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TWAMP Value-Added Octets
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Status of This Memo

Abstract

This memo describes optional extensions to the TWAMP test protocol for identifying and managing packet trains, which enables measuring capacity metrics like the available path capacity, tight section capacity and UDP delivery rate in the forward and reverse path directions.

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1 Introduction

The notion of embedding a number of meaningful fields in the padding octets has been established as a viable methodology for carrying additional information within the TWAMP-Test protocol running between a Session-Sender and a Session-Reflector [RFC5357] [RFC6038].

This memo describes an extension to the Two-Way Active Measurement Protocol [RFC5357]. It is called the Value-Added Octets feature.

This feature enables the controller host to measure capacity metrics like the IP-type-P available path capacity (APC) [RFC5136], IP-layer tight section capacity (TSC) [Y1540] and UDP delivery rate (e.g. as defined in [RFC1242]) on both forward and reverse paths using a single TWAMP test session with symmetrical or asymmetrical test packet sizes. The actual method to calculate the APC, TSC or the UDP delivery rate from packet-level data performance data is not discussed in this memo.

The Valued-Added Octets feature consists of new behaviors for the Session-Sender and Session-Reflector, and a set of value-added octets of information that are placed at the beginning of the Packet Padding field [RFC5357] or at the beginning of the Packet Padding (to be reflected) field [RFC6038] by the Session-Sender, and are reflected or returned by the Session-Reflector. The length of the value-added octets (version 1) is 14 octets.

1.1 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].

2 Purpose and scope

The purpose of this memo is to describe the Valued-Added Octets feature for TWAMP [RFC5357].

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

- o The definition of a structure for embedding a sequence of value-added fields at the beginning of the Packet Padding field [RFC5037] or Packet Padding (to be reflected) field [RFC6038] in the TWAMP test packets and,

- o The definition of new Session-Sender and Session-Reflector behaviors

The motivation for this feature is to enable the measurements of capacity metrics on both the forward and reverse paths with symmetrical or asymmetrical test packet sizes.

This memo does not extend the modes of operation through assignment of a new value in the Modes field (see Section 3.1 of [RFC4656] for the format of the Server Greeting message). However a new mode is required to communicate feature capability and use in an interoperable manner. For instance, when the Server and Control-Client have agreed to use the Value-Added Octets Version 1 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.

The packet padding octets are designed to retain backward compatibility with the original TWAMP test protocol [RFC5357].

3 Capacity Measurement Principles

Most capacity estimation methods for APC [RRBNC][PDM][ENHJMMB][SBW] and for UDP delivery rate need to send and receive packets in groups, called packet trains or simply trains. Each train is sent at a specific transmission rate in a given direction. These trains must be identified within each bi-directional test session stream.

The first measurement principle is to send multiple trains within a test session stream from one IP node to another IP node in order to estimate the APC, TSC or UDP delivery rate in the forward direction. Each train consists of a group of test packets which are separated from each other by a packet interval, as shown in the picture below. The packet interval is measured using either the first bit or the last bit of two consecutive packets.

```
      tt                     tt                     tt
|<---------->|          |<---------->|          |<---------->|
|            |          |            |          |            |
+------------+          +------------+          +------------+
|  Packet 1  |          |  Packet 2  |          |  Packet 3  |
+------------+          +------------+          +------------+
|                       |                       |
|<--------------------->|<--------------------->|
   packet interval 1       packet interval 2
```

The test packet size and interval between consecutive packets for

each train sent by the Session-Sender and reflected by the Session-Reflector MUST be calculated and determined by the controller or an application or entity communicating with the controller. The packet size and interval MAY vary within a train, between trains and MAY also be different depending on forward or reverse transmission direction. Determination of the packet size and interval is implementation-specific.

The transmission time tt to send one packet (i.e. determined by the interface speed and the IP packet size) is also shown in the picture. Observe that the packet interval MUST be larger than or equal to tt.

At the Session-Reflector, each received test packet within a forward train is time stamped. This provides a second set of packet interval values. Methods for measuring the APC, TSC and UDP delivery rate use the packet intervals obtained from both end points in the estimation process. The method to measuring the UDP delivery rate may also require the packet loss at the receiving end. The estimation process itself as well as any requirements on software or hardware is implementation-specific.

The second measurement principle is referred to as self-induced congestion. According to this principle, in order to measure APC, TSC and UDP delivery rate, some trains MUST cause momentary congestion on the network path. In essence this means that some trains MUST be sent at a higher rate than what is available on the network path.

In order to fulfill the above measurement principles and to measure the APC, TSC and UDP delivery rate in the reverse direction, the test packets at the Session-Reflector MUST be re-grouped into trains and then transmitted back to the Session-Sender with a provided packet interval.

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.

TWAMP connection establishment follows the procedure defined in Section 3.1 of [RFC4656] and Section 3.1 of [RFC5357]. For interoperability, the Value-added octet feature require one new bit position (and value) to identify the ability of the Server/Session-Reflector to read and act upon the new fields in the value-added octets. Such bit position (and value) is not defined in this memo.

Both the Reflect Octets mode and Symmetrical Size mode MAY be

selected to ensure the reflection of the value-added padding octets by the Session-Reflector and symmetrical size TWAMP-Test packets in the forward and reverse directions of transmission.

5 Extended TWAMP Test

The forward and reverse APC, TSC and UDP delivery rate measurement characteristics depend on the size and packet intervals of the test packets. This memo allows variable packet sizes and packet intervals between trains in different transmission directions, trains in the same transmission direction and even between packets in the same train. The functionality is described below.

The TWAMP-test protocol carrying the value-added padding octets is identical to TWAMP [RFC5357] except for the definition of first 14 octets in Packet Padding that the Session-Sender expects to be reflected. The new octets define fields for Value-Added Octets Version, Flags, Last Sequence Number in Train, Desired Reverse Packet Interval and Desired Reverse Padding Length. Each of these fields are described in detail below.

The Session-Sender and Session-Reflector behaviors are also modified.

5.1 Sender Behavior

This section describes the 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 Session-Sender Packet Format

The Session-Sender packet format follows the same procedure and guidelines as defined in TWAMP [RFC5357] and TWAMP Reflect Octets and Symmetrical Size Features [RFC6038].

This feature allows the Session-Sender to set the first few octets in the TWAMP-Test Packet Padding field with information to communicate value-added padding version number, flag bits, sequence number of the last packet in a train, desired reverse packet interval (or per-packet waiting time) and desired reverse padding length for the reverse path direction of transmission.

A version number and a sequence of flag bits are defined at the very

beginning of the value-added padding octets. The version number identifies the version of the value-added padding octets and meaning of the flag bits and corresponding fields. Each flag bit indicates if a specific field is used in the valued-added padding octets. The version number and flag bits provide an effective method for extracting information at Session-Reflector and Session-Sender. This document defines version 1 with three flag bits: L, I and P.

The format of the test packet depends on the TWAMP mode and flag bits being used. The Value-Added Octets Version 1 mode is intended to work with any TWAMP modes.

The Session-Sender SHALL use the following TWAMP test packet format when the Value-Added Octets Version 1 is selected in conjunction with the 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        |  Ver  |L|I|P|   Reserved      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Last Seqno In Train                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Desired Reverse Packet Interval                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Desired Reverse Padding Length                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-|
|                   Additional Packet Padding                   |
.                                                               .
.                                                               .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Session-Sender SHALL use the following TWAMP test packet format when the Value-Added Octets Version 1 is selected in conjunction with the unauthenticated mode, Symmetrical Size mode and Reflect Octets 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)                       |
    |                                                               |
    |                                                               |
    |                                                               |
    |               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               |  Ver  |L|I|P|    Reserved     |    Last...    |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               Seqno in Train                  |   Desired...  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |         Reverse Packet Interval               |   Desired...  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |         Reverse Padding Length                |               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+               |
    |         Additional Packet Padding                             |
    .                                                               .
    .                                                               .
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Session-Sender SHALL use the following TWAMP test packet format when the Value-Added Octets Version 1 is selected in conjunction with the unauthenticated mode, Symmetrical Size mode and Reflect Octets mode with a non-zero value in the Server octets field:

```
     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)                       |
    |                                                               |
    |                                                               |
    |                                                               |
    |               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               |         Server octets         |  Ver  |L|I|P| |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |    Reserved   |         Last Seqno in Train                   |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               |         Desired Reverse Packet Interval       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               |         Desired  Reverse Padding Length       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |               |         Additional Packet Padding             |
    +-+-+-+-+-+-+-+-+                                               |
    |                                                               |
    .                                                               .
    .                                                               .
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In the mode using Reflect Octets illustrated above, the value-added padding octets are embedded in the Packet Padding (to be reflected) field.

The Version (Ver) field MUST be encoded in the first 4 bits. It identifies the version number of the value-added padding octets and meaning of the flag bits and the corresponding fields. This memo defines version 1. When the Value-Added Octets Version 1 mode is selected, the Session-Sender MUST set the Ver field to 1.

The 3 bits after the Version field are used for flags: L, I and P.

The Last Seqno in Train bit (L) is the first flag. When the Value-Added Octets Version 1 mode is selected, the Session-Sender MAY set the Last Seqno in Train bit L to 1.

The Desired Reverse Packet Interval bit (I) is the second flag. When the Value-Added Octets Version 1 mode is selected, the Session-Sender MAY set the Desired Reverse Packet Interval bit I to 1.

The Desired Reverse Padding Length bit (P) is the third flag. When the Value-Added Octets Version 1 mode is selected, the Session-Sender MAY set the Desired Reverse Padding Length bit P to 1.

The Reserved field is reserved for future use. All 9 bits of the Reserved field MUST be transmitted as zero by the Session-Sender.

If the Last Seqno in Train bit is set to 1, then the Last Seqno in Train field MUST contain an unsigned 32 bit integer generated by the Session-Sender. It MUST indicate the expected sequence number of the last packet in the train. It SHOULD be used by the Session-Sender and Session-reflector to identify the train a test packet belongs to. The packets belonging to a train are determined by observing the test packet sequence number in relation to the Last Seqno for a train. The Last Seqno in Train MUST be higher or equal to the sequence number of the packet. It must also be higher than the Last Seqno in Train for the previous train. If the L bit is set to 0, the Session-Sender shall set all the bits in the Last Seqno in Train field to zero.

If the Desired Reverse Packet Interval bit is set to 1, then the Desired Reverse Packet Interval field MUST contain an unsigned 32 bit integer generated by the Session-Sender. It MUST indicate the desired packet interval (or the waiting time) that the Session-Reflector SHOULD use when transmitting the reflected test packets towards the Session-Sender. The value 0 means the The Session-Reflector SHOULD return the test packet to the Session-Sender as quickly as possible. The format of this field MUST be a fractional part of a second as defined in OWAMP [RFC4656]. If I bit is set to 0, the Session-Sender shall set all the bits in the Desired Reverse Packet Interval field to zero.

If the Desired Reverse Padding Length bit is set to 1, then the

Desired Reverse Padding Length field MUST contain an unsigned 32 bit integer generated by the Session-Sender. It MUST specify the number of padding octets that the Session-Reflector will append to the TWAMP-Test packet to be reflected. The Desired Reverse Padding Length includes the Value-added octets. If P bit is set to 0, the Session-Sender shall set all the bits in the Desired Reverse Padding Length field to zero.

The values of the above fields are usually provided by a measurement method, tool or algorithm. This measurement algorithm is outside the scope of this specification.

5.2 Reflector behavior

The TWAMP Session-Reflector follows the procedures and guidelines in Section 4.2 of [RFC5357], with some changes and additional functions.

When the Value-Added Octets Version 1 is selected, the behavior of the Session-Reflector SHALL be as follows:

- o The Session-Reflector MUST read the Version field. If Ver = 1, the Session-Reflector MUST read the L, I and P flag bits.

- o If L=1 and I=1, the Session-Reflector MUST read and extract the information from the Last Seqno in Train field and the Desired Reverse Packet Interval field in the value-added padding octets.

  - The Last Seqno in Train field MUST be compared to Sequence number in the same packet in order to determine when a complete train has been collected. The Session-Reflector SHOULD buffer the packets belonging to the current train (or store the packet-level performance data). After the last packet of the train has been received, the Session-Reflector SHOULD transmit the packets belonging to a reverse train with a waiting time (packet interval) for each packet indicated in the Desired Reverse Packet Interval field. If the Desired Reverse Packet Interval field is set to zero, then the Session-Reflector SHOULD transmit the packets as

quickly as possible. The last packet within a train has Sender Sequence Number = Last Seqno in Train.

  - The Last Seqno in Train of a packet MUST also be compared to the Last Seqno in Train of the previous packet in order to determine if a new train needs to be collected. In case of packet loss, the Session-Reflector MUST transmit the incomplete train when it receives a packet with a Last SeqNo in Train belonging to the another train (e.g. next train) of the test session, or after a timeout. The timeout MAY be the REFWAIT timer specified in section 4.2 of [RFC5357].

  - Packets arriving out-of-order within a train MUST be buffered at the Session-Reflector if the train is not yet transmitted to the Session-Sender. If the train is already transmitted, the test packet SHOULD be returned to the Session-Sender as quickly as possible. The Session-Reflector MUST not reorder the test packets if they happen to arrive out-of-sequence.

- Duplicate packets within a train MUST be buffered at the Session-Reflector if the train is not yet transmitted to the Session-Sender. If the train is already transmitted, the duplicate test packet SHOULD be returned to the Session-Sender as quickly as possible. The Session-Reflector MUST not discard duplicate test packets.

o If P=1, the Session-Reflector MUST read and extract the information from the Desired Reverse Padding Length field in the value-added padding octets.

  - The Session-Reflector SHOULD transmit the packet with the Desired Reverse Padding Length. If Symmetrical-Size mode is used the Desired Reverse Padding Length must be ignored by the Session-Reflector. The actual reflected packet size MUST be large enough to contain all data required to be reflected according to selected modes. If the Desired Reverse Padding Length is larger than the Session-Reflector MTU, the MTU MUST be used.

The Session-Reflector MUST implement the changes described above when the Value-Added Octets Version 1 mode is selected.

5.2.1 Session-Reflector Packet Format

The Session-Reflector packet format follows the same procedure and

guidelines as defined in TWAMP [RFC5357] and TWAMP Reflect Octets and Symmetrical Size Features [RFC6038], with the following changes:

o The Session-Reflector MUST re-use (reflect) the value-added padding octets (14 octets) provided in the Sender's Packet Padding.

o The Session-Reflector MAY re-use the rest of the padding octets in the Sender's Packet Padding.

The truncation process [RFC5357] is recommended when the Desired

Reverse Padding Length (P) bit is 0 and the Symmetrical mode is not used. The Session-Reflector MUST truncate exactly 27 octets of padding in Unauthenticated mode,and exactly 56 octets in Authenticated and Encrypted modes.

5.3 Additional Considerations

Capacity measurements introduce an additional consideration when the test sessions operate in TWAMP Light. When the Session-Reflector does not have knowledge of the session state, the measurement system will only be capable to estimate or calculate the capacity metrics in the forward path direction of transmission. Capacity measurements in the reverse path direction requires the Session-Reflector to have knowledge of the session state and be capable to identify the test packets belonging to a specific test session. The method for creating a session state from the initial test packets on the TWAMP Light Session-Reflector is outside the scope of this specification.

6 Security Considerations

The value-added padding octets permit DoS attacks on the responder host communicating with core TWAMP [RFC5357]. The responder host MUST provide a mechanism to protect or limit the use of its local memory, buffer space or maximum transmission time for a train.

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

7 IANA Considerations

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]. 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, new features are usually assigned increasing registry values that correspond to single bit positions.

This memo does not define a new TWAMP mode. Therefore it is not a recognized extension mechanism for TWAMP. A new mode is required to communicate feature capability and use in an interoperable manner. This is outside the scope of this memo.

8 References

8.1 Normative References

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8.2 Informative References

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