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Simple Two-Way Active Measurement Protocol

Abstract

This document describes the Simple Two-way Active Measurement Protocol (STAMP), which enables the measurement of both one-way and round-trip performance metrics, like delay, delay variation, and packet loss.

Status of This Memo

This is an Internet Standards Track document.

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

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc8762.

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1. Introduction

Development and deployment of the Two-Way Active Measurement Protocol (TWAMP) [RFC5357] and its extensions (e.g., [RFC6038], which defines Symmetrical Size for TWAMP) provided invaluable experience. Several independent implementations of both TWAMP and TWAMP Light exist, have been deployed, and provide important operational performance measurements.

At the same time, there has been noticeable interest in using a more straightforward mechanism for active performance monitoring that can provide deterministic behavior and inherent separation of control (vendor-specific configuration or orchestration) and test functions. Recent work on "Performance Measurement from IP Edge to Customer Equipment using TWAMP Light" [BBF.TR-390] by the Broadband Forum demonstrates that interoperability among implementations of TWAMP Light is difficult because the composition and operation of TWAMP Light were not sufficiently specified in [RFC5357]. According to [RFC8545], TWAMP Light includes a subset of TWAMP-Test functions. Thus, to have a comprehensive tool to measure packet loss and delay requires support by other applications that provide, for example, control and security.

This document defines an active performance measurement test protocol, Simple Two-way Active Measurement Protocol (STAMP), that enables measurement of both one-way and round-trip performance metrics, like delay, delay variation, and packet loss. Support of some optional TWAMP extensions, e.g., [RFC7750], is discussed in [STAMP-OPTION].

2. Conventions Used in This Document

2.1. Terminology

STAMP: Simple Two-way Active Measurement Protocol

NTP: Network Time Protocol

PTP: Precision Time Protocol

HMAC: Hashed Message Authentication Code

OWAMP: One-Way Active Measurement Protocol

TWAMP: Two-Way Active Measurement Protocol

MBZ: Must be Zero

PDU: Protocol Data Unit

2.2. Requirements Language

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

3. Operation and Management of Performance Measurement Based on STAMP

Figure 1 presents the Simple Two-way Active Measurement Protocol (STAMP) Session-Sender and Session-Reflector with a measurement session. In this document, a measurement session, also referred to as a "STAMP session", is the bidirectional packet flow between one specific Session-Sender and one particular Session-Reflector for a time duration. The configuration and management of the STAMP Session-Sender, Session-Reflector, and sessions are outside the scope of this document and can be achieved through various means. A few examples are Command Line Interface, telecommunication services' Operational Support System (OSS) / Business Support System (BSS), SNMP, and NETCONF/YANG-based Software-Defined Networking (SDN) controllers.

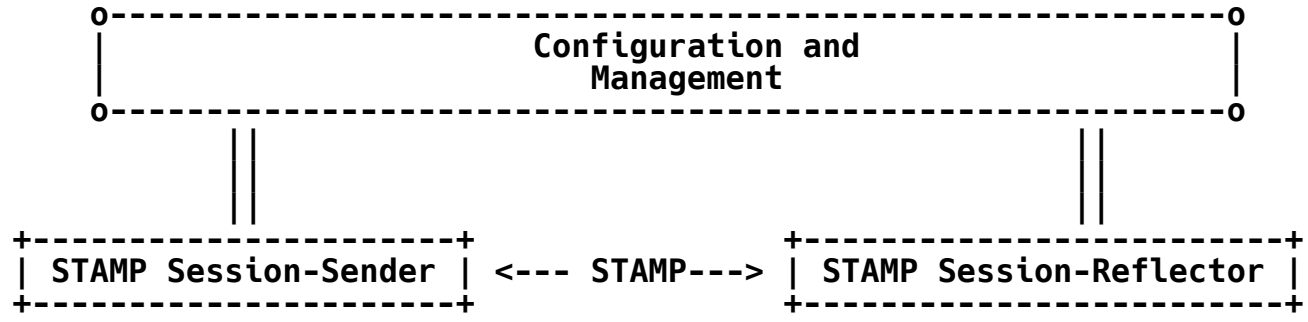


Figure 1: STAMP Reference Model

4. Theory of Operation

The STAMP Session-Sender transmits test packets over UDP transport toward the STAMP Session-Reflector. The STAMP Session-Reflector receives the Session-Sender's packet and acts according to the configuration. Two modes of the STAMP Session-Reflector characterize

the expected behavior and, consequently, performance metrics that can be measured:

Stateless:
The STAMP Session-Reflector does not maintain test state and will use the value in the Sequence Number field in the received packet as the value for the Sequence Number field in the reflected packet. As a result, values in the Sequence Number and Session-Sender Sequence Number fields are the same, and only round-trip packet loss can be calculated while the reflector is operating in stateless mode.

Stateful:
STAMP Session-Reflector maintains the test state, thus allowing the Session-Sender to determine directionality of loss using the combination of gaps recognized in the Session Sender Sequence Number and Sequence Number fields, respectively. As a result, both near-end (forward) and far-end (backward) packet loss can be computed. That implies that the STAMP Session-Reflector MUST maintain a state for each configured STAMP-Test session, thereby uniquely associating STAMP-Test packets with one such session instance and, thus, enabling the addition of a sequence number in the test reply that is individually incremented by one on a per-session basis.

STAMP supports two authentication modes: unauthenticated and authenticated. Unauthenticated STAMP-Test packets, defined in Sections 4.2.1 and 4.3.1, ensure interworking between STAMP and TWAMP Light, as described in Section 4.6 regarding packet formats.

By default, STAMP uses symmetrical packets, i.e., the size of the packet transmitted by the Session-Reflector equals the size of the packet received by the Session-Reflector.

4.1. UDP Port Numbers in STAMP Testing

A STAMP Session-Sender MUST use UDP port 862 (TWAMP-Test Receiver Port) as the default destination UDP port number. A STAMP implementation of the Session-Sender MUST be able to be used as the destination UDP port numbers from the User Ports (aka Registered Ports) and Dynamic Ports (aka Private or Ephemeral Ports) ranges defined in [RFC6335]. Before using numbers from the User Ports range, the possible impact on the network MUST be carefully studied and agreed on by all users of the network domain where the test has been planned.

By default, an implementation of the STAMP Session-Reflector MUST receive STAMP-Test packets on UDP port 862. An implementation of the Session-Reflector that supports this specification MUST be able to define the port number to receive STAMP-Test packets from User Ports and Dynamic Ports ranges, which are defined in [RFC6335]. STAMP defines two different test packet formats: one for packets transmitted by the STAMP Session-Sender and one for packets transmitted by the STAMP Session-Reflector.

4.2. Session-Sender Behavior and Packet Format

A STAMP Session-Reflector supports the symmetrical size of test packets, as defined in Section 3 of [RFC6038], as the default behavior. A reflected base test packet includes information from the Session-Reflector and, thus, is larger. To maintain the symmetry between base STAMP packets, the base STAMP Session-Sender packet includes the Must-Be-Zero (MBZ) field to match to the size of a base reflected STAMP test packet. Hence, the base STAMP Session-Sender packet has a minimum size of 44 octets in unauthenticated mode (see Figure 2) and 112 octets in the authenticated mode (see Figure 4). Generating variable length of a test packet in STAMP is defined in [STAMP-OPTION].

4.2.1. Session-Sender Packet Format in Unauthenticated Mode

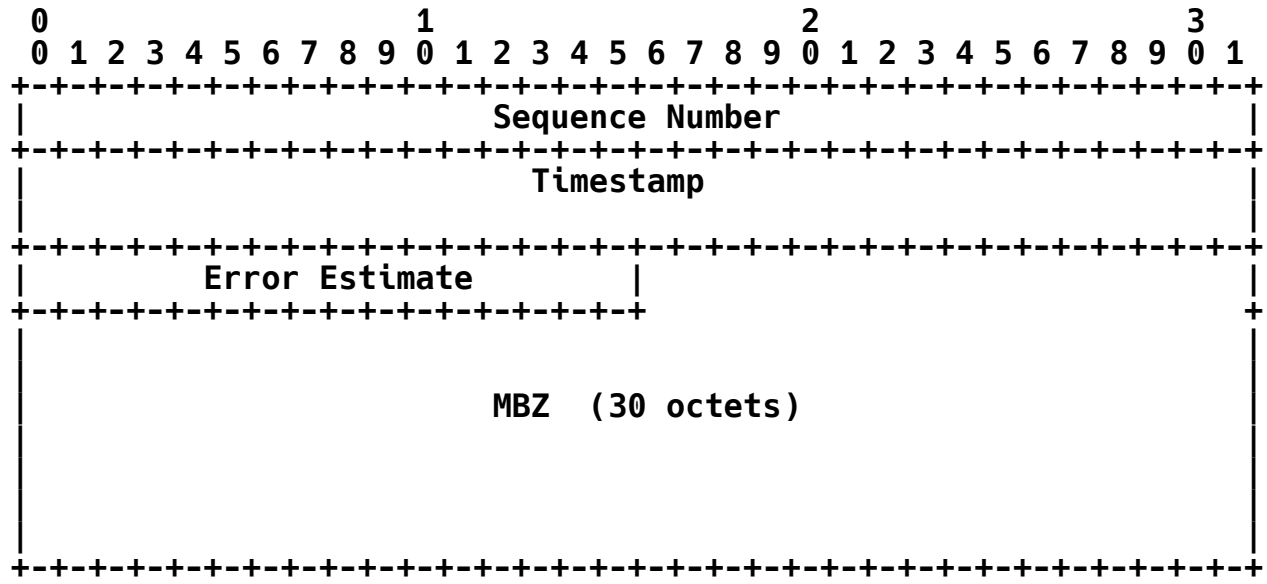


Figure 2: STAMP Session-Sender Test Packet Format in Unauthenticated Mode

The fields are defined as following:

* The Sequence Number field is four octets long. For each new session, its value starts at zero and is incremented by one with each transmitted packet.

* The Timestamp field is eight octets long. The STAMP node MUST support the Network Time Protocol (NTP) version 4 64-bit timestamp format [RFC5905], the format used in [RFC5357]. The STAMP node MAY support the IEEE 1588v2 Precision Time Protocol (PTP) truncated 64-bit timestamp format [IEEE.1588.2008], the format used in [RFC8186]. The use of the specific format, NTP or PTP, is part of configuration of the Session-Sender or the particular test session.

* The Error Estimate field is two octets long with the format displayed in Figure 3:

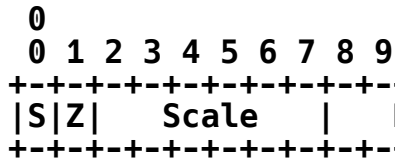


Figure 3: Error Estimate Format

The S, Scale, and Multiplier fields are interpreted as they are defined in Section 4.1.2 of [RFC4656]. The Z field is interpreted as it is defined in Section 2.3 of [RFC8186]:

0: NTP 64-bit format of a timestamp

1: PTPv2 truncated format of a timestamp

The default behavior of the STAMP Session-Sender and Session-Reflector is to use the NTP 64-bit timestamp format (Z field value of 0). An operator using configuration/management function MAY configure the STAMP Session-Sender and Session-Reflector to use the PTPv2 truncated format of a timestamp (Z field value of 1). Note that an implementation of a Session-Sender that supports this specification MAY be configured to use the PTPv2 format of a timestamp even though the Session-Reflector is configured to use NTP format.

* The MBZ field in the Session-Sender unauthenticated packet is 30 octets long. It MUST be all zeroed on the transmission and MUST be ignored on receipt.

4.2.2. Session-Sender Packet Format in Authenticated Mode

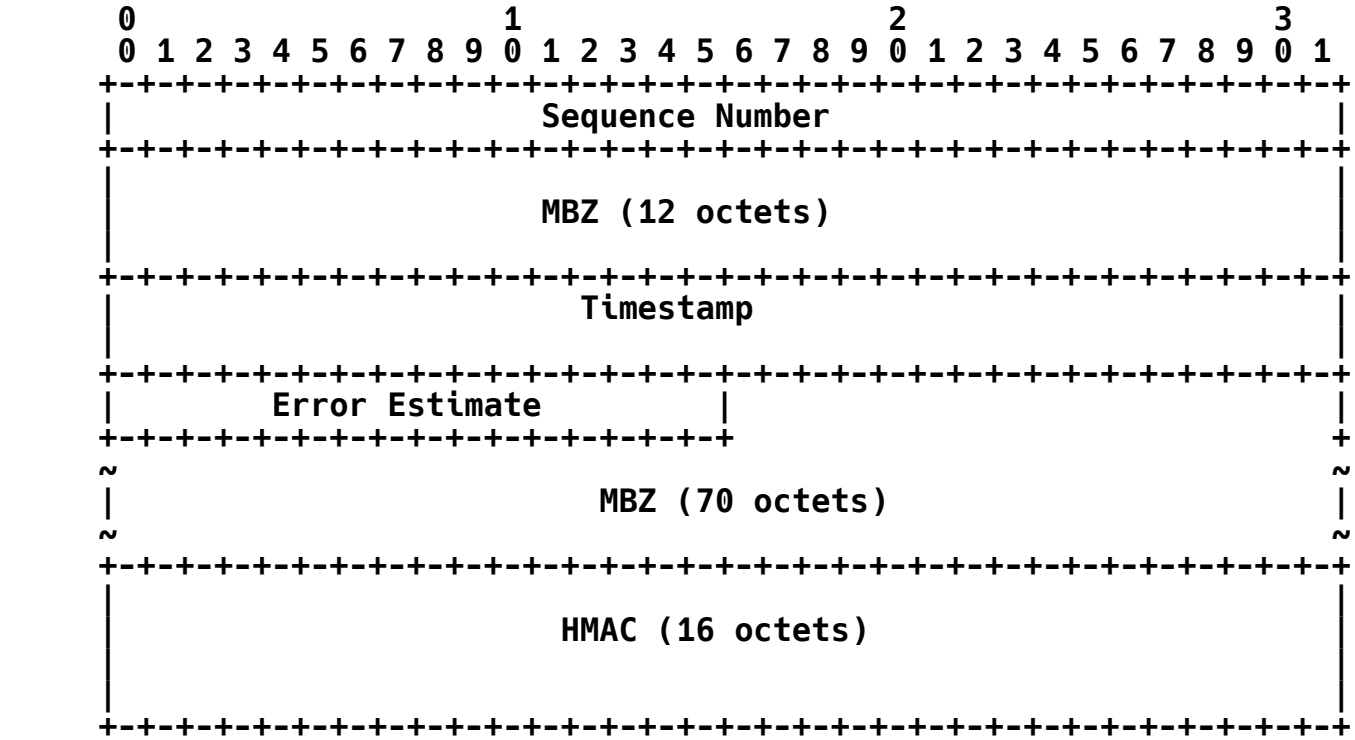


Figure 4: STAMP Session-Sender Test Packet Format in Authenticated Mode

The field definitions are the same as the unauthenticated mode, listed in Section 4.2.1. Also, MBZ fields are used to make the packet length a multiple of 16 octets. The value of the field MUST be zeroed on transmission and MUST be ignored on receipt. Note, that both MBZ fields are used to calculate a key hashed message authentication code (HMAC) [RFC2104] hash. Also, the packet includes an HMAC hash at the end of the PDU. The detailed use of the HMAC field is described in Section 4.4.

4.3. Session-Reflector Behavior and Packet Format

The Session-Reflector receives the STAMP-Test packet and verifies it. If the base STAMP-Test packet is validated, the Session-Reflector that supports this specification prepares and transmits the reflected test packet symmetric to the packet received from the Session-Sender copying the content beyond the size of the base STAMP packet (see Section 4.2).

4.3.1. Session-Reflector Packet Format in Unauthenticated Mode

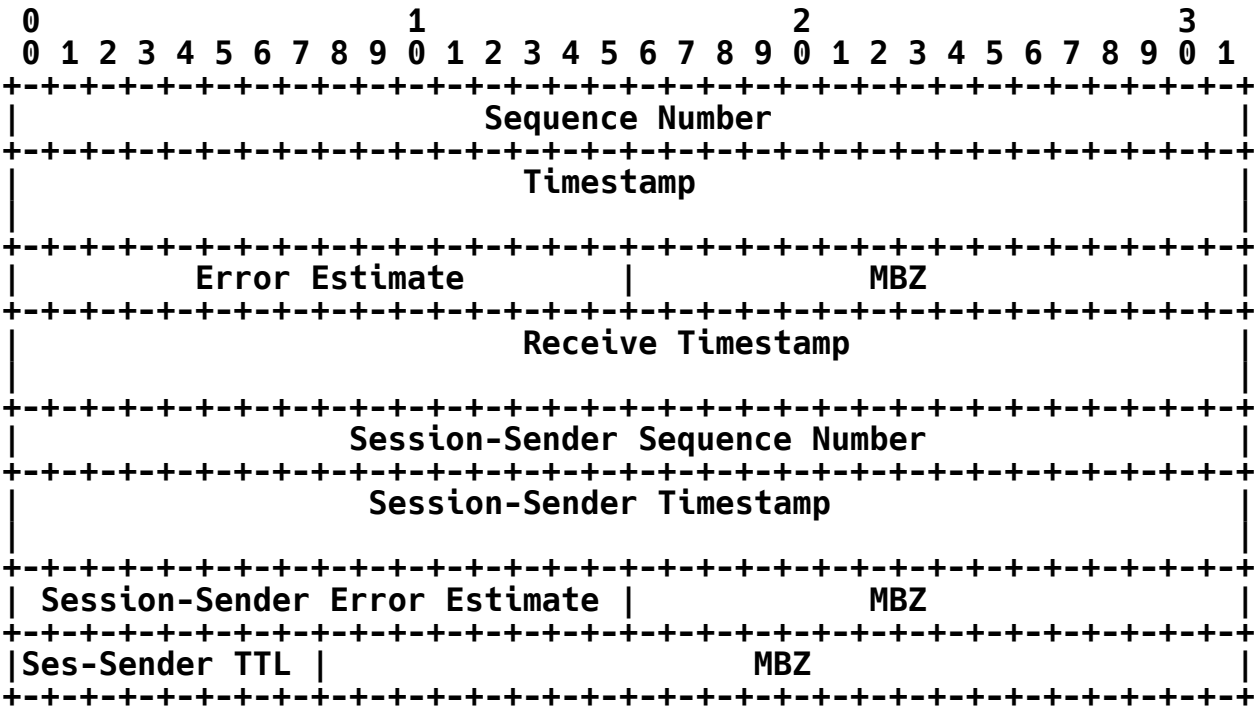


Figure 5: STAMP Session-Reflector Test Packet Format in Unauthenticated Mode

Fields are defined as the following:

* The Sequence Number field is four octets long. The value of the Sequence Number field is set according to the mode of the STAMP

Session-Reflector:

- In the stateless mode, the Session-Reflector copies the value from the received STAMP-Test packet's Sequence Number field.

- In the stateful mode, the Session-Reflector counts the transmitted STAMP-Test packets. It starts with zero and is incremented by one for each subsequent packet for each test session. The Session-Reflector uses that counter to set the value of the Sequence Number field.

* The Timestamp and Receive Timestamp fields are each eight octets long. The format of these fields, NTP or PTPv2, is indicated by the Z field of the Error Estimate field, as described in Section 4.2.1. Receive Timestamp is the time the test packet was received by the Session-Reflector. Timestamp is the time taken by the Session-Reflector at the start of transmitting the test packet.

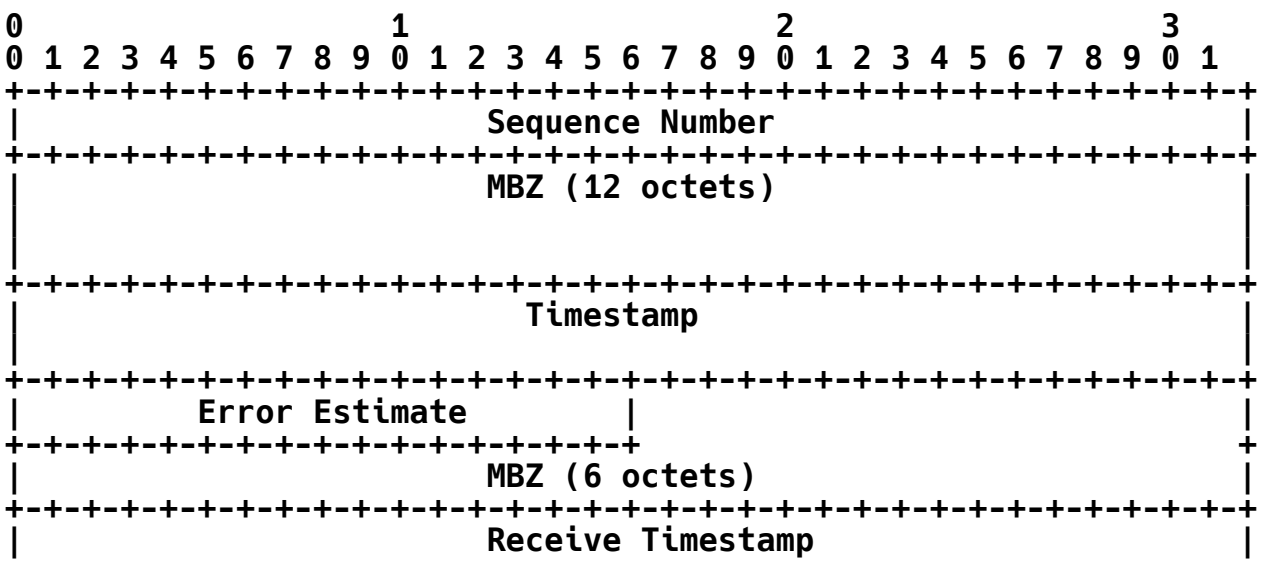
* The Error Estimate field has the same size and interpretation as described in Section 4.2.1. It is applicable to both Timestamp and Receive Timestamp.

* The Session-Sender Sequence Number, Session-Sender Timestamp, and Session-Sender Error Estimate fields are copies of the corresponding fields in the STAMP-Test packet sent by the Session-Sender.

* The Session-Sender TTL field is one octet long, and its value is the copy of the TTL field in IPv4 (or Hop Limit in IPv6) from the received STAMP-Test packet.

* The MBZ fields are used to achieve alignment of fields within the packet on a four-octet boundary. The value of each MBZ field MUST be zeroed on transmission and MUST be ignored on receipt.

4.3.2. Session-Reflector Packet Format in Authenticated Mode



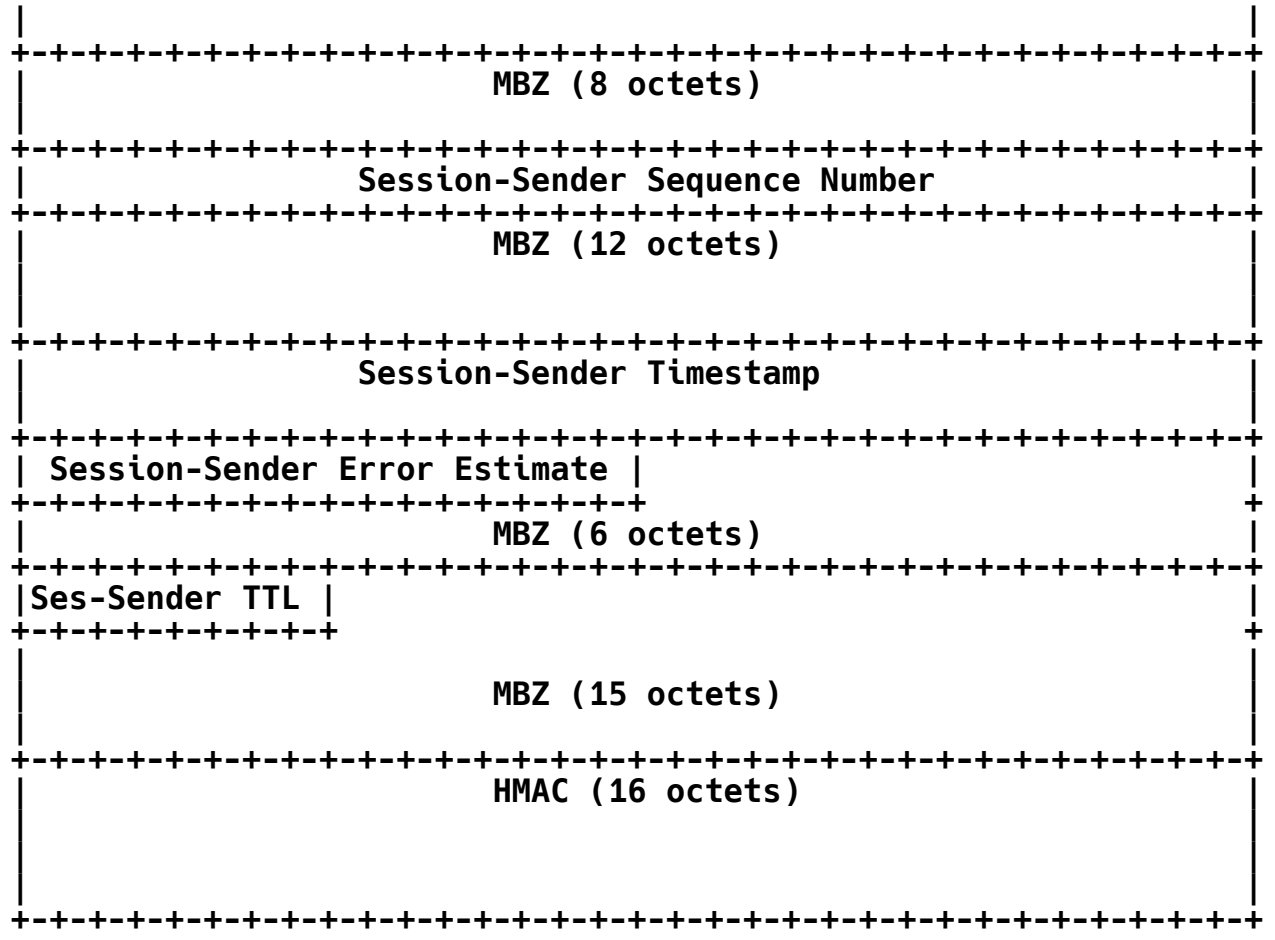


Figure 6: STAMP Session-Reflector Test Packet Format in Authenticated Mode

The field definitions are the same as the unauthenticated mode, listed in Section 4.3.1. Additionally, the MBZ field is used to make the packet length a multiple of 16 octets. The value of the field MUST be zeroed on transmission and MUST be ignored on receipt. Note that the MBZ field is used to calculate the HMAC hash value. Also, the STAMP Session-Reflector test packet format in authenticated mode includes the HMAC [RFC2104] hash at the end of the PDU. The detailed use of the HMAC field is in Section 4.4.

4.4. Integrity Protection in STAMP

Authenticated mode provides integrity protection to each STAMP message by adding Hashed Message Authentication Code (HMAC). STAMP uses HMAC-SHA-256 truncated to 128 bits (similarly to the use of it in IPsec defined in [RFC4868]); hence, the length of the HMAC field is 16 octets. In the authenticated mode, HMAC covers the first six blocks (96 octets). HMAC uses its own key, which may be unique for each STAMP-Test session; key management and the mechanisms to distribute the HMAC key are outside the scope of this specification. One example is to use an orchestrator to configure the HMAC key based on the STAMP YANG data model [STAMP-YANG]. HMAC MUST be verified as early as possible to avoid using or propagating corrupted data.

Future specifications may define the use of other, more advanced cryptographic algorithms, possibly providing an update to the STAMP YANG data model [STAMP-YANG].

4.5. Confidentiality Protection in STAMP

If confidentiality protection for STAMP is required, a STAMP-Test session MUST use a secured transport. For example, STAMP packets could be transmitted in the dedicated IPsec tunnel or share the IPsec tunnel with the monitored flow. Also, the Datagram Transport Layer Security protocol would provide the desired confidentiality protection.

4.6. Interoperability with TWAMP Light

One of the essential requirements to STAMP is the ability to interwork with a TWAMP Light device. Because STAMP and TWAMP use different algorithms in authenticated mode (HMAC-SHA-256 versus HMAC-SHA-1), interoperability is only considered for unauthenticated mode. There are two possible combinations for such a use case:

* STAMP Session-Sender with TWAMP Light Session-Reflector

* TWAMP Light Session-Sender with STAMP Session-Reflector

In the former case, the Session-Sender might not be aware that its Session-Reflector does not support STAMP. For example, a TWAMP Light Session-Reflector may not support the use of UDP port 862, as specified in [RFC8545]. Thus, Section 4 permits a STAMP Session-Sender to use alternative ports. If any of STAMP extensions are used, the TWAMP Light Session-Reflector will view them as the Packet Padding field.

In the latter scenario, if a TWAMP Light Session-Sender does not support the use of UDP port 862, the test management system MUST set the STAMP Session-Reflector to use UDP port number, as permitted by Section 4. The Session-Reflector MUST be set to use the default format for its timestamps, NTP.

A STAMP Session-Reflector that supports this specification will transmit the base packet (Figure 5) if it receives a packet smaller than the STAMP base packet. If the packet received from the TWAMP Session-Sender is larger than the STAMP base packet, the STAMP Session-Reflector that supports this specification will copy the content of the remainder of the received packet to transmit a reflected packet of symmetrical size.

5. Operational Considerations

STAMP is intended to be used on production networks to enable the operator to assess service level agreements based on packet delay, delay variation, and loss. When using STAMP over the Internet, especially when STAMP-Test packets are transmitted with the destination UDP port number from the User Ports range, the possible impact of the STAMP-Test packets MUST be thoroughly analyzed. The use of STAMP for each case MUST be agreed by users of nodes hosting

the Session-Sender and Session-Reflector before starting the STAMP-Test session.

Also, the use of the well-known port number as the destination UDP port number in STAMP-Test packets transmitted by a Session-Sender would not impede the ability to measure performance in an Equal-Cost Multipath environment, and analysis in Section 5.3 of [RFC8545] fully applies to STAMP.

6. IANA Considerations

This document has no IANA actions.

7. Security Considerations

[RFC5357] does not identify security considerations specific to TWAMP-Test but refers to security considerations identified for OWAMP in [RFC4656]. Since both OWAMP and TWAMP include control-plane and data-plane components, only security considerations related to OWAMP-Test discussed in Sections 6.2 and 6.3 of [RFC4656] apply to STAMP.

STAMP uses the well-known UDP port number allocated for the OWAMP-Test/TWAMP-Test Receiver Port. Thus, the security considerations and measures to mitigate the risk of the attack using the registered port number documented in Section 6 of [RFC8545] equally apply to STAMP. Because of the control and management of a STAMP-Test being outside the scope of this specification, only the more general requirement is set:

> To mitigate the possible attack vector, the control and management of a STAMP-Test session MUST use the secured transport.
>
> The load of the STAMP-Test packets offered to a network MUST be carefully estimated, and the possible impact on the existing services MUST be thoroughly analyzed before launching the test session. Section 3.1.5 of [RFC8085] provides guidance on handling network load for UDP-based protocol. While the characteristic of test traffic depends on the test objective, it is highly recommended to stay in the limits, as provided in [RFC8085].

Use of HMAC-SHA-256 in the authenticated mode protects the data integrity of the STAMP-Test packets.

8. References

8.1. Normative References

[IEEE.1588.2008] IEEE, "IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems", IEEE Standard 1588, July 2008.

[RFC2104] Krawczyk, H., Bellare, M., and R. Canetti, "HMAC: Keyed-Hashing for Message Authentication", RFC 2104, DOI 10.17487/RFC2104, February 1997, <https://www.rfc-editor.org/info/rfc2104>.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC4656] Shalunov, S., Teitelbaum, B., Karp, A., Boote, J., and M. Zekauskas, "A One-way Active Measurement Protocol (OWAMP)", RFC 4656, DOI 10.17487/RFC4656, September 2006, <https://www.rfc-editor.org/info/rfc4656>.

[RFC5357] Hedayat, K., Krzanowski, R., Morton, A., Yum, K., and J. Babiarz, "A Two-Way Active Measurement Protocol (TWAMP)", RFC 5357, DOI 10.17487/RFC5357, October 2008, <https://www.rfc-editor.org/info/rfc5357>.

[RFC5905] Mills, D., Martin, J., Ed., Burbank, J., and W. Kasch, "Network Time Protocol Version 4: Protocol and Algorithms Specification", RFC 5905, DOI 10.17487/RFC5905, June 2010, <https://www.rfc-editor.org/info/rfc5905>.

[RFC6038] Morton, A. and L. Ciavattone, "Two-Way Active Measurement Protocol (TWAMP) Reflect Octets and Symmetrical Size Features", RFC 6038, DOI 10.17487/RFC6038, October 2010, <https://www.rfc-editor.org/info/rfc6038>.

[RFC6335] Cotton, M., Eggert, L., Touch, J., Westerlund, M., and S. Cheshire, "Internet Assigned Numbers Authority (IANA) Procedures for the Management of the Service Name and Transport Protocol Port Number Registry", BCP 165, RFC 6335, DOI 10.17487/RFC6335, August 2011, <https://www.rfc-editor.org/info/rfc6335>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC8186] Mirsky, G. and I. Meilik, "Support of the IEEE 1588 Timestamp Format in a Two-Way Active Measurement Protocol (TWAMP)", RFC 8186, DOI 10.17487/RFC8186, June 2017, <https://www.rfc-editor.org/info/rfc8186>.

[RFC8545] Morton, A., Ed. and G. Mirsky, Ed., "Well-Known Port Assignments for the One-Way Active Measurement Protocol (OWAMP) and the Two-Way Active Measurement Protocol (TWAMP)", RFC 8545, DOI 10.17487/RFC8545, March 2019, <https://www.rfc-editor.org/info/rfc8545>.

8.2. Informative References

[BBF.TR-390] Broadband Forum, "Performance Measurement from IP Edge to Customer Equipment using TWAMP Light", TR-390 Issue 1, May 2017.

[RFC4868] Kelly, S. and S. Frankel, "Using HMAC-SHA-256, HMAC-SHA-

384, and HMAC-SHA-512 with IPsec", RFC 4868, DOI 10.17487/RFC4868, May 2007, <https://www.rfc-editor.org/info/rfc4868>.

[RFC7750] Hedin, J., Mirsky, G., and S. Baillargeon, "Differentiated Service Code Point and Explicit Congestion Notification Monitoring in the Two-Way Active Measurement Protocol (TWAMP)", RFC 7750, DOI 10.17487/RFC7750, February 2016, <https://www.rfc-editor.org/info/rfc7750>.

[RFC8085] Eggert, L., Fairhurst, G., and G. Shepherd, "UDP Usage Guidelines", BCP 145, RFC 8085, DOI 10.17487/RFC8085, March 2017, <https://www.rfc-editor.org/info/rfc8085>.

[STAMP-OPTION] Mirsky, G., Xiao, M., Nydell, H., Foote, R., Masputra, A., and E. Ruffini, "Simple Two-way Active Measurement Protocol Optional Extensions", Work in Progress, Internet-Draft, draft-ietf-ippm-stamp-option-tlv-03, 21 February 2020, <https://tools.ietf.org/html/draft-ietf-ippm-stamp-option-tlv-03>.

[STAMP-YANG] Mirsky, G., Xiao, M., and W. Luo, "Simple Two-way Active Measurement Protocol (STAMP) Data Model", Work in Progress, Internet-Draft, draft-ietf-ippm-stamp-yang-05, 25 October 2019, <https://tools.ietf.org/html/draft-ietf-ippm-stamp-yang-05>.

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