xml:ns:yang:ietf-twamp

prefix: twamp

reference: RFC XXXX

9. Acknowledgements

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[Appendix A](#). Detailed Data Model Examples

This appendix extends the example presented in [Section 6](#) by configuring more fields such as authentication parameters, DSCP values and so on.

[A.1](#). Control-Client

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <client>
```



```
<admin-state>true</admin-state>
<mode-preference-chain>
  <priority>0</priority>
  <mode>authenticated</mode>
</mode-preference-chain>
<mode-preference-chain>
  <priority>1</priority>
  <mode>unauthenticated</mode>
</mode-preference-chain>
<key-chain>
  <key-id>KeyClient1ToRouterA</key-id>
  <secret-key>secret1</secret-key>
</key-chain>
<key-chain>
  <key-id>KeyForRouterB</key-id>
  <secret-key>secret2</secret-key>
</key-chain>
<ctrl-connection>
  <name>RouterA</name>
  <client-ip>203.0.113.1</client-ip>
  <server-ip>203.0.113.2</server-ip>
  <dscp>32</dscp>
  <key-id>KeyClient1ToRouterA</key-id>
  <test-session-request>
    <name>Test1</name>
    <sender-ip>10.1.1.1</sender-ip>
    <sender-udp-port>4000</sender-udp-port>
    <reflector-ip>10.1.1.2</reflector-ip>
    <reflector-udp-port>5000</reflector-udp-port>
    <padding-length>64</padding-length>
    <start-time>0</start-time>
    <state>ok</state>
    <sid>1232</sid>
  </test-session-request>
  <test-session-request>
    <name>Test2</name>
    <sender-ip>203.0.113.1</sender-ip>
    <sender-udp-port>4001</sender-udp-port>
    <reflector-ip>203.0.113.2</reflector-ip>
    <reflector-udp-port>5001</reflector-udp-port>
    <padding-length>128</padding-length>
    <start-time>0</start-time>
    <state>ok</state>
    <sid>178943</sid>
  </test-session-request>
</ctrl-connection>
</client>
</twamp>
```



```
</data>
```

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <client>
      <admin-state>true</admin-state>
      <mode-preference-chain>
        <priority>0</priority>
        <mode>authenticated</mode>
      </mode-preference-chain>
      <mode-preference-chain>
        <priority>1</priority>
        <mode>unauthenticated</mode>
      </mode-preference-chain>
      <key-chain>
        <key-id>KeyClient1ToRouterA</key-id>
        <secret-key>secret1</secret-key>
      </key-chain>
      <key-chain>
        <key-id>KeyForRouterB</key-id>
        <secret-key>secret2</secret-key>
      </key-chain>
      <ctrl-connection>
        <name>RouterA</name>
        <client-ip>2001:DB8:203:0:113::1</client-ip>
        <server-ip>2001:DB8:203:0:113::2</server-ip>
        <dscp>32</dscp>
        <key-id>KeyClient1ToRouterA</key-id>
        <test-session-request>
          <name>Test1</name>
          <sender-ip>2001:DB8:10:1:1::1</sender-ip>
          <sender-udp-port>4000</sender-udp-port>
          <reflector-ip>2001:DB8:10:1:1::2</reflector-ip>
          <reflector-udp-port>5000</reflector-udp-port>
          <padding-length>64</padding-length>
          <start-time>0</start-time>
          <state>ok</state>
          <sid>1232</sid>
        </test-session-request>
        <test-session-request>
          <name>Test2</name>
          <sender-ip>2001:DB8:203:0:113::1</sender-ip>
          <sender-udp-port>4001</sender-udp-port>
          <reflector-ip>2001:DB8:203:0:113::2</reflector-ip>
          <reflector-udp-port>5001</reflector-udp-port>
          <padding-length>128</padding-length>
          <start-time>0</start-time>
```



```
        <state>ok</state>
        <sid>178943</sid>
      </test-session-request>
    </ctrl-connection>
  </client>
</twamp>
</data>
```

[A.2.](#) Server

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <server>
      <admin-state>true</admin-state>
      <servwait>1800</servwait>
      <dscp>32</dscp>
      <modes>authenticated unauthenticated</modes>
      <count>1024</count>
      <key-chain>
        <key-id>KeyClient1ToRouterA</key-id>
        <secret-key>secret1</secret-key>
      </key-chain>
      <key-chain>
        <key-id>KeyClient10ToRouterA</key-id>
        <secret-key>secret10</secret-key>
      </key-chain>
      <ctrl-connection>
        <client-ip>203.0.113.1</client-ip>
        <client-tcp-port>16341</client-tcp-port>
        <server-ip>203.0.113.2</server-ip>
        <server-tcp-port>862</server-tcp-port>
        <state>
          active
        </state>
        <dscp>32</dscp>
        <selected-mode>unauthenticated</selected-mode>
        <key-id>KeyClient1ToRouterA</key-id>
        <count>1024</count>
      </ctrl-connection>
    </server>
  </twamp>
</data>

<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <server>
```



```
<admin-state>true</admin-state>
<servwait>1800</servwait>
<dscp>32</dscp>
<modes>authenticated unauthenticated</modes>
<count>1024</count>
<key-chain>
  <key-id>KeyClient1ToRouterA</key-id>
  <secret-key>secret1</secret-key>
</key-chain>
<key-chain>
  <key-id>KeyClient10ToRouterA</key-id>
  <secret-key>secret10</secret-key>
</key-chain>
<ctrl-connection>
  <client-ip>2001:DB8:203:0:113::1</client-ip>
  <client-tcp-port>16341</client-tcp-port>
  <server-ip>2001:DB8:203:0:113::2</server-ip>
  <server-tcp-port>862</server-tcp-port>
  <state>
    active
  </state>
  <dscp>32</dscp>
  <selected-mode>unauthenticated</selected-mode>
  <key-id>KeyClient1ToRouterA</key-id>
  <count>1024</count>
</ctrl-connection>
</server>
</twamp>
</data>
```

[A.3.](#) Session-Sender


```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <session-sender>
      <admin-state>true</admin-state>
      <test-session>
        <name>Test1</name>
        <ctrl-connection-name>RouterA</ctrl-connection-name>
        <fill-mode>zero</fill-mode>
        <number-of-packets>900</number-of-packets>
        <periodic-interval>1</periodic-interval>
        <periodic-interval-units>
          seconds
        </periodic-interval-units>
        <state>setup</state>
        <sent-packets>2</sent-packets>
        <rcv-packets>2</rcv-packets>
        <last-sent-seq>1</last-sent-seq>
        <last-rcv-seq>1</last-rcv-seq>
      </test-session>
      <test-session>
        <name>Test2</name>
        <ctrl-connection-name>
          RouterA
        </ctrl-connection-name>
        <fill-mode>random</fill-mode>
        <number-of-packets>900</number-of-packets>
        <lambda>1</lambda>
        <lambda-units>1</lambda-units>
        <max-interval>2</max-interval>
        <truncation-point-units>seconds</truncation-point-units>
        <state>setup</state>
        <sent-packets>21</sent-packets>
        <rcv-packets>21</rcv-packets>
        <last-sent-seq>20</last-sent-seq>
        <last-rcv-seq>20</last-rcv-seq>
      </test-session>
    </session-sender>
  </twamp>
</data>
```

[A.4.](#) Session-Reflector

```
<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <session-reflector>
      <admin-state>
```



```
    true
  </admin-state>
  <test-session>
    <sender-ip>10.1.1.1</sender-ip>
    <sender-udp-port>4000</sender-udp-port>
    <reflector-ip>10.1.1.2</reflector-ip>
    <reflector-udp-port>5000</reflector-udp-port>
    <sid>1232</sid>
    <parent-connection-client-ip>
      203.0.113.1
    </parent-connection-client-ip>
    <parent-connection-client-tcp-port>
      16341
    </parent-connection-client-tcp-port>
    <parent-connection-server-ip>
      203.0.113.2
    </parent-connection-server-ip>
    <parent-connection-server-tcp-port>
      862
    </parent-connection-server-tcp-port>
    <dscp>32</dscp>
    <sent-packets>2</sent-packets>
    <rcv-packets>2</rcv-packets>
    <last-sent-seq>1</last-sent-seq>
    <last-rcv-seq>1</last-rcv-seq>
  </test-session>
  <test-session>
    <sender-ip>203.0.113.1</sender-ip>
    <sender-udp-port>4001</sender-udp-port>
    <reflector-ip>192.68.0.2</reflector-ip>
    <reflector-udp-port>5001</reflector-udp-port>
    <sid>178943</sid>
    <parent-connection-client-ip>
      203.0.113.1
    </parent-connection-client-ip>
    <parent-connection-client-tcp-port>
      16341
    </parent-connection-client-tcp-port>
    <parent-connection-server-ip>
      203.0.113.2
    </parent-connection-server-ip>
    <parent-connection-server-tcp-port>
      862
    </parent-connection-server-tcp-port>
    <dscp>32</dscp>
    <sent-packets>21</sent-packets>
    <rcv-packets>21</rcv-packets>
    <last-sent-seq>20</last-sent-seq>
```



```
        <last-rcv-seq>20</last-rcv-seq>
      </test-session>
    </session-reflector>
  </twamp>
</data>

<?xml version="1.0" encoding="utf-8"?>
<data xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <twamp xmlns="urn:ietf:params:xml:ns:yang:ietf-twamp">
    <session-reflector>
      <admin-state>true</admin-state>
      <test-session>
        <sender-ip>2001:DB8:10:1:1::1</sender-ip>
        <sender-udp-port>4000</sender-udp-port>
        <reflector-ip>2001:DB8:10:1:1::2</reflector-ip>
        <reflector-udp-port>5000</reflector-udp-port>
        <sid>1232</sid>
        <parent-connection-client-ip>
          2001:DB8:203:0:113::1
        </parent-connection-client-ip>
        <parent-connection-client-tcp-port>
          16341
        </parent-connection-client-tcp-port>
        <parent-connection-server-ip>
          2001:DB8:203:0:113::2
        </parent-connection-server-ip>
        <parent-connection-server-tcp-port>
          862
        </parent-connection-server-tcp-port>
        <dscp>32</dscp>
        <sent-packets>2</sent-packets>
        <rcv-packets>2</rcv-packets>
        <last-sent-seq>1</last-sent-seq>
        <last-rcv-seq>1</last-rcv-seq>
      </test-session>
    <test-session>
      <sender-ip>2001:DB8:203:0:113::1</sender-ip>
      <sender-udp-port>4001</sender-udp-port>
      <reflector-ip>2001:DB8:192:68::2</reflector-ip>
      <reflector-udp-port>5001</reflector-udp-port>
      <sid>178943</sid>
      <parent-connection-client-ip>
        2001:DB8:203:0:113::1
      </parent-connection-client-ip>
      <parent-connection-client-tcp-port>
        16341
      </parent-connection-client-tcp-port>
      <parent-connection-server-ip>
```



```
        2001:DB8:203:0:113::2
      </parent-connection-server-ip>
    <parent-connection-server-tcp-port>
      862
    </parent-connection-server-tcp-port>
    <dscp>32</dscp>
    <sent-packets>21</sent-packets>
    <rcv-packets>21</rcv-packets>
    <last-sent-seq>20</last-sent-seq>
    <last-rcv-seq>20</last-rcv-seq>
  </test-session>
</session-reflector>
</twamp>
</data>
```

Appendix B. TWAMP Operational Commands

TWAMP operational commands could be performed programmatically or manually, e.g. using a command-line interface (CLI).

With respect to programmability, YANG can be used to define NETCONF Remote Procedure Calls (RPC), therefore it would be, in principle, possible to define TWAMP RPC operations for actions such as starting or stopping control connections or test sessions or groups of sessions; retrieving results; clearing stored results, and so on.

However, [RFC5357] does not attempt to describe such operational actions. Refer also to [Section 2](#) and the unlabeled links in Figure 1. In actual deployments different TWAMP implementations may support different sets of operational commands, with different restrictions. Therefore, this document considers it the responsibility of the individual implementation to define its corresponding TWAMP operational commands data model.

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