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Simple Two-Way Active Measurement Protocol (STAMP) Extensions for  
Residual Bit Error Rate Measurement  
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## Abstract

The Simple Two-Way Active Measurement Protocol (STAMP), as defined in RFC 8762, along with its optional extensions specified in RFC 8972, can be utilized for active measurement. Networks may experience transmission bit errors due to various factors, including poor fiber quality. Even with efficient CRC and FEC mechanisms, some bit errors may escape detection and correction, referred to as residual bit errors. This document further augments the STAMP extensions specified in RFC 8972 to enable the measurement of residual bit error rate within the "Extra Padding" TLV of STAMP packets.

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## 1. Introduction

The Simple Two-Way Active Measurement Protocol (STAMP) is designed to measure various performance metrics in IP networks without relying on a control channel to pre-signal session parameters, as specified in [RFC8762]. STAMP test packets are sent between a Session-Sender and a Session-Reflector to measure delay and packet loss along the path.

[RFC8972] introduces optional extensions for STAMP in the form of Type-Length-Value (TLV) objects, including the capability to transmit "Extra Padding" TLV within STAMP test packets.

Networks may experience transmission bit errors due to various factors, such as poor fiber quality, thereby corrupting packets. The bit error can be a single bit error or a burst of bit errors at a time. The bit errors in the received packets can be detected using Cyclic Redundancy Check (CRC). The packets with the CRC checksum failures may be dropped or corrected using Forward Error Correction (FEC). Even with efficient CRC and FEC mechanisms, some bit errors may escape detection and correction, referred to as residual bit errors. These bit errors result in upper-layer (such as UDP or TCP) checksum failures. It is beneficial to measure the Residual Bit Error Rate (BER) using active measurement packets between two nodes to detect service degradation. For accurate BER measurement, transmitting large-sized active measurement packets is preferable, especially on links with low bit error rates. Furthermore, there is a need to transmit test packets at a high rate to measure BER on high-capacity links.

The STAMP test packets use a UDP header with a checksum field that can be used for checking the integrity of the header and payload data. The UDP checksum is optional for IPv4 header. The UDP checksum may be set to 0 (to bypass the UDP check) for IPv4 and IPv6 headers for the STAMP destination UDP port. However, the checksum field does not provide an accurate measurement of bit errors.

Authenticated mode provides data integrity protection for the STAMP test packets by adding a Hashed Message Authentication Code (HMAC), such as HMAC-SHA-256 [RFC8762]. However, the authenticated mode does not provide an accurate measurement of bit errors. In addition, the HMAC TLV defined in [RFC8972] for authenticating STAMP TLVs does not include checking the "Extra Padding" TLV.

This document further augments the STAMP extensions defined in [RFC8972] to enable the measurement of residual bit error rate within the "Extra Padding" TLV of STAMP packets.

## 2. Conventions Used in This Document

### 2.1. 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.

## 2.2. Abbreviations

BER: Bit Error Rate

CRC: Cyclic Redundancy Check

FEC: Forward Error Correction

MTU: Maximum Transmission Unit

STAMP: Simple Two-way Active Measurement Protocol

TLV: Type-Length-Value

## 2.3. STAMP Reference Topology

In the STAMP reference topology shown in Figure 1, the STAMP Session-Sender S1 initiates Session-Sender test packets, and the STAMP Session-Reflector R1 transmits reply Session-Reflector test packets.

T1 is a transmit timestamp, and T4 is a receive timestamp added by node S1. T2 is a receive timestamp, and T3 is a transmit timestamp added by node R1.

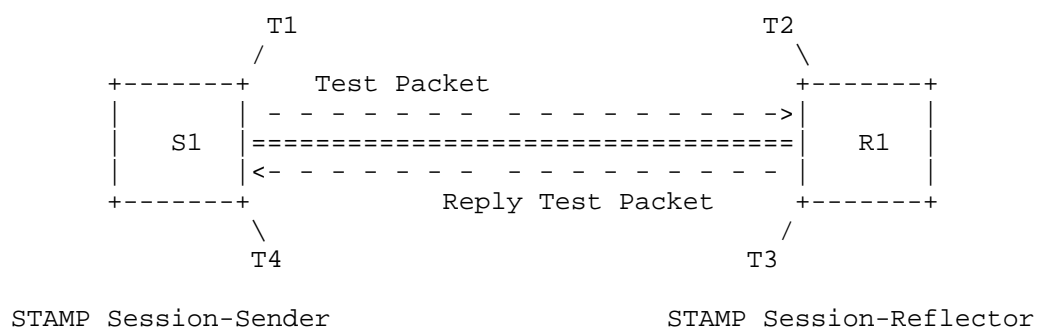


Figure 1: STAMP Reference Topology

## 3. Overview

The optional extensions for STAMP test packets [RFC8762] are defined in [RFC8762] in the form of TLVs. The Session-Sender transmits optional STAMP TLVs, and the Session-Reflector reflects all received STAMP TLVs from the Session-Sender test packets. [RFC8972] defines an optional TLV extension specifically for transmitting "Extra Padding" (Type=1) TLV in the STAMP test packets. The "Extra Padding" TLV can be filled using either a predefined fixed pattern or a random pattern of bits [RFC8972].

This document defines a procedure to measure residual BER within the "Extra Padding" TLV. The process involves the Session-Sender transmitting the extra padding filled with a predefined bit pattern. The Session-Reflector then checks for bit errors by comparing the received padding against the predefined bit pattern. This allows for the detection of a single bit error or a burst of bit errors and the measurement of the residual BER. The Session-Reflector does not discard the STAMP test packet with bit errors but instead reflects it back to the Session-Sender after correcting the bit errors. The Session-Reflector also returns the bit error count to the Session-Sender.

Residual BER is measured in both the forward and reverse directions between the Session-Sender and the Session-Reflector using the procedure and extensions defined in this document. The Residual BER is calculated using the number of bit errors detected and the number of bits received in the extra padding.

As specified in [RFC8972], the Session-Sender and Session-Reflector test packets are symmetric in size. The Session-Sender and Session-Reflector MUST ensure that the resulting test packets do not exceed the path MTU after adding the STAMP TLVs.

### 3.1. Bit Errors in Non-measurement Fields of STAMP

Note that the procedure and extensions defined in this document do not use the base STAMP packets, packet headers, or STAMP TLVs other than the "Extra Padding" TLV for residual BER measurement. It is possible that the bit errors impact those non-measurement fields of the STAMP test packets causing verification failures. Such STAMP test packets are reported using a different measurement metric. The integrity of those fields can be verified using the HMAC mechanisms defined in [RFC8762] and [RFC8972].

## 4. STAMP Procedure

This document defines two TLV options for STAMP: "Bit Pattern in Padding" TLV (Type=TBA1) and "Bit Error Count in Padding" TLV (Type=TBA2).

An example of a STAMP test packet used for measuring residual BER is shown in Figure 2. It uses the "Extra Padding" TLV, the optional "Bit Pattern in Padding" TLV, and the "Bit Error Count in Padding" TLV.

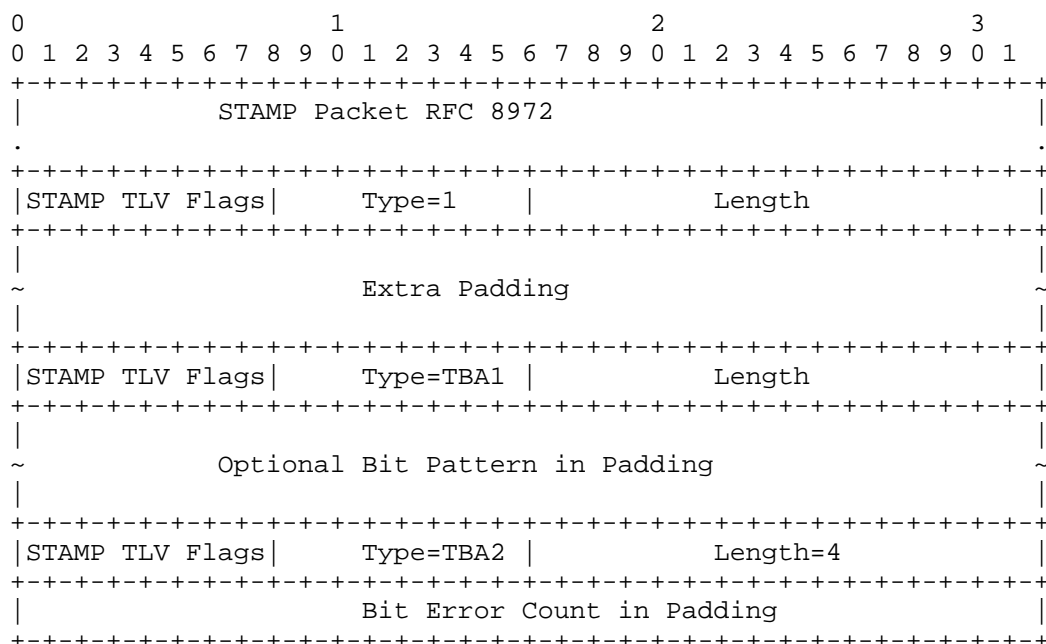


Figure 2: Example STAMP Packet to Measure BER

#### 4.1. STAMP Session-Sender

When a STAMP Session-Sender is set up to measure BER, it adds an "Extra Padding" (Type=1) TLV, a "Bit Error Count in Padding" (Type=TBA2) TLV, and optionally, a "Bit Pattern in Padding" (Type=TBA1) TLV in Session-Sender test packets. The Session-Sender test packets carry only one "Bit Error Count in Padding" TLV, only one "Extra Padding" TLV [RFC8972] and optionally carry only one "Bit Pattern in Padding" TLV.

The Session-Sender MUST add an "Extra Padding" TLV [RFC8972] when it adds a "Bit Pattern in Padding" TLV to the Session-Sender test packets. The variable-length data in the "Bit Pattern in Padding" TLV MUST contain the bit pattern employed in the "Extra Padding" TLV. It is RECOMMENDED to have the length of the extra padding as an integer multiple of the length of the Bit Pattern to ease implementation.

The Session-Sender MUST also add an "Extra Padding" TLV [RFC8972] when it adds a "Bit Error Count in Padding" TLV in the Session-Sender test packets. The bit error count in padding MUST be set to 0.

Note that the integrity of the "Bit Pattern in Padding" and "Bit Error Count in Padding" TLVs can be protected using the HMAC mechanisms defined in [RFC8972].

#### 4.1.1. Considerations for Bit Pattern

It is possible that the bit pattern in the "Bit Pattern in Padding" TLV itself has bit errors. This can result in a measurement error due to mismatch between the bit pattern and the extra padding. One way to avoid this issue is for the Session-Sender and Session-Reflector to use the local configuration with the default value of 0xFF00 as the bit pattern. In this case, the "Bit Pattern in Padding" TLV is not transmitted in the STAMP test packets.

#### 4.2. STAMP Session-Reflector

When the Session-Reflector receives a STAMP test packet with a "Bit Pattern in Padding" TLV, the Session-Reflector that supports this TLV MUST check the extra padding in the "Extra Padding" TLV against the bit pattern to detect any bits that do not match the bit pattern and count them as bit errors.

When the Session-Reflector receives a STAMP test packet with a "Bit Error Count in Padding" TLV, the Session-Reflector that supports this TLV MUST check the "Extra Padding" TLV against the expected bit pattern to detect if there are any bits not matching the bit pattern and count them as bit errors. The Session-Reflector updates the count of bit errors in the received "Bit Error Count in Padding" TLV and reflects the TLV back to the Session-Sender. If no bit errors are detected, the bit error count remains as 0 in the reflected "Bit Error Count in Padding" TLV.

The Session-Reflector corrects the bit errors in the "Extra Padding" TLV by matching the bit pattern and reflects the corrected "Extra Padding" TLV to the Session-Sender. The corrected "Extra Padding" TLV is used to measure the residual BER in the reverse direction.

##### 4.2.1. STAMP TLV Conformance Check

If the Session-Reflector receives a STAMP test packet with a "Bit Pattern in Padding" TLV or a "Bit Error Count in Padding" TLV without an "Extra Padding" TLV or with more than one "Extra Padding" TLV, it MUST set the C flag (Conformant) defined in [I-D.ietf-ippm-asymmetrical-pkts] to 1 in the STAMP TLV Flags in the reflected STAMP test packet for those STAMP TLVs.

If the Session-Reflector receives a STAMP test packet that contains more than one "Bit Pattern in Padding" TLV or more than one "Bit Error Count in Padding" TLV, it MUST set the C flag (Conformant) defined in [I-D.ietf-ippm-asymmetrical-pkts] to 1 in the STAMP TLV Flags in the reflected STAMP test packet for those STAMP TLVs.

#### 4.3. Considerations for Link Aggregation Group

Networks may experience transmission bit errors differently for different link members of a Link Aggregation Group (LAG). The procedure and extensions defined in this document are equally applicable for measuring residual BER for each individual member of the LAG.

For delay measurement of LAG member links, a separate STAMP micro-session is created for each member of the LAG. The STAMP extension for the Micro-Session ID TLV, as defined in [RFC9534], is used to identify each member link of the LAG associated with the STAMP micro-session on the Session-Sender and Session-Reflector. The Session-Reflector replies on the same member of the LAG in the reverse direction based on the received Session-Sender test packet and on either the local configuration or the received information from the data plane.

Note that in order to get a good approximation of the BER, it is RECOMMENDED to transmit the STAMP test packets with padding that match the link MTU size.

### 5. STAMP Extensions

#### 5.1. Bit Pattern in Padding STAMP TLV

The "Bit Pattern in Padding" TLV is optional and is carried by Session-Sender and Session-Reflector test packets. The format of the TLV is shown in Figure 3.

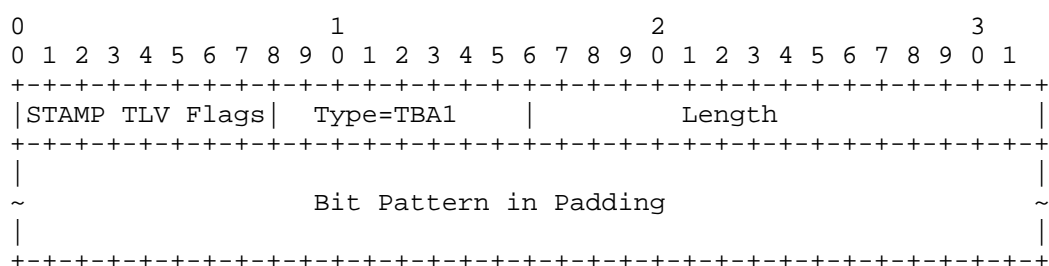


Figure 3: Bit Pattern in Padding STAMP TLV



The TLV fields are defined as follows:

Type: Type (value TBA1)

STAMP TLV Flags: The STAMP TLV Flags follow the procedures described in [RFC8972].

Length: A two-octet field equal to the length of the Data in octets.

## 5.2. Bit Error Count in Padding STAMP TLV

The "Bit Error Count in Padding" TLV is optional and is carried by Session-Sender and Session-Reflector test packets. The format of the TLV is shown in Figure 4.

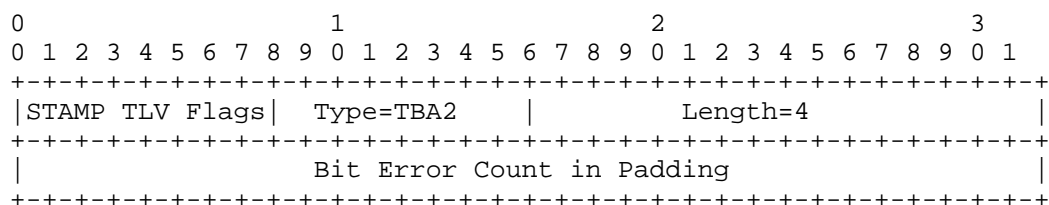


Figure 4: Bit Error Count in Padding STAMP TLV

The TLV fields are defined as follows:

Type: Type (value TBA2)

STAMP TLV Flags: The STAMP TLV Flags follow the procedures described in [RFC8972].

Length: A two-octet field set to 4 for the Data.

## 6. Data Model Parameters

### 6.1. Configuration Data Model Parameters

The configuration data model for the residual BER measurement using STAMP MUST allow to set the following parameters:

- Padding size (number of bytes)
- Padding bit pattern (with variable length of bytes)
- Transmit interval for STAMP test packets

- Computation interval as a multiple of transmit interval for reporting the BER

## 6.2. Operational Data Model Parameters

The operational data model for the residual BER measurement using STAMP MUST allow to telemetry the following parameters:

Forward direction (near-end) residual BER measurement:

- Number of total packets received in the computation interval
- Number of total packets received with non-zero Bit Error Count in TLV in the computation interval
- Number of total bits in the padding TLV of all received packets in the computation interval
- Number of total Bit Error Count in TLV of all received packets in the computation interval

Reverse direction (far-end) residual BER measurement:

- Number of total packets received in the computation interval
- Number of total packets received with bit errors in the computation interval
- Number of total bits in the padding TLV of all received packets in the computation interval
- Number of total bit errors in all received packets in the computation interval

Thresholds are defined for the forward and reverse directions of the residual BER measurement, as number of bit errors per million and number of packets with bit errors per million, computed during the computation interval. An alarm is generated, and an event-driven telemetry is triggered when the computed metric crosses the threshold.

## 7. Security Considerations

The security considerations specified in [RFC8762] and [RFC8972] apply to the procedure and extensions defined in this document.

## 8. Implementation Status

Editorial note: Please remove this section prior to publication.

An open-source implementation of the Simple Two-Way Active Measurement Protocol (RFC 8762) is available in Teaparty.

<https://github.com/cerfcast/teaparty>

An implementation of the solution in this document is available at the following location:

[https://github.com/cerfcast/teaparty/  
commit/592558a38dbcf9b273acb2a2fe8ab0d8f16d0709](https://github.com/cerfcast/teaparty/commit/592558a38dbcf9b273acb2a2fe8ab0d8f16d0709)

And (as bonus) there is also support for the BER in the Wireshark dissector:

[https://github.com/cerfcast/teaparty/  
commit/608b9e89fce2f25ed88eaa367d0bacc693845da2](https://github.com/cerfcast/teaparty/commit/608b9e89fce2f25ed88eaa367d0bacc693845da2)

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## 9. IANA Considerations

IANA has created the "STAMP TLV Types" registry for [RFC8972]. IANA is requested to allocate a value for the "Bit Pattern in Padding" TLV Type and a value for the "Bit Error Count in Padding" TLV Type from the IETF Review TLV range of the same registry.

Value	Description	Reference
TBA1	Bit Pattern in Padding	This document
TBA2	Bit Error Count in Padding	This document

Table 1: STAMP TLV Types

## 10. References

## 10.1. Normative References

- [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>>.
- [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>>.
- [RFC8762] Mirsky, G., Jun, G., Nydell, H., and R. Foote, "Simple Two-Way Active Measurement Protocol", RFC 8762, DOI 10.17487/RFC8762, March 2020, <<https://www.rfc-editor.org/info/rfc8762>>.
- [RFC8972] Mirsky, G., Min, X., Nydell, H., Foote, R., Masputra, A., and E. Ruffini, "Simple Two-Way Active Measurement Protocol Optional Extensions", RFC 8972, DOI 10.17487/RFC8972, January 2021, <<https://www.rfc-editor.org/info/rfc8972>>.
- [I-D.ietf-ippm-asymmetrical-pkts]  
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## 10.2. Informative References

- [RFC9534] Li, Z., Zhou, T., Guo, J., Mirsky, G., and R. Gandhi, "Simple Two-Way Active Measurement Protocol Extensions for Performance Measurement on a Link Aggregation Group", RFC 9534, DOI 10.17487/RFC9534, January 2024, <<https://www.rfc-editor.org/info/rfc9534>>.

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