Two-Way Active Measurement Protocol (TWAMP) Reflect Octets and
Symmetrical Size Features

Abstract

   This memo describes two closely related features for the core
   specification of the Two-Way Active Measurement Protocol (TWAMP): an
   optional capability where the responding host returns some of the
   command octets or padding octets to the sender, and an optional
   sender packet format that ensures equal test packet sizes are used in
   both directions.

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 5741.

   Information about the current status of this document, any errata,
   and how to provide feedback on it may be obtained at
   http://www.rfc-editor.org/info/rfc6038.

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1. Introduction

   The Two-Way Active Measurement Protocol (TWAMP) [RFC5357] is an
   extension of the One-way Active Measurement Protocol (OWAMP)
   [RFC4656]. The TWAMP specification gathered wide review as it
   approached completion, and the by-products were several
   recommendations for new features in TWAMP.

   This memo describes two closely related features for TWAMP.

   One is the OPTIONAL capability for the responder host to return a
   limited number of unassigned (padding) octets to the Control-Client
   or Session-Sender entities in both the TWAMP-Control and TWAMP-Test
   protocols. With this capability, the Control-Client or Session-
   Sender can embed octets of information it deems useful and have the
   assurance that the corresponding reply/test packet will contain that
   information when it is reflected and returned (by the Server or
   Session-Reflector).

   The memo also adds an OPTIONAL capability to ensure that reflected
   test packets are the same size in both directions of transmission.
   This is accomplished by specifying a new TWAMP-Test Session-Sender
   packet format. Although TWAMP [RFC5357] recommends padding
   truncation to achieve symmetrical sizes (to compensate for the
   Session-Reflector's larger test packet header), it's not guaranteed
   that the Session-Reflector will truncate the padding, and it's not
   possible if there's insufficient padding.

   This memo is an update to the TWAMP core protocol specified in
   [RFC5357]. Measurement systems are not required to implement the
   features described in this memo to claim compliance with [RFC5357].

   Throughout this memo, the bits marked MBZ (Must Be Zero) MUST be set
   to zero by senders and MUST be ignored by receivers. Also, the HMAC
   (Hashed Message Authentication Code) MUST be calculated as defined in
   Section 3.2 of [RFC4656].

2. Requirements Language

   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 RFC 2119 [RFC2119].

3. Purpose and Scope

   The purpose of this memo is to define two OPTIONAL closely related
   features for TWAMP [RFC5357]. The features enhance the TWAMP host's
   capabilities to perform a simple operation on control and test
   packets: the reflection of octets or padding, and the capability to
   ensure symmetrical size TWAMP-Test packets. Motivations include
   permitting the controller host to tag packets with an index for
   simplified identification, and/or assert that the same size test
   packets will be used in each direction.

   The scope of the memo is limited to specifications of the following
   features:

   o Reflect Octets: the capability of the Server/Session-Reflector to
      reflect specific octets back to the Client/Session-Sender, and a
      similar service provided by the Client and Session-Sender.

   o Symmetrical Size: the capability to ensure that TWAMP-Test
      protocol uses the same packet size in both directions through
      support of a new TWAMP-Test Session-Sender test packet format in
      both the Session-Sender and the Session-Reflector. Only the
      Session-Sender test packet format is new.

   This memo extends the modes of operation through assignment of two
   new values in the Modes field (see Section 3.1 of [RFC4656] for the
   format of the Server Greeting message), while retaining backward
   compatibility with the core TWAMP [RFC5357] implementations. The two
   new values correspond to the two features defined in this memo.

   When the Server and Control-Client have agreed to use the Reflect
   Octets mode during control connection setup, then the Control-Client,
   the Server, the Session-Sender, and the Session-Reflector MUST all
   conform to the requirements of that mode, as identified below.

   When the Server and Control-Client have agreed to use the Symmetrical
   Size mode during control connection setup, then the Control-Client,
   the Server, the Session-Sender, and the Session-Reflector MUST all
   conform to the requirements of that mode, as identified below.

4. TWAMP Control Extensions

   TWAMP-Control protocol [RFC5357] uses the Modes field to identify and
   select specific communication capabilities, and this field is a
   recognized extension mechanism. The following sections describe two
   such extensions.

4.1. Connection Setup with New Features

   TWAMP connection establishment follows the procedure defined in
   Section 3.1 of [RFC4656] and Section 3.1 of [RFC5357]. The new
   features require two new bit positions (and values) to identify the
   ability of the Server/Session-Reflector to reflect specific octets
   back to the Control-Client/Session-Sender, and to support the new
   Session-Sender packet format in the TWAMP-Test protocol. See the
   IANA section for details on the assigned values and bit positions.

   The Server sets one or both of the new bit positions in the Modes
   field of the Server Greeting message to indicate its capabilities and
   willingness to operate in either of these modes (or both) if desired.

   If the Control-Client intends to operate all test sessions invoked
   with this control connection using one or both of the new modes, it
   MUST set the Mode field bit corresponding to each function in the
   Setup Response message. With this and other extensions, the Control-
   Client MAY set multiple Mode field bits in the Setup Response
   message.

4.2. Reflect Octets: Request-TW-Session Packet Format

   The bits designated for the Reflect Octets feature in the Request-TW-
   Session command are as shown in the packet format below.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      5        | MBZ | IPVN |  Conf-Sender  | Conf-Receiver |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Number of Schedule Slots                  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   .                                                             .
   .           ... Many fields (66 octets) not shown ...        .
   .                                                             .
   .                                                             .
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Padding Length  (4 octets)               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Start Time  (8 octets)                  |
   |                                                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      Timeout  (8 octets)                    |
   |                                                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      Type-P Descriptor                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Octets to be reflected    |  Length of padding to reflect |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      MBZ (4 octets)                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                                                             |
   |                      HMAC (16 octets)                       |
   |                                                             |
   |                                                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
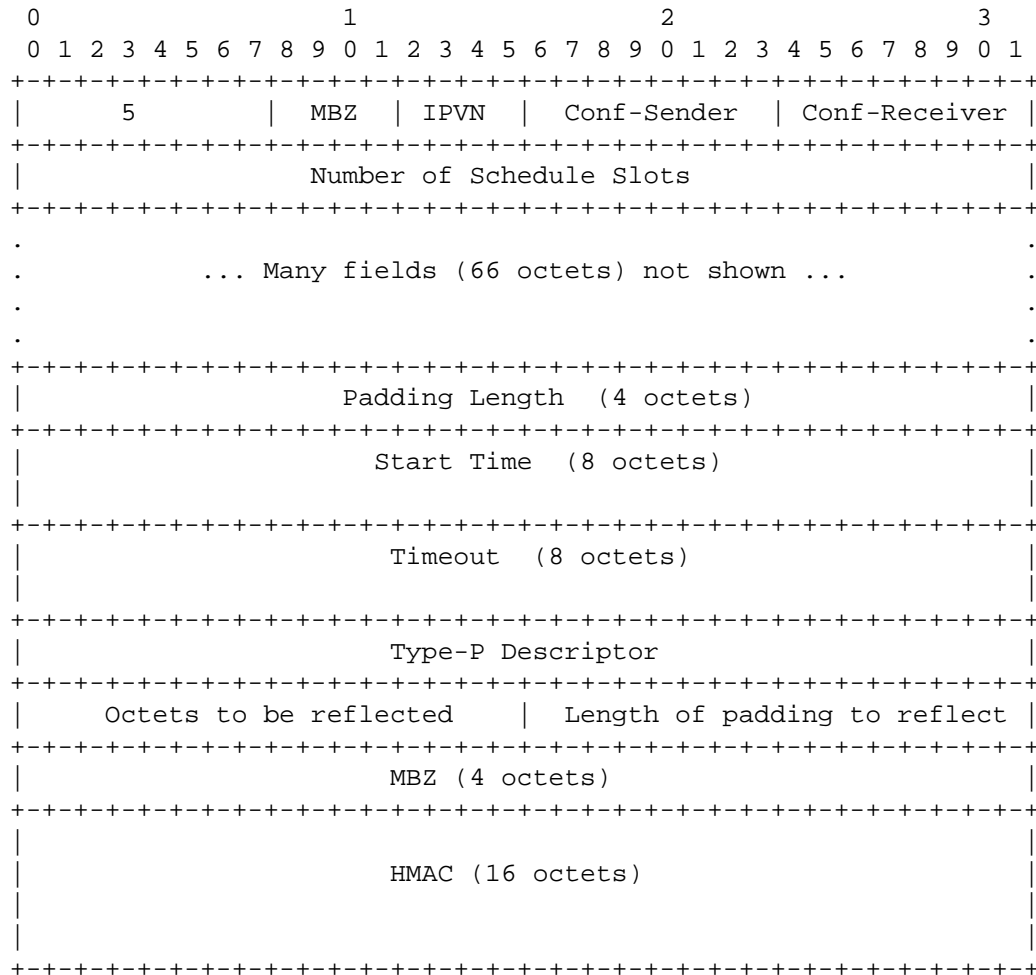
   It is important to note that the Padding Length field continues to
   specify the number of padding octets that the Session-Sender will
   append to ALL TWAMP-Test packets associated with this test session.
   See below for considerations on the minimum length of the padding
   octets following the definitions of the two new fields that follow
   the Type-P Descriptor.

   Note that the number of padding octets appended to the Session-
   Reflector's test packet depends on support for the truncation process
   that TWAMP recommends, see Section 4.2.1 of [RFC5357].

The Octets to be reflected field SHALL be 2 octets long, as shown,
and contain the octets that the Server MUST reflect in the Accept
Session message as specified below.

The Length of padding to reflect field SHALL be 2 octets long and
contain an unsigned binary value in units of octets. This field
communicates the length of the padding in the TWAMP-Test Packet that
the Session-Sender expects to be reflected and the length of octets
that the Session-Reflector SHALL return in its TWAMP-Test packet
format (see Section 5.2). By including this length field in the
Request-TW-Session message, a Server is able to determine if it can
comply with a specific request to reflect padding in the TWAMP-Test
packets and to arrange for the Session-Reflector processing in
advance.

The Padding Length SHOULD be >= 27 octets when specifying a test
session using the Unauthenticated TWAMP-Test mode to allow for the
truncation process that TWAMP recommends, see Section 4.2.1 of
[RFC5357].

The Padding Length SHOULD be >= 56 octets when specifying a test
session using the Authenticated or Encrypted TWAMP-Test modes to
allow for the truncation process that TWAMP recommends, see Section
4.2.1 of [RFC5357].

The Padding Length SHALL be > the Length of padding to reflect when
specifying a test session using the OPTIONAL Reflect Octets mode.

In Unauthenticated TWAMP-Test mode, the Padding Length SHALL be >= 27
+ Length of padding to reflect octets when specifying a test session
using both the OPTIONAL Reflect Octets mode and the truncation
process that TWAMP recommends, see Section 4.2.1 of [RFC5357].

In Authenticated or Encrypted TWAMP-Test modes, the Padding Length
SHALL be >= 56 + Length of padding to reflect octets when specifying
a test session using both the OPTIONAL Reflect Octets mode and the
truncation process that TWAMP recommends, see Section 4.2.1 of
[RFC5357].

4.3. Reflect Octets: Accept Session Packet Format

The bits designated for the Reflect Padding feature in the Accept
Session command are as shown in the packet format below.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Accept     |     MBZ       |             Port              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-|
|                                                               |
|                                                               |
|                      SID (16 octets)                          |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Reflected octets         |        Server octets          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      MBZ (8 octets)                           |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                      HMAC (16 octets)                         |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
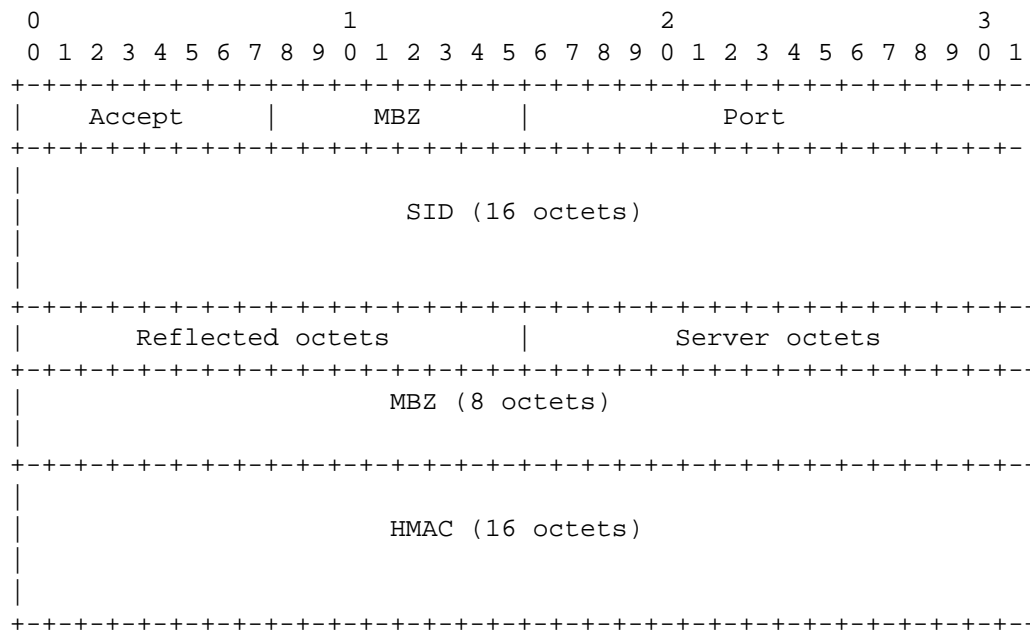
The Reflected octets field SHALL contain the octets from the Request-
TW-Session Octets to be reflected field and be 2 octets long, as
shown.

The Server octets field SHALL contain information that the Server
intends to be returned in the TWAMP-Test Packet Padding (to be
reflected) field, OR SHALL be zero, and be 2 octets long, as shown.
Although the Server determines the SID, this field is very long (16
octets) and does not normally appear in TWAMP-Test packets. The
following items MUST be part of compliant implementations using the
Reflect Octets feature:

o When a Server does not require octets to be returned in TWAMP-Test
   packets, it MUST send all zeros in the Server octets field.

o When a Server intends octets to be returned in TWAMP-Test packets,
   it MUST send a non-zero value in the Server octets field, and the
   TWAMP-Test Sender MUST include those octets at the beginning of
   the Packet Padding (to be reflected) field.

o Section 4.1.2 defines how Server octets MUST be included in the
   TWAMP-Test packet padding when this service is desired by the
   Server (indicated in the second of two figures in this section).

When performing the truncation process that TWAMP recommends, see
Section 4.2.1 of [RFC5357], if calculations on the Padding lengths
reveal that there are insufficient octets supplied to produce equal-
length Session-Sender and Session-Reflector test packets, then the
Accept field MUST be set to 3 to indicate that some aspect of the
request is not supported.

4.4. Additional Considerations

The value of the Modes field sent by the Server in the Server
Greeting message is the bit-wise OR of the mode values that it is
willing to support during this session.

With the publication of this memo as an RFC, the last 7 bit positions
of the Modes 32-bit field are used. A Control-Client conforming to
this extension of [RFC5357] MAY ignore the values in the higher bits
of the Modes field, or it MAY support other features that are
communicated in those bit positions. The other bits are available
for future protocol extensions.

5. Extended TWAMP Test

The TWAMP-Test protocol is similar to the OWAMP [RFC4656] test
protocol with the exception that the Session-Reflector transmits test
packets to the Session-Sender in response to each test packet it
receives. TWAMP, see Section 4 of [RFC5357], defines two additional
test packet formats for packets transmitted by the Session-Reflector.
The appropriate format depends on the security mode chosen. The new
modes specified here utilize some of the padding octets within each
test packet format or require truncation of those octets depending on
the security mode in use.

5.1. Sender Behavior

This section describes extensions to the behavior of the TWAMP
Session-Sender.

5.1.1. Packet Timings

The Send Schedule is not utilized in TWAMP, and this is unchanged in
this memo.

5.1.2. Reflect Octets: Packet Formats and Contents

The Session-Sender packet format and content follow the same
procedure and guidelines as defined in Section 4.1.2 of [RFC4656] (as
indicated in Section 4.1.2 of [RFC5357]).

The Reflect Octets mode re-designates the original TWAMP-Test Packet
Padding field (see Section 4.1.2 of [RFC4656]), as shown below for
Unauthenticated mode:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Sequence Number                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Timestamp                              |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Error Estimate        |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
|                                                               |
|                Packet Padding (to be reflected)               |
.             (length in octets specified in command)          .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
.                                                               .
.                 Additional Packet Padding                    .
.                                                               .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
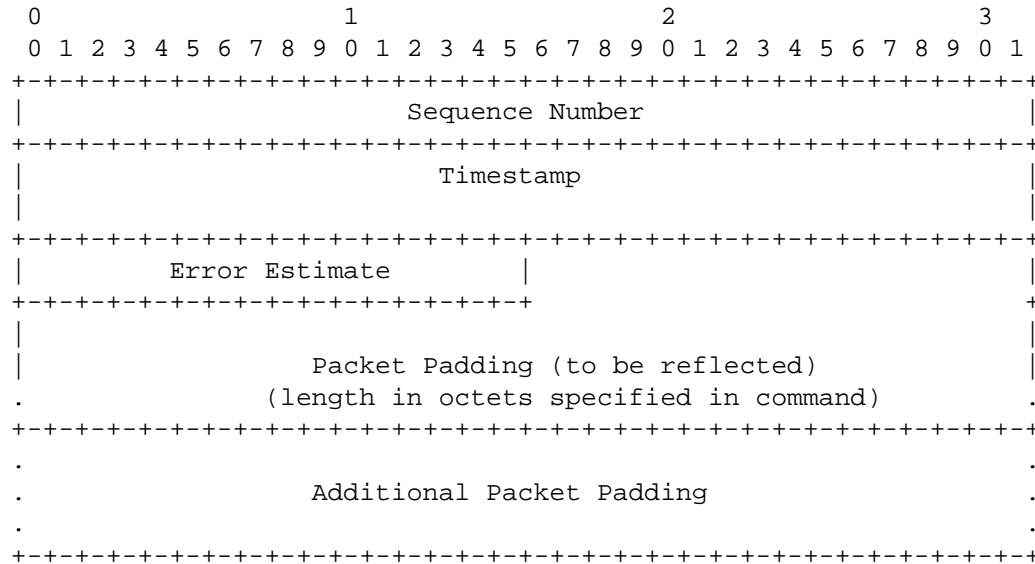
The Packet Padding (to be reflected) field SHALL correspond to the
length of octets specified in the Request-TW-Session Length of
padding to reflect field to this test session. These are the octets
that the Session-Sender expects will be returned by the Session-
Reflector.

The length of the Additional Packet Padding field is the difference
between two fields in the Request-TW-Session command, as follows:

Additional Packet Padding, in octets =

Padding Length - Length of padding to reflect

When a Server intends octets to be returned in TWAMP-Test packets, it
MUST send a non-zero value in the Server octets field, and the TWAMP-
Test Session-Sender MUST include those octets in the first 2 octets
of the Packet Padding (to be reflected) field as shown below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                |          Server octets        |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
 |              Remaining Packet Padding (to be reflected)       |
 .            (total length in octets specified in command)      .
 .                                                               .
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   The Server octets field contains the same information that the Server
   returned to the Control-Client in the Accept-Session message
   corresponding to this specific test session (see Section 4.3). At
   the Session-Reflector, these octets MUST be reflected the same as the
   rest of the Packet Padding (to be reflected) field.

   Note that it is permissible for the Session-Sender to insert the same
   octets used in the Octets to be reflected field of the Request-TW-
   Session command elsewhere in the Packet Padding (to be reflected)
   field.

5.1.3. Reflect Octets: Interaction with Padding Truncation

   When the Reflect Octets mode is selected, and performing the
   truncation process that TWAMP recommends, see Section 4.2.1 of
   [RFC5357], the Session-Sender MUST anticipate a minimum padding
   required to achieve equal-size test packets in both directions. The
   amount of padding needed to achieve symmetrical packet size depends
   on both the security mode (Unauthenticated/Authenticated/Encrypted)
   and whether the Reflect Octets mode is selected simultaneously.

   When using the truncation process in TWAMP alone, see Section 4.2.1
   of [RFC5357], the Session-Sender MUST append sufficient Packet
   Padding octets to allow the same IP packet payload lengths to be used
   in each direction of transmission (this is usually desirable). To
   compensate for the Session-Reflector's larger test packet format, the
   Session-Sender MUST append at least 27 octets of padding in
   Unauthenticated mode, and at least 56 octets in Authenticated and
   Encrypted modes. The sizes of TWAMP-Test protocol packets and the
   resulting truncated padding to achieve equal packet sizes in both
   directions are shown in the table below:

```
+-------------------+---------------------+---------------------+
| Octets in:        | Unauthenticated Mode | Auth/Encrypted Mode |
+-------------------+---------------------+---------------------+
| Reflector Header  | 41                  | 104                 |
| Sender Header     | 14                  | 48                  |
| Truncated Padding | 27                  | 56                  |
+-------------------+---------------------+---------------------+
```

TWAMP-Test Padding Truncation

When using the Reflect Octets mode simultaneously with the truncation
process that TWAMP recommends in Section 4.2.1 of [RFC5357], the
Session-Sender MUST append at least 27 octets of padding plus the
Length of the padding to reflect octets when operating in
Unauthenticated mode. The Session-Sender MUST append at least 56
octets of padding plus the Length of the padding to reflect octets
when operating in Authenticated and Encrypted modes.

5.1.4. Symmetrical Size: Session-Sender Packet Format

   When the Symmetrical Size mode is selected, the Session-Sender SHALL
   use the following TWAMP-Test Packet Format in Unauthenticated mode:

   Unauthenticated Mode

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                        Sequence Number                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                          Timestamp                            |
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         Error Estimate        |                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
   |                                                               |
   |                                                               |
   |                        MBZ (27 octets)                        |
   |                                                               |
   |                                                               |
   |                                                               |
   +                     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     |                                         |
   +-+-+-+-+-+-+-+-+-+                                             +
   .                                                               .
   .                        Packet Padding                         .
   .                                                               .
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
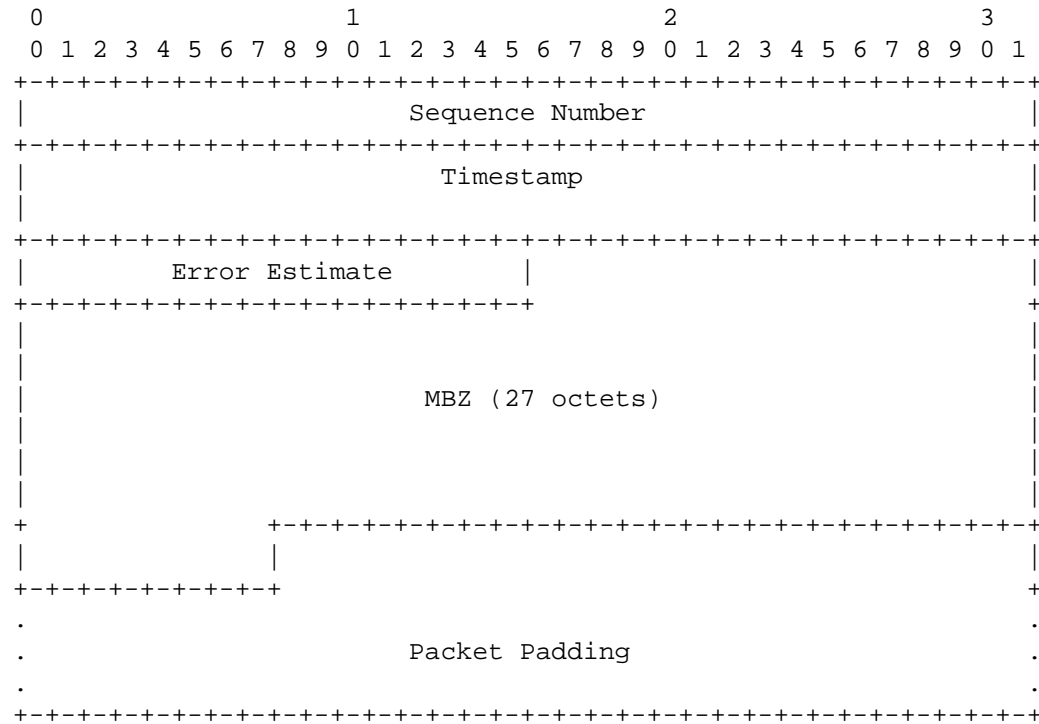
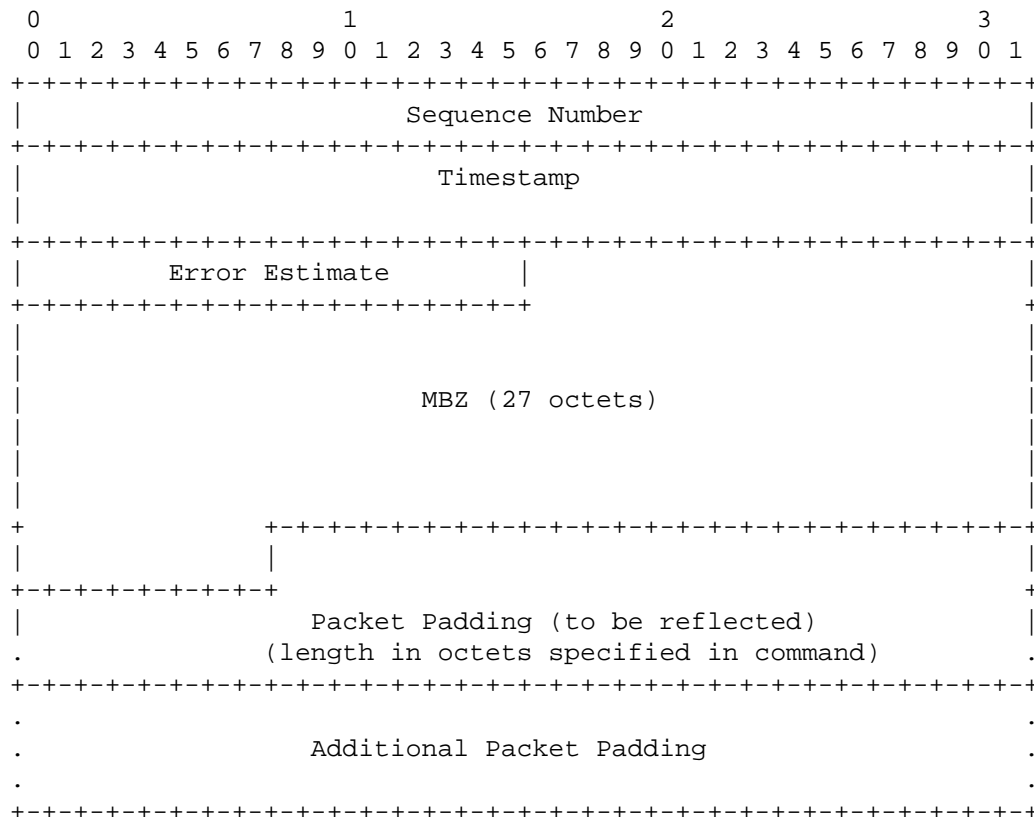   This feature REQUIRES only a new Session-Sender test packet format,
   the Session-Reflector test packet format is unchanged.

5.1.5. Symmetrical Size AND Reflect Octets: Session-Sender Packet
        Format

   When both the Symmetrical Size mode and the Reflect Octets mode are
   selected, the Session-Sender SHALL use the following TWAMP-Test
   Packet Format in Unauthenticated mode:

   Unauthenticated Mode

    0   1   2   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+
   | Sequence Number |
   +-+
   | Timestamp |
   | |
   +-+
   | Error Estimate | |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+   +
   | |
   | |
   | MBZ (27 octets) |
   | |
   | |
   | |
   +   +-+
   | | |
   +-+-+-+-+-+-+-+-+   +
   | Packet Padding (to be reflected) |
   .   (length in octets specified in command)   .
   +-+
   .   .
   .   Additional Packet Padding   .
   .   .
   +-+

   In this combined mode, the Packet Padding to be reflected follows the
   27 MBZ octets. In Authenticated or Encrypted modes, the Packet
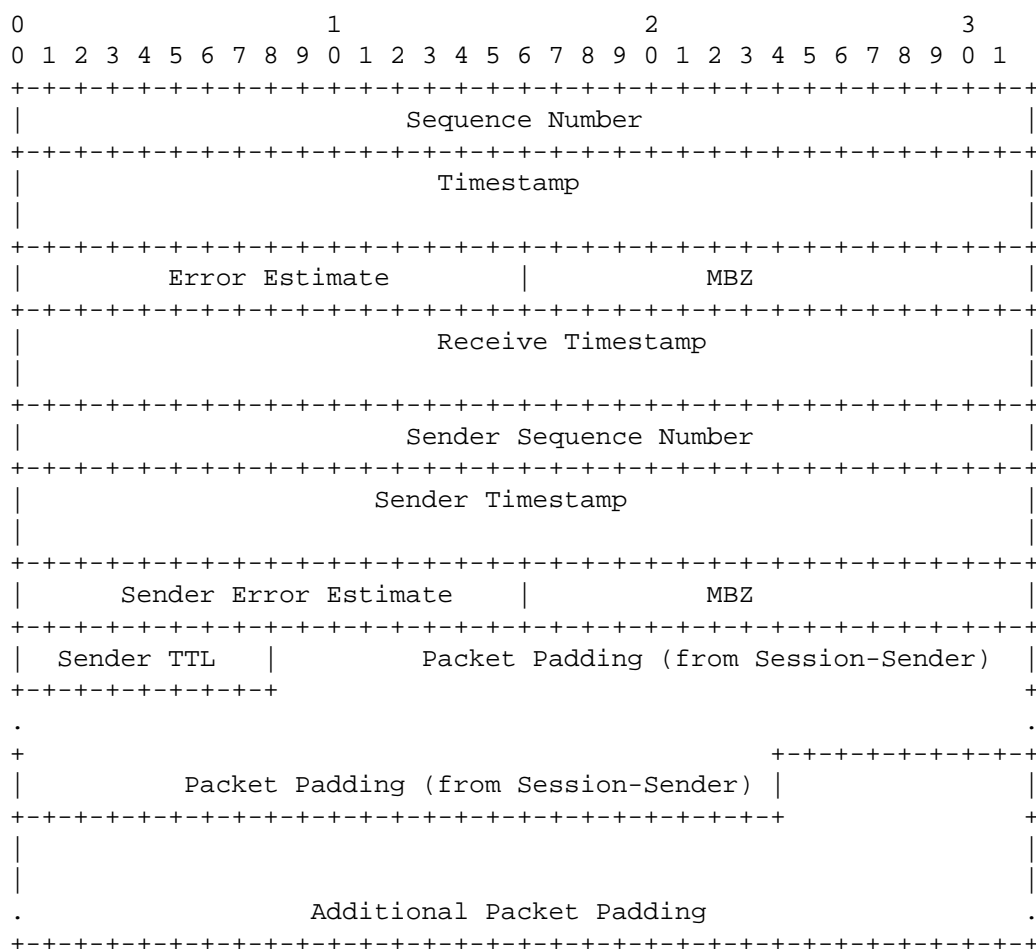   Padding to be reflected follows the 56 MBZ octets.

5.2. Reflector Behavior

   The TWAMP Reflector follows the procedures and guidelines in Section
   4.2 of [RFC5357], with the following additional functions:

   o Reflect Octets mode: Designated octets in the Packet Padding (to
      be reflected) field of the Session-Sender's test packet MUST be
      included in the Session-Reflector's test packet.

   o Symmetrical Size mode: The Session-Reflector MUST operate using
      the Session_Reflector Packet Format defined in Section 5.1.4,
      where the Padding Octets are separated from the information
      fields.

5.2.1. Reflect Octets: Session-Reflector Packet Format and Contents

   The Reflect Padding feature re-designates the Packet Padding field,
   as shown below. When the Reflect Octets mode is selected, the
   Session-Sender SHALL use the following TWAMP-Test Packet Format in
   Unauthenticated mode:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sequence Number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Timestamp                            |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Error Estimate        |             MBZ               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Receive Timestamp                       |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Sender Sequence Number                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sender Timestamp                       |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Sender Error Estimate    |             MBZ               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Sender TTL  |      Packet Padding (from Session-Sender)     |
+-+-+-+-+-+-+-+-+                                               +
.                                                               .
+                                       +-+-+-+-+-+-+-+-+
|        Packet Padding (from Session-Sender) |                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                 +
|                                                               |
|                                                               |
.                   Additional Packet Padding                   .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   The Packet Padding (from Session-Sender) field MUST be the same
   octets as the Packet Padding (to be reflected) field in the Session-
   Sender's test packet, and therefore MUST conform to the length
   specified in the Request-TW-Session message.

When the Server has returned a non-zero value in the Server octets
field of the Accept Session message (as described in Section 4.3),
then the Session-Reflector SHALL reflect these octets the same as the
rest of the Packet Padding (to be reflected) field.

Section 4.2.1 of [RFC5357] recommends a padding truncation process
for use in TWAMP. When using that process in conjunction with the
Reflect Octets mode, the Session-Reflector MUST reflect the
designated octets from the Session-Sender's test packet in the Packet
Padding (from Session-Sender) field, and MAY re-use additional Packet
Padding from the Session-Sender. The Session-Reflector MUST truncate
the padding such that the highest number octets are discarded, and
the test packet length equals the Session-Sender's packet length.
When using the recommended truncation process, the Session-Reflector
MUST truncate exactly 27 octets of padding in Unauthenticated mode,
and exactly 56 octets in Authenticated and Encrypted modes.

In any case, the Session-Reflector MAY re-use the Sender's Packet
Padding (since the requirements for padding generation are the same
for each).

5.2.2. Symmetrical Size: Session-Reflector Packet Format

When Symmetrical Size mode is selected, the Session-Reflector packet
formats for Unauthenticated and Authenticated/Encrypted modes are
identical to the core TWAMP specification, see Section 4.2.1 of
[RFC5357]. Thus, the Session-Reflector test packet format is
unchanged.

The Session-Reflector MUST construct its test packet using the
information in the Session-Sender's test packet. The length of the
Session-Reflector's test packet SHALL equal the length of the
Session-Sender's test packet.

5.2.3. Symmetrical Size AND Reflect Octets: Session-Sender Packet
        Format

When both the Symmetrical Size mode and the Reflect Octets mode are
selected, the Session-Reflector MUST operate using the Session-Sender
Packet Format defined in Section 5.1.5, where the Padding Octets are
separated from the information fields, and the Packet Padding (to be
reflected) field precedes the Additional Padding.

The Session-Reflector SHALL use the same TWAMP-Test Packet Format as
specified in Section 5.2.1, above.

6. Security Considerations

   These extended modes of operation do not appear to permit any new
   attacks on hosts communicating with core TWAMP [RFC5357].

   The security considerations that apply to any active measurement of
   live networks are relevant here as well. See [RFC4656] and
   [RFC5357].

7. IANA Considerations

   This memo adds two modes to the IANA registry for the TWAMP Modes
   field, and describes behavior when the new modes are used. This
   field is a recognized extension mechanism for TWAMP.

7.1. Registry Specification

   IANA has created a TWAMP-Modes registry (as requested in [RFC5618]).
   TWAMP-Modes are specified in TWAMP Server Greeting messages and Setup
   Response messages, as described in Section 3.1 of [RFC5357],
   consistent with Section 3.1 of [RFC4656], and extended by this memo.
   Modes are indicated by setting bits in the 32-bit Modes field that
   correspond to values in the Modes registry. For the TWAMP-Modes
   registry, we expect that new features will be assigned increasing
   registry values that correspond to single bit positions, unless there
   is a good reason to do otherwise (more complex encoding than single-
   bit positions may be used in the future to access the 2^32 value
   space).

7.2. Registry Contents

   The TWAMP-Modes registry has been augmented as follows:

   Value   Description   Semantics Definition
   ----
   32   Reflect Octets   this memo, Section 3.1
           Capability   new bit position (5)
   64   Symmetrical Size   this memo, Section 3.1
           Sender Test Packet Format new bit position (6)

8. Acknowledgements

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   for helpful review and comments.

9. Normative References

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