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Stream Control Transmission Protocol: Errata and Issues in RFC 4960

Abstract

This document is a compilation of issues found since the publication of RFC 4960 in September 2007, based on experience with implementing, testing, and using the Stream Control Transmission Protocol (SCTP) along with the suggested fixes. This document provides deltas to RFC 4960 and is organized in a time-ordered way. The issues are listed in the order in which they were brought up. Because some text is changed several times, the last delta in the text is the one that should be applied. In addition to the deltas, a description of each problem and the details of the solution for each are also provided.

Status of This Memo

This document is not an Internet Standards Track specification; it is published for informational purposes.

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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/rfc8540.

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1. Introduction

This document contains a compilation of all defects for [RFC4960] ("Stream Control Transmission Protocol") that were found up until the publication of this document. These defects may be of an editorial or technical nature. This document may be thought of as a companion document to be used in the implementation of the Stream Control Transmission Protocol (SCTP) to clarify errors in the original SCTP document.

This document provides a history of the changes that will be compiled into a bis document for [RFC4960]. It is structured similarly to [RFC4460].

Each error will be detailed within this document in the form of:

- The problem description,
- The text quoted from [RFC4960],
- The replacement text that should be placed into an upcoming bis document, and
- A description of the solution.

Note that when reading this document one must use care to ensure that a field or item is not updated later on within the document. Since this document is a historical record of the sequential changes that have been found necessary at various interop events and through discussion on the Transport Area Working Group mailing list, the last delta in the text is the one that should be applied.

2. Conventions

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. Corrections to RFC 4960

3.1. Path Error Counter Threshold Handling

3.1.1. Description of the Problem

The handling of the 'Path.Max.Retrans' parameter is described in Sections 8.2 and 8.3 of [RFC4960] in an inconsistent way. Whereas Section 8.2 of [RFC4960] says that a path is marked inactive when the path error counter exceeds the threshold, Section 8.3 of [RFC4960] says that the path is marked inactive when the path error counter reaches the threshold.

This issue was reported as an errata for [RFC4960] with Errata ID 1440.

3.1.2. Text Changes to the Document

Old text: (Section 8.3)

When the value of this counter reaches the protocol parameter 'Path.Max.Retrans', the endpoint should mark the corresponding destination address as inactive if it is not so marked, and may also optionally report to the upper layer the change of reachability of this destination address. After this, the endpoint should continue HEARTBEAT on this destination address but should stop increasing the counter.

New text: (Section 8.3)

When the value of this counter exceeds the protocol parameter 'Path.Max.Retrans', the endpoint SHOULD mark the corresponding destination address as inactive if it is not so marked and MAY also optionally report to the upper layer the change in reachability of this destination address. After this, the endpoint SHOULD continue HEARTBEAT on this destination address but SHOULD stop increasing the counter.

This text has been modified by multiple errata. It is further updated in Section 3.23.

3.1.3. Solution Description

The intended state change should happen when the threshold is exceeded.

3.2. Upper-Layer Protocol Shutdown Request Handling

3.2.1. Description of the Problem

Section 9.2 of [RFC4960] describes the handling of received SHUTDOWN chunks in the SHUTDOWN-RECEIVED state instead of the handling of shutdown requests from its upper layer in this state.

This issue was reported as an errata for [RFC4960] with Errata ID 1574.

3.2.2. Text Changes to the Document

Old text: (Section 9.2)

Once an endpoint has reached the SHUTDOWN-RECEIVED state, it MUST NOT send a SHUTDOWN in response to a ULP request, and should discard subsequent SHUTDOWN chunks.

New text: (Section 9.2)

Once an endpoint has reached the SHUTDOWN-RECEIVED state, it MUST ignore ULP shutdown requests but MUST continue responding to SHUTDOWN chunks from its peer.

This text is in final form and is not further updated in this document.

3.2.3. Solution Description

The text never intended that the SCTP endpoint ignore SHUTDOWN chunks from its peer. If it did, the endpoints could never gracefully terminate associations in some cases.

3.3. Registration of New Chunk Types

3.3.1. Description of the Problem

Section 14.1 of [RFC4960] should deal with new chunk types; however, the text only refers to parameter types.

This issue was reported as an errata for [RFC4960] with Errata ID 2592.

3.3.2. Text Changes to the Document

Old text: (Section 14.1)

The assignment of new chunk parameter type codes is done through an IETF Consensus action, as defined in [RFC2434]. Documentation of the chunk parameter MUST contain the following information:

New text: (Section 14.1)

The assignment of new chunk type codes is done through an IETF Consensus action, as defined in [RFC8126]. Documentation for the chunk type MUST contain the following information:

This text has been modified by multiple errata. It is further updated in Section 3.43.

3.3.3. Solution Description

The new text refers to chunk types as intended and changes the reference to [RFC8126].

3.4. Variable Parameters for INIT Chunks

3.4.1. Description of the Problem

In Section 3.3.2 of [RFC4960], newlines in wrong places break the layout of the table of variable parameters for the INIT chunk.

This issue was reported as an errata for [RFC4960] with Errata ID 3291 and Errata ID 3804.

3.4.2. Text Changes to the Document

Old text: (Section 3.3.2)

Variable Parameters Status Type Value

IPv4 Address (Note 1) Optional 5 IPv6 Address
(Note 1) Optional 6 Cookie Preservative
Optional 9 Reserved for ECN Capable (Note 2) Optional
32768 (0x8000) Host Name Address (Note 3) Optional
11 Supported Address Types (Note 4) Optional 12

New text: (Section 3.3.2)

Variable Parameters	Status	Type Value
IPv4 Address (Note 1)	Optional	5
IPv6 Address (Note 1)	Optional	6
Cookie Preservative	Optional	9
Reserved for ECN Capable (Note 2)	Optional	32768 (0x8000)
Host Name Address (Note 3)	Optional	11
Supported Address Types (Note 4)	Optional	12

This text is in final form and is not further updated in this document.

3.4.3. Solution Description

The formatting of the table is corrected.

3.5. CRC32c Sample Code on 64-Bit Platforms

3.5.1. Description of the Problem

The sample code for CRC32c computation, as provided in [RFC4960], assumes that a variable of type unsigned long uses 32 bits. This is not true on some 64-bit platforms (for example, platforms that use LP64).

This issue was reported as an errata for [RFC4960] with Errata ID 3423.

3.5.2. Text Changes to the Document

Old text: (Appendix C)

```
unsigned long
generate_crc32c(unsigned char *buffer, unsigned int length)
{
  unsigned int i;
  unsigned long crc32 = ~0L;
```

New text: (Appendix C)

```
unsigned long
generate_crc32c(unsigned char *buffer, unsigned int length)
{
  unsigned int i;
  unsigned long crc32 = 0xffffffffL;
```

This text has been modified by multiple errata. It is further updated in Section 3.10 and again in Section 3.46.

3.5.3. Solution Description

The new text uses 0xffffffffL instead of ~0L; this gives the same value on platforms using 32 bits or 64 bits for variables of type unsigned long.

3.6. Endpoint Failure Detection

3.6.1. Description of the Problem

The handling of the association error counter defined in Section 8.1 of [RFC4960] can result in an association failure even if the path used for data transmission is available (but idle).

This issue was reported as an errata for [RFC4960] with Errata ID 3788.

3.6.2. Text Changes to the Document

Old text: (Section 8.1)

An endpoint shall keep a counter on the total number of consecutive retransmissions to its peer (this includes retransmissions to all the destination transport addresses of the peer if it is multi-homed), including unacknowledged HEARTBEAT chunks.

New text: (Section 8.1)

An endpoint SHOULD keep a counter on the total number of consecutive retransmissions to its peer (this includes data retransmissions to all the destination transport addresses of the peer if it is

multi-homed), including the number of unacknowledged HEARTBEAT chunks observed on the path that is currently used for data transfer. Unacknowledged HEARTBEAT chunks observed on paths different from the path currently used for data transfer SHOULD NOT increment the association error counter, as this could lead to association closure even if the path that is currently used for data transfer is available (but idle).

This text has been modified by multiple errata. It is further updated in Section 3.23.

3.6.3. Solution Description

A more refined handling of the association error counter is defined.

3.7. Data Transmission Rules

3.7.1. Description of the Problem

When integrating the changes to Section 6.1 A) of [RFC2960] as described in Section 2.15.2 of [RFC4460], some text was duplicated and became the final paragraph of Section 6.1 A) of [RFC4960].

This issue was reported as an errata for [RFC4960] with Errata ID 4071.

3.7.2. Text Changes to the Document

Old text: (Section 6.1 A))

The sender MUST also have an algorithm for sending new DATA chunks to avoid silly window syndrome (SWS) as described in [RFC0813]. The algorithm can be similar to the one described in Section 4.2.3.4 of [RFC1122].

However, regardless of the value of rwnd (including if it is 0), the data sender can always have one DATA chunk in flight to the receiver if allowed by cwnd (see rule B below). This rule allows the sender to probe for a change in rwnd that the sender missed due to the SACK having been lost in transit from the data receiver to the data sender.

New text: (Section 6.1 A))

The sender MUST also have an algorithm for sending new DATA chunks to avoid silly window syndrome (SWS) as described in [RFC1122]. The algorithm can be similar to the algorithm described in Section 4.2.3.4 of [RFC1122].

This text is in final form and is not further updated in this document.

3.7.3. Solution Description

The last paragraph of Section 6.1 A) is removed, as had been intended in Section 2.15.2 of [RFC4460].

3.8. T1-Cookie Timer

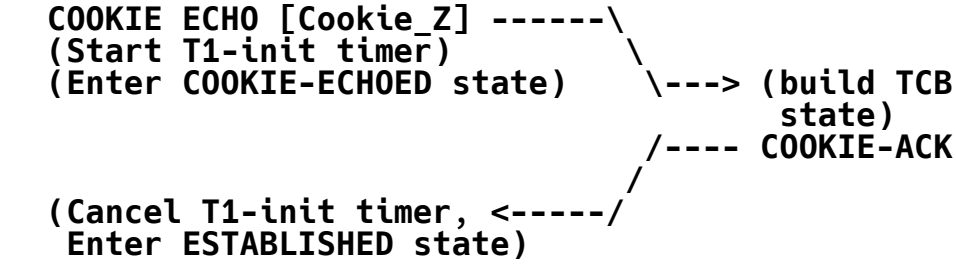
3.8.1. Description of the Problem

Figure 4 of [RFC4960] illustrates the SCTP association setup. However, it incorrectly shows that the T1-init timer is used in the COOKIE-ECHOED state, whereas the T1-cookie timer should have been used instead.

This issue was reported as an errata for [RFC4960] with Errata ID 4400.

3.8.2. Text Changes to the Document

Old text: (Section 5.1.6, Figure 4)



New text: (Section 5.1.6, Figure 4)

```
COOKIE ECHO [Cookie_Z] ------\
(Start T1-cookie timer)       \
(Enter COOKIE-ECHOED state)    \---> (build TCB, enter ESTABLISHED
                                      state)
                                /---- COOKIE-ACK
                               /
(Cancel T1-cookie timer, <---/
 enter ESTABLISHED state)
```

This text has been modified by multiple errata. It is further updated in Section 3.9.

3.8.3. Solution Description

The figure is changed such that the T1-cookie timer is used instead of the T1-init timer.

3.9. Miscellaneous Typos

3.9.1. Description of the Problem

While processing [RFC4960], some typos were not caught.

One typo was reported as an errata for [RFC4960] with Errata ID 5003.

3.9.2. Text Changes to the Document

Old text: (Section 1.6)

Transmission Sequence Numbers wrap around when they reach 2**32 - 1. That is, the next TSN a DATA chunk MUST use after transmitting TSN = 2*32 - 1 is TSN = 0.

New text: (Section 1.6)

Transmission Sequence Numbers wrap around when they reach 2**32 - 1. That is, the next TSN a DATA chunk MUST use after transmitting TSN = 2**32 - 1 is TSN = 0.

This text is in final form and is not further updated in this document.

Old text: (Section 3.3.10.9)

No User Data: This error cause is returned to the originator of a

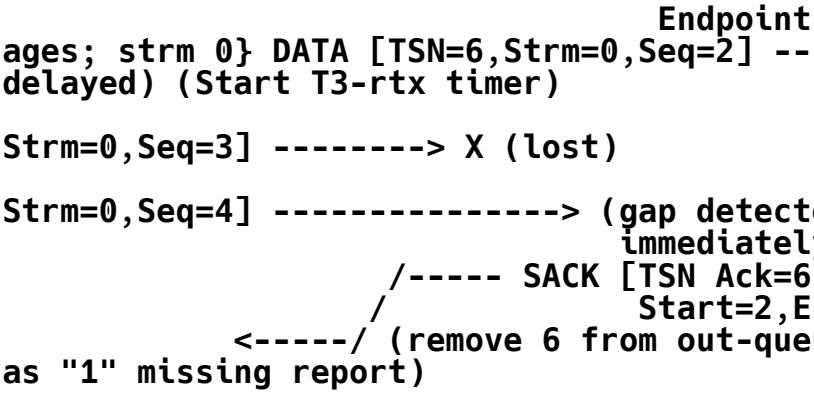
DATA chunk if a received DATA chunk has no user data.

New text: (Section 3.3.10.9)

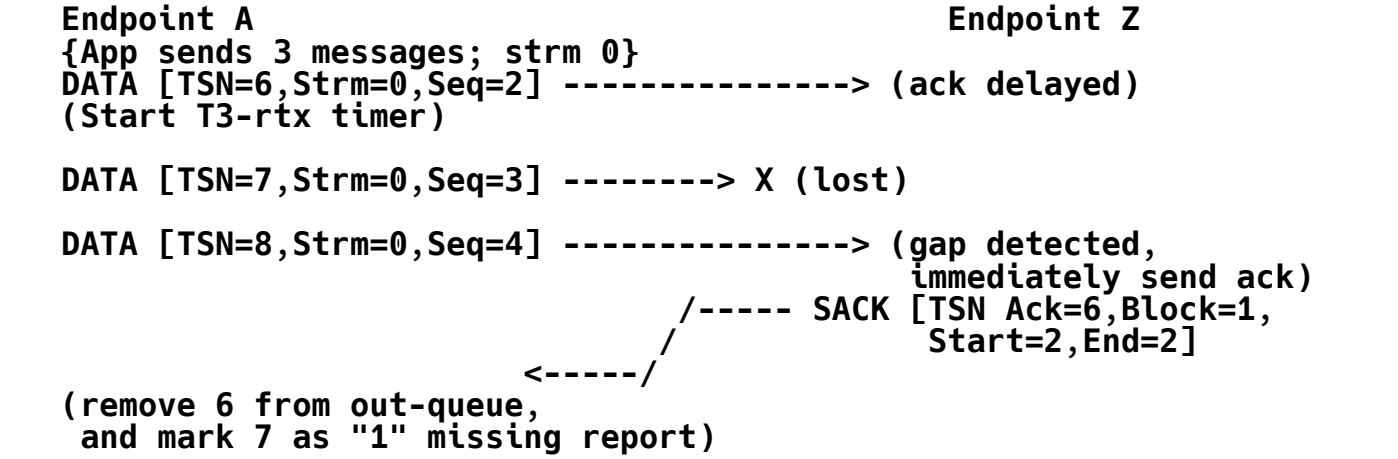
No User Data: This error cause is returned to the originator of a DATA chunk if a received DATA chunk has no user data.

This text is in final form and is not further updated in this document.

Old text: (Section 6.7, Figure 9)



New text: (Section 6.7, Figure 9)



This text is in final form and is not further updated in this document.

Old text: (Section 6.10)

An endpoint bundles chunks by simply including multiple chunks in one outbound SCTP packet. The total size of the resultant IP datagram,

including the SCTP packet and IP headers, MUST be less that or equal to the current Path MTU.

New text: (Section 6.10)

An endpoint bundles chunks by simply including multiple chunks in one outbound SCTP packet. The total size of the resultant IP datagram, including the SCTP packet and IP headers, MUST be less than or equal to the current Path MTU (PMTU).

This text is in final form and is not further updated in this document.

Old text: (Section 10.1 O))
---

o Receive Unacknowledged Message

Format: RECEIVE_UNACKED(data retrieval id, buffer address, buffer size, [,stream id] [, stream sequence number] [,partial flag] [,payload protocol-id])

New text: (Section 10.1 O))

O) Receive Unacknowledged Message

Format: RECEIVE_UNACKED(data retrieval id, buffer address, buffer size [,stream id] [,stream sequence number] [,partial flag] [,payload protocol-id])

This text is in final form and is not further updated in this document.

Old text: (Section 10.1 M))

M) Set Protocol Parameters

Format: SETPROTOCOLPARAMETERS(association id,
[,destination transport address,]
protocol parameter list)

New text: (Section 10.1 M))

M) Set Protocol Parameters

Format: SETPROTOCOLPARAMETERS(association id,
[destination transport address,]
protocol parameter list)

This text is in final form and is not further updated in this document.

Old text: (Appendix C)

ICMP2) An implementation MAY ignore all ICMPv6 messages where the
type field is not "Destination Unreachable", "Parameter
Problem",, or "Packet Too Big".

New text: (Appendix C)

ICMP2) An implementation MAY ignore all ICMPv6 messages where the
type field is not "Destination Unreachable", "Parameter
Problem", or "Packet Too Big".

This text is in final form and is not further updated in this document.

Old text: (Appendix C)

ICMP7) If the ICMP message is either a v6 "Packet Too Big" or a v4
"Fragmentation Needed", an implementation MAY process this
information as defined for PATH MTU discovery.

New text: (Appendix C)

ICMP7) If the ICMP message is either a v6 "Packet Too Big" or a v4
"Fragmentation Needed", an implementation MAY process this
information as defined for PMTU discovery.

This text is in final form and is not further updated in this document.

Old text: (Section 5.4)
---

2) For the receiver of the COOKIE ECHO, the only CONFIRMED address
is the one to which the INIT-ACK was sent.

New text: (Section 5.4)
---

2) For the receiver of the COOKIE ECHO, the only CONFIRMED address
is the address to which the INIT ACK was sent.

This text is in final form and is not further updated in this document.

Old text: (Section 5.1.6, Figure 4)

```
COOKIE ECHO [Cookie_Z] ------\
(Start T1-init timer)        \
(Enter COOKIE-ECHOED state)    \---> (build TCB enter ESTABLISHED
                                      state)
                                /---- COOKIE-ACK
                               /
(Cancel T1-init timer, <-----/
 Enter ESTABLISHED state)
```

New text: (Section 5.1.6, Figure 4)

```
COOKIE ECHO [Cookie_Z] ------\
(Start T1-cookie timer)      \
(Enter COOKIE-ECHOED state)    \---> (build TCB, enter ESTABLISHED
                                      state)
                                /---- COOKIE ACK
                               /
(Cancel T1-cookie timer, <---/
 enter ESTABLISHED state)
```

This text has been modified by multiple errata. It includes modifications from Section 3.8. It is in final form and is not further updated in this document.

Old text: (Section 5.2.5)

5.2.5. Handle Duplicate COOKIE-ACK.

New text: (Section 5.2.5)

5.2.5. Handle Duplicate COOKIE ACK.

This text is in final form and is not further updated in this document.

Old text: (Section 8.3)

By default, an SCTP endpoint SHOULD monitor the reachability of the idle destination transport address(es) of its peer by sending a HEARTBEAT chunk periodically to the destination transport address(es). HEARTBEAT sending MAY begin upon reaching the ESTABLISHED state and is discontinued after sending either SHUTDOWN or SHUTDOWN-ACK. A receiver of a HEARTBEAT MUST respond to a HEARTBEAT with a HEARTBEAT-ACK after entering the COOKIE-ECHOED state (INIT sender) or the ESTABLISHED state (INIT receiver), up until reaching the SHUTDOWN-SENT state (SHUTDOWN sender) or the SHUTDOWN-ACK-SENT state (SHUTDOWN receiver).

New text: (Section 8.3)

By default, an SCTP endpoint SHOULD monitor the reachability of the idle destination transport address(es) of its peer by sending a HEARTBEAT chunk periodically to the destination transport address(es). HEARTBEAT sending MAY begin upon reaching the ESTABLISHED state and is discontinued after sending either SHUTDOWN or SHUTDOWN ACK. A receiver of a HEARTBEAT MUST respond to a HEARTBEAT with a HEARTBEAT ACK after entering the COOKIE-ECHOED state (INIT sender) or the ESTABLISHED state (INIT receiver), up until reaching the SHUTDOWN-SENT state (SHUTDOWN sender) or the SHUTDOWN-ACK-SENT state (SHUTDOWN receiver).

This text is in final form and is not further updated in this document.

3.9.3. Solution Description

Several typos have been fixed.

3.10. CRC32c Sample Code

3.10.1. Description of the Problem

The CRC32c computation is described in Appendix B of [RFC4960]. However, the corresponding sample code and its explanation appear at the end of Appendix C of [RFC4960], which deals with ICMP handling.

3.10.2. Text Changes to the Document

The text in Appendix C of [RFC4960], starting with the following sentence, needs to be moved to the end of Appendix B.

> The following non-normative sample code is taken from an open-source CRC generator [WILLIAMS93], using the "mirroring" technique and yielding a lookup table for SCTP CRC32c with 256 entries, each 32 bits wide.

This text has been modified by multiple errata. It includes modifications from Section 3.5. It is further updated in Section 3.46.

3.10.3. Solution Description

The text is moved to the appropriate location.

3.11. partial_bytes_acked after T3-rtx Expiration

3.11.1. Description of the Problem

Section 7.2.3 of [RFC4960] explicitly states that partial_bytes_acked should be reset to 0 after packet loss detection from selective acknowledgment (SACK), but this information is not accounted for in the case of T3-rtx timer expiration.

3.11.2. Text Changes to the Document

```
---------
Old text: (Section 7.2.3)
---------

When the T3-rtx timer expires on an address, SCTP should perform slow
start by:

ssthresh = max(cwnd/2, 4*MTU)
cwnd = 1*MTU
```

New text: (Section 7.2.3)

When the T3-rtx timer expires on an address, SCTP SHOULD perform slow start by:

ssthresh = max(cwnd/2, 4*MTU)
cwnd = 1*MTU
partial_bytes_acked = 0

This text is in final form and is not further updated in this document.

3.11.3. Solution Description

The new text specifies that partial_bytes_acked should be reset to 0 after T3-rtx timer expiration.

3.12. Order of Adjustments of partial_bytes_acked and cwnd

3.12.1. Description of the Problem

Section 7.2.2 of [RFC4960] likely implies the wrong order of adjustments applied to partial_bytes_acked and cwnd in the congestion avoidance phase.

3.12.2. Text Changes to the Document

Old text: (Section 7.2.2)
---

o When partial_bytes_acked is equal to or greater than cwnd and before the arrival of the SACK the sender had cwnd or more bytes of data outstanding (i.e., before arrival of the SACK, flightsize was greater than or equal to cwnd), increase cwnd by MTU, and reset partial_bytes_acked to (partial_bytes_acked - cwnd).

New text: (Section 7.2.2)
---

o (1) when partial_bytes_acked is equal to or greater than cwnd and (2) before the arrival of the SACK the sender had cwnd or more bytes of data outstanding (i.e., before the arrival of the SACK,

flightsize was greater than or equal to cwnd), partial_bytes_acked is reset to (partial_bytes_acked - cwnd). Next, cwnd is increased by 1*MTU.

This text has been modified by multiple errata. It is further updated in Section 3.26.

3.12.3. Solution Description

The new text defines the exact order of adjustments of partial_bytes_acked and cwnd in the congestion avoidance phase.

3.13. HEARTBEAT ACK and the Association Error Counter

3.13.1. Description of the Problem

Sections 8.1 and 8.3 of [RFC4960] prescribe that the receiver of a HEARTBEAT ACK must reset the association overall error count. In some circumstances, e.g., when a router discards DATA chunks but not HEARTBEAT chunks due to the larger size of the DATA chunk, it might be better to not clear the association error counter on reception of the HEARTBEAT ACK and reset it only on reception of the SACK to avoid stalling the association.

3.13.2. Text Changes to the Document

Old text: (Section 8.1)

The counter shall be reset each time a DATA chunk sent to that peer endpoint is acknowledged (by the reception of a SACK) or a HEARTBEAT ACK is received from the peer endpoint.

New text: (Section 8.1)

The counter MUST be reset each time a DATA chunk sent to that peer endpoint is acknowledged (by the reception of a SACK). When a HEARTBEAT ACK is received from the peer endpoint, the counter SHOULD also be reset. The receiver of the HEARTBEAT ACK MAY choose not to clear the counter if there is outstanding data on the association. This allows for handling the possible difference in reachability based on DATA chunks and HEARTBEAT chunks.

This text is in final form and is not further updated in this document.

Old text: (Section 8.3)

Upon the receipt of the HEARTBEAT ACK, the sender of the HEARTBEAT should clear the error counter of the destination transport address to which the HEARTBEAT was sent, and mark the destination transport address as active if it is not so marked. The endpoint may optionally report to the upper layer when an inactive destination address is marked as active due to the reception of the latest HEARTBEAT ACK. The receiver of the HEARTBEAT ACK must also clear the association overall error count as well (as defined in Section 8.1).

New text: (Section 8.3)

Upon the receipt of the HEARTBEAT ACK, the sender of the HEARTBEAT MUST clear the error counter of the destination transport address to which the HEARTBEAT was sent and mark the destination transport address as active if it is not so marked. The endpoint MAY optionally report to the upper layer when an inactive destination address is marked as active due to the reception of the latest HEARTBEAT ACK. The receiver of the HEARTBEAT ACK SHOULD also clear the association overall error count (as defined in Section 8.1).

This text has been modified by multiple errata. It is further updated in Section 3.23.

3.13.3. Solution Description

The new text provides the possibility of not resetting the association overall error count when a HEARTBEAT ACK is received if there are valid reasons for not doing so.

3.14. Path for Fast Retransmission

3.14.1. Description of the Problem

[RFC4960] clearly describes where to retransmit data that is timed out when the peer is multi-homed, but the same is not stated for fast retransmissions.

3.14.2. Text Changes to the Document

Old text: (Section 6.4)

Furthermore, when its peer is multi-homed, an endpoint SHOULD try to retransmit a chunk that timed out to an active destination transport address that is different from the last destination address to which the DATA chunk was sent.

New text: (Section 6.4)

Furthermore, when its peer is multi-homed, an endpoint SHOULD try to retransmit a chunk that timed out to an active destination transport address that is different from the last destination address to which the DATA chunk was sent.

When its peer is multi-homed, an endpoint SHOULD send fast retransmissions to the same destination transport address to which the original data was sent. If the primary path has been changed and the original data was sent to the old primary path before the Fast Retransmit, the implementation MAY send it to the new primary path.

This text is in final form and is not further updated in this document.

3.14.3. Solution Description

The new text clarifies where to send fast retransmissions.

3.15. Transmittal in Fast Recovery

3.15.1. Description of the Problem

The Fast Retransmit on Gap Reports algorithm intends that only the very first packet may be sent regardless of cwnd in the Fast Recovery phase, but rule 3) in Section 7.2.4 of [RFC4960] misses this clarification.

3.15.2. Text Changes to the Document

Old text: (Section 7.2.4)

> 3) Determine how many of the earliest (i.e., lowest TSN) DATA chunks marked for retransmission will fit into a single packet, subject to constraint of the path MTU of the destination transport address to which the packet is being sent. Call this value K. Retransmit those K DATA chunks in a single packet. When a Fast Retransmit is being performed, the sender SHOULD ignore the value of cwnd and SHOULD NOT delay retransmission for this single packet.

New text: (Section 7.2.4)

> 3) If not in Fast Recovery, determine how many of the earliest (i.e., lowest TSN) DATA chunks marked for retransmission will fit into a single packet, subject to constraint of the PMTU of the destination transport address to which the packet is being sent. Call this value K. Retransmit those K DATA chunks in a single packet. When a Fast Retransmit is being performed, the sender SHOULD ignore the value of cwnd and SHOULD NOT delay retransmission for this single packet.

This text is in final form and is not further updated in this document.

3.15.3. Solution Description

The new text explicitly specifies that only the first packet in the Fast Recovery phase be sent and that the cwnd limitations be disregarded.

3.16. Initial Value of ssthresh

3.16.1. Description of the Problem

The initial value of ssthresh should be set arbitrarily high. Using the advertised receiver window of the peer is inappropriate if the peer increases its window after the handshake. Furthermore, a higher requirement level needs to be used, since not following the advice may result in performance problems.

3.16.2. Text Changes to the Document

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Old text: (Section 7.2.1)
---------
```

o The initial value of ssthresh MAY be arbitrarily high (for example, implementations MAY use the size of the receiver advertised window).

```
---------
New text: (Section 7.2.1)
---------
```

o The initial value of ssthresh SHOULD be arbitrarily high (e.g., the size of the largest possible advertised window).

This text is in final form and is not further updated in this document.

3.16.3. Solution Description

The same value as the value suggested in [RFC5681], Section 3.1, is now used as an appropriate initial value. Also, the same requirement level is used.

3.17. Automatically CONFIRMED Addresses

3.17.1. Description of the Problem

The Path Verification procedure of [RFC4960] prescribes that any address passed to the sender of the INIT by its upper layer be automatically CONFIRMED. This, however, is unclear if (1) only addresses in the request to initiate association establishment or (2) any addresses provided by the upper layer in any requests (e.g., in 'Set Primary') are considered.

3.17.2. Text Changes to the Document

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Old text: (Section 5.4)
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```

1) Any address passed to the sender of the INIT by its upper layer is automatically considered to be CONFIRMED.

New text: (Section 5.4)
---

1) Any addresses passed to the sender of the INIT by its upper layer in the request to initialize an association are automatically considered to be CONFIRMED.

This text is in final form and is not further updated in this document.

3.17.3. Solution Description

The new text clarifies that only addresses provided by the upper layer in the request to initialize an association are automatically CONFIRMED.

3.18. Only One Packet after Retransmission Timeout

3.18.1. Description of the Problem

[RFC4960] is not completely clear when it describes data transmission after T3-rtx timer expiration. Section 7.2.1 of [RFC4960] does not specify how many packets are allowed to be sent after T3-rtx timer expiration if more than one packet fits into cwnd. At the same time, Section 7.2.3 of [RFC4960] has text without normative language saying that SCTP should ensure that no more than one packet will be in flight after T3-rtx timer expiration until successful acknowledgement. The text is therefore inconsistent.

3.18.2. Text Changes to the Document

Old text: (Section 7.2.1)

- The initial cwnd after a retransmission timeout MUST be no more than 1*MTU.

New text: (Section 7.2.1)

- The initial cwnd after a retransmission timeout MUST be no more than 1*MTU, and only one packet is allowed to be in flight until successful acknowledgement.

This text is in final form and is not further updated in this document.

3.18.3. Solution Description

The new text clearly specifies that only one packet is allowed to be sent after T3-rtx timer expiration until successful acknowledgement.

3.19. INIT ACK Path for INIT in COOKIE-WAIT State

3.19.1. Description of the Problem

In the case of an INIT received in the COOKIE-WAIT state, [RFC4960] prescribes that an INIT ACK be sent to the same destination address to which the original INIT has been sent. [RFC4960] does not address the possibility of the upper layer providing multiple remote IP addresses while requesting the association establishment. If the upper layer has provided multiple IP addresses and only a subset of these addresses are supported by the peer, then the destination address of the original INIT may be absent in the incoming INIT and sending an INIT ACK to that address is useless.

3.19.2. Text Changes to the Document

Old text: (Section 5.2.1)

Upon receipt of an INIT in the COOKIE-WAIT state, an endpoint MUST respond with an INIT ACK using the same parameters it sent in its original INIT chunk (including its Initiate Tag, unchanged). When responding, the endpoint MUST send the INIT ACK back to the same address that the original INIT (sent by this endpoint) was sent.

New text: (Section 5.2.1)

Upon receipt of an INIT in the COOKIE-WAIT state, an endpoint MUST respond with an INIT ACK using the same parameters it sent in its original INIT chunk (including its Initiate Tag, unchanged). When responding, the following rules MUST be applied:

1) The INIT ACK MUST only be sent to an address passed by the upper layer in the request to initialize the association.

2) The INIT ACK MUST only be sent to an address reported in the incoming INIT.

3) The INIT ACK SHOULD be sent to the source address of the received INIT.

This text is in final form and is not further updated in this document.

3.19.3. Solution Description

The new text requires sending an INIT ACK to a destination address that is passed by the upper layer and reported in the incoming INIT. If the source address of the INIT meets these conditions, sending the INIT ACK to the source address of the INIT is the preferred behavior.

3.20. Zero Window Probing and Unreachable Primary Path

3.20.1. Description of the Problem

Section 6.1 of [RFC4960] states that when sending zero window probes, SCTP should neither increment the association counter nor increment the destination address error counter if it continues to receive new packets from the peer. However, the reception of new packets from the peer does not guarantee the peer's reachability, and if the destination address becomes unreachable during zero window probing, SCTP cannot get an updated rwnd until it switches the destination address for probes.

3.20.2. Text Changes to the Document

Old text: (Section 6.1 A))

If the sender continues to receive new packets from the receiver while doing zero window probing, the unacknowledged window probes should not increment the error counter for the association or any destination transport address. This is because the receiver MAY keep its window closed for an indefinite time. Refer to Section 6.2 on the receiver behavior when it advertises a zero window.

New text: (Section 6.1 A))

If the sender continues to receive SACKs from the peer while doing zero window probing, the unacknowledged window probes SHOULD NOT increment the error counter for the association or any destination

transport address. This is because the receiver could keep its window closed for an indefinite time. Section 6.2 describes the receiver behavior when it advertises a zero window.

This text is in final form and is not further updated in this document.

3.20.3. Solution Description

The new text clarifies that if the receiver continues to send SACKs, the sender of probes should not increment the error counter of the association and the destination address even if the SACKs do not acknowledge the probes.

3.21. Normative Language in Section 10 of RFC 4960

3.21.1. Description of the Problem

Section 10 of [RFC4960] is informative. Therefore, normative language such as MUST and MAY cannot be used there. However, there are several places in Section 10 of [RFC4960] where MUST and MAY are used.

3.21.2. Text Changes to the Document

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---------
Old text: (Section 10.1 E))
---------
```

o no-bundle flag - instructs SCTP not to bundle this user data with other outbound DATA chunks. SCTP MAY still bundle even when this flag is present, when faced with network congestion.

```
---------
New text: (Section 10.1 E))
---------
```

o no-bundle flag - instructs SCTP not to bundle this user data with other outbound DATA chunks. When faced with network congestion, SCTP may still bundle the data, even when this flag is present.

This text is in final form and is not further updated in this document.

Old text: (Section 10.1 G))

- Stream Sequence Number - the Stream Sequence Number assigned by the sending SCTP peer.

- partial flag - if this returned flag is set to 1, then this Receive contains a partial delivery of the whole message. When this flag is set, the stream id and Stream Sequence Number MUST accompany this receive. When this flag is set to 0, it indicates that no more deliveries will be received for this Stream Sequence Number.

New text: (Section 10.1 G))

- stream sequence number - the Stream Sequence Number assigned by the sending SCTP peer.

- partial flag - if this returned flag is set to 1, then this primitive contains a partial delivery of the whole message. When this flag is set, the stream id and stream sequence number must accompany this primitive. When this flag is set to 0, it indicates that no more deliveries will be received for this stream sequence number.

This text is in final form and is not further updated in this document.

Old text: (Section 10.1 N))

- Stream Sequence Number - this value is returned indicating the Stream Sequence Number that was associated with the message.

- partial flag - if this returned flag is set to 1, then this message is a partial delivery of the whole message. When this flag is set, the stream id and Stream Sequence Number MUST accompany this receive. When this flag is set to 0, it indicates that no more deliveries will be received for this Stream Sequence Number.

New text: (Section 10.1 N))

- stream sequence number - this value is returned indicating the Stream Sequence Number that was associated with the message.

- partial flag - if this returned flag is set to 1, then this message is a partial delivery of the whole message. When this flag is set, the stream id and stream sequence number must accompany this primitive. When this flag is set to 0, it indicates that no more deliveries will be received for this stream sequence number.

This text is in final form and is not further updated in this document.

Old text: (Section 10.1 O))

- Stream Sequence Number - this value is returned indicating the Stream Sequence Number that was associated with the message.

- partial flag - if this returned flag is set to 1, then this message is a partial delivery of the whole message. When this flag is set, the stream id and Stream Sequence Number MUST accompany this receive. When this flag is set to 0, it indicates that no more deliveries will be received for this Stream Sequence Number.

New text: (Section 10.1 O))

- stream sequence number - this value is returned indicating the Stream Sequence Number that was associated with the message.

- partial flag - if this returned flag is set to 1, then this message is a partial delivery of the whole message. When this flag is set, the stream id and stream sequence number must accompany this primitive. When this flag is set to 0, it indicates that no more deliveries will be received for this stream sequence number.

This text is in final form and is not further updated in this document.

3.21.3. Solution Description

The normative language is removed from Section 10. In addition, the consistency of the text has been improved.

3.22. Increase of partial_bytes_acked in Congestion Avoidance

3.22.1. Description of the Problem

Two issues have been discovered in the text in Section 7.2.2 of [RFC4960] regarding partial_bytes_acked handling:

- If the Cumulative TSN Ack Point is not advanced but the SACK chunk acknowledges new TSNs in the Gap Ack Blocks, these newly acknowledged TSNs are not considered for partial_bytes_acked even though these TSNs were successfully received by the peer.

- Duplicate TSNs are not considered in partial_bytes_acked even though they confirm that the DATA chunks were successfully received by the peer.

3.22.2. Text Changes to the Document

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Old text: (Section 7.2.2)
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```

- Whenever cwnd is greater than ssthresh, upon each SACK arrival that advances the Cumulative TSN Ack Point, increase partial_bytes_acked by the total number of bytes of all new chunks acknowledged in that SACK including chunks acknowledged by the new Cumulative TSN Ack and by Gap Ack Blocks.

```
---------
New text: (Section 7.2.2)
---------
```

- Whenever cwnd is greater than ssthresh, upon each SACK arrival, increase partial_bytes_acked by the total number of bytes of all new chunks acknowledged in that SACK, including chunks acknowledged by the new Cumulative TSN Ack, by Gap Ack Blocks, and by the number of bytes of duplicated chunks reported in Duplicate TSNs.

This text has been modified by multiple errata. It is further updated in Section 3.26.

3.22.3. Solution Description

In the new text, partial_bytes_acked is increased by TSNs reported as duplicated, as well as TSNs newly acknowledged in Gap Ack Blocks, even if the Cumulative TSN Ack Point is not advanced.

3.23. Inconsistent Handling of Notifications

3.23.1. Description of the Problem

[RFC4960] uses inconsistent normative and non-normative language when describing rules for sending notifications to the upper layer. For example, Section 8.2 of [RFC4960] says that when a destination address becomes inactive due to an unacknowledged DATA chunk or HEARTBEAT chunk, SCTP SHOULD send a notification to the upper layer; however, Section 8.3 of [RFC4960] says that when a destination address becomes inactive due to an unacknowledged HEARTBEAT chunk, SCTP may send a notification to the upper layer.

These inconsistent descriptions need to be corrected.

3.23.2. Text Changes to the Document

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Old text: (Section 8.1)
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```

An endpoint shall keep a counter on the total number of consecutive retransmissions to its peer (this includes retransmissions to all the destination transport addresses of the peer if it is multi-homed), including unacknowledged HEARTBEAT chunks.

```
---------
New text: (Section 8.1)
---------
```

An endpoint SHOULD keep a counter on the total number of consecutive retransmissions to its peer (this includes data retransmissions to all the destination transport addresses of the peer if it is multi-homed), including the number of unacknowledged HEARTBEAT chunks observed on the path that is currently used for data transfer. Unacknowledged HEARTBEAT chunks observed on paths different from the path currently used for data transfer SHOULD NOT increment the association error counter, as this could lead to association closure even if the path that is currently used for data transfer is available (but idle). If the value of this counter exceeds the limit indicated in the protocol parameter 'Association.Max.Retrans', the endpoint SHOULD consider the peer endpoint unreachable and SHALL stop

transmitting any more data to it (and thus the association enters the CLOSED state). In addition, the endpoint SHOULD report the failure to the upper layer and optionally report back all outstanding user data remaining in its outbound queue. The association is automatically closed when the peer endpoint becomes unreachable.

This text has been modified by multiple errata. It includes modifications from Section 3.6. It is in final form and is not further updated in this document.

Old text: (Section 8.2)

When an outstanding TSN is acknowledged or a HEARTBEAT sent to that address is acknowledged with a HEARTBEAT ACK, the endpoint shall clear the error counter of the destination transport address to which the DATA chunk was last sent (or HEARTBEAT was sent). When the peer endpoint is multi-homed and the last chunk sent to it was a retransmission to an alternate address, there exists an ambiguity as to whether or not the acknowledgement should be credited to the address of the last chunk sent. However, this ambiguity does not seem to bear any significant consequence to SCTP behavior. If this ambiguity is undesirable, the transmitter may choose not to clear the error counter if the last chunk sent was a retransmission.

New text: (Section 8.2)

When an outstanding TSN is acknowledged or a HEARTBEAT sent to that address is acknowledged with a HEARTBEAT ACK, the endpoint SHOULD clear the error counter of the destination transport address to which the DATA chunk was last sent (or HEARTBEAT was sent) and SHOULD also report to the upper layer when an inactive destination address is marked as active. When the peer endpoint is multi-homed and the last chunk sent to it was a retransmission to an alternate address, there exists an ambiguity as to whether or not the acknowledgement could be credited to the address of the last chunk sent. However, this ambiguity does not seem to have significant consequences for SCTP behavior. If this ambiguity is undesirable, the transmitter MAY choose not to clear the error counter if the last chunk sent was a retransmission.

This text is in final form and is not further updated in this document.

Old text: (Section 8.3)

When the value of this counter reaches the protocol parameter 'Path.Max.Retrans', the endpoint should mark the corresponding destination address as inactive if it is not so marked, and may also optionally report to the upper layer the change of reachability of this destination address. After this, the endpoint should continue HEARTBEAT on this destination address but should stop increasing the counter.

New text: (Section 8.3)

When the value of this counter exceeds the protocol parameter 'Path.Max.Retrans', the endpoint SHOULD mark the corresponding destination address as inactive if it is not so marked and SHOULD also report to the upper layer the change in reachability of this destination address. After this, the endpoint SHOULD continue HEARTBEAT on this destination address but SHOULD stop increasing the counter.

This text has been modified by multiple errata. It includes modifications from Section 3.1. It is in final form and is not further updated in this document.

Old text: (Section 8.3)

Upon the receipt of the HEARTBEAT ACK, the sender of the HEARTBEAT should clear the error counter of the destination transport address to which the HEARTBEAT was sent, and mark the destination transport address as active if it is not so marked. The endpoint may optionally report to the upper layer when an inactive destination address is marked as active due to the reception of the latest HEARTBEAT ACK. The receiver of the HEARTBEAT ACK must also clear the association overall error count as well (as defined in Section 8.1).

New text: (Section 8.3)

Upon the receipt of the HEARTBEAT ACK, the sender of the HEARTBEAT SHOULD clear the error counter of the destination transport address to which the HEARTBEAT was sent and mark the destination transport

address as active if it is not so marked. The endpoint SHOULD report to the upper layer when an inactive destination address is marked as active due to the reception of the latest HEARTBEAT ACK. The receiver of the HEARTBEAT ACK SHOULD also clear the association overall error count (as defined in Section 8.1).

This text has been modified by multiple errata. It includes modifications from Section 3.13. It is in final form and is not further updated in this document.

Old text: (Section 9.2)

An endpoint should limit the number of retransmissions of the SHUTDOWN chunk to the protocol parameter 'Association.Max.Retrans'. If this threshold is exceeded, the endpoint should destroy the TCB and MUST report the peer endpoint unreachable to the upper layer (and thus the association enters the CLOSED state).

New text: (Section 9.2)

An endpoint SHOULD limit the number of retransmissions of the SHUTDOWN chunk to the protocol parameter 'Association.Max.Retrans'. If this threshold is exceeded, the endpoint SHOULD destroy the TCB and SHOULD report the peer endpoint unreachable to the upper layer (and thus the association enters the CLOSED state).

This text is in final form and is not further updated in this document.

Old text: (Section 9.2)

The sender of the SHUTDOWN ACK should limit the number of retransmissions of the SHUTDOWN ACK chunk to the protocol parameter 'Association.Max.Retrans'. If this threshold is exceeded, the endpoint should destroy the TCB and may report the peer endpoint unreachable to the upper layer (and thus the association enters the CLOSED state).

New text: (Section 9.2)

The sender of the SHUTDOWN ACK SHOULD limit the number of retransmissions of the SHUTDOWN ACK chunk to the protocol parameter 'Association.Max.Retrans'. If this threshold is exceeded, the endpoint SHOULD destroy the TCB and SHOULD report the peer endpoint unreachable to the upper layer (and thus the association enters the CLOSED state).

This text is in final form and is not further updated in this document.

3.23.3. Solution Description

The inconsistencies are removed by consistently using SHOULD.

3.24. SACK.Delay Not Listed as a Protocol Parameter

3.24.1. Description of the Problem

SCTP as specified in [RFC4960] supports delaying SACKs. The timer value for this is a parameter, and Section 6.2 of [RFC4960] specifies a default and maximum value for it. However, (1) defining a name for this parameter and (2) listing it in the table of protocol parameters in Section 15 of [RFC4960] are missing.

This issue was reported as an errata for [RFC4960] with Errata ID 4656.

3.24.2. Text Changes to the Document

Old text: (Section 6.2)

An implementation MUST NOT allow the maximum delay to be configured to be more than 500 ms. In other words, an implementation MAY lower this value below 500 ms but MUST NOT raise it above 500 ms.

New text: (Section 6.2)

An implementation MUST NOT allow the maximum delay (protocol parameter 'SACK.Delay') to be configured to be more than 500 ms. In other words, an implementation MAY lower the value of SACK.Delay below 500 ms but MUST NOT raise it above 500 ms.

This text is in final form and is not further updated in this document.

Old text: (Section 15)

The following protocol parameters are RECOMMENDED:

RTO.Initial - 3 seconds
RTO.Min - 1 second
RTO.Max - 60 seconds
Max.Burst - 4
RTO.Alpha - 1/8
RTO.Beta - 1/4
Valid.Cookie.Life - 60 seconds
Association.Max.Retrans - 10 attempts
Path.Max.Retrans - 5 attempts (per destination address)
Max.Init.Retransmits - 8 attempts
HB.interval - 30 seconds
HB.Max.Burst - 1

New text: (Section 15)

The following protocol parameters are RECOMMENDED:

```
RTO.Initial: 3 seconds
RTO.Min: 1 second
RTO.Max: 60 seconds
Max.Burst: 4
RTO.Alpha: 1/8
RTO.Beta: 1/4
Valid.Cookie.Life: 60 seconds
Association.Max.Retrans: 10 attempts
Path.Max.Retrans: 5 attempts (per destination address)
Max.Init.Retransmits: 8 attempts
HB.interval: 30 seconds
HB.Max.Burst: 1
SACK.Delay: 200 milliseconds
```

This text has been modified by multiple errata. It is further updated in Section 3.32.

3.24.3. Solution Description

The parameter is given the name 'SACK.Delay' and added to the list of protocol parameters.

3.25. Processing of Chunks in an Incoming SCTP Packet

3.25.1. Description of the Problem

There are a few places in [RFC4960] where text specifies that the receiver of a packet must discard it while processing the chunks of the packet. Whether or not the receiver has to roll back state changes already performed while processing the packet is unclear.

The intention of [RFC4960] is to process an incoming packet chunk by chunk and not to perform any prescreening of chunks in the received packet. Thus, by discarding one chunk, the receiver also causes the discarding of all further chunks.

3.25.2. Text Changes to the Document

Old text: (Section 3.2)
---

00 - Stop processing this SCTP packet and discard it, do not process any further chunks within it.

01 - Stop processing this SCTP packet and discard it, do not process any further chunks within it, and report the unrecognized chunk in an 'Unrecognized Chunk Type'.

New text: (Section 3.2)
---

00 - Stop processing this SCTP packet; discard the unrecognized chunk and all further chunks.

01 - Stop processing this SCTP packet, discard the unrecognized chunk and all further chunks, and report the unrecognized chunk in an 'Unrecognized Chunk Type'.

This text is in final form and is not further updated in this document.

Old text: (Section 11.3)

It is helpful for some firewalls if they can inspect just the first fragment of a fragmented SCTP packet and unambiguously determine whether it corresponds to an INIT chunk (for further information, please refer to [RFC1858]). Accordingly, we stress the requirements, stated in Section 3.1, that (1) an INIT chunk MUST NOT be bundled with any other chunk in a packet, and (2) a packet containing an INIT chunk MUST have a zero Verification Tag. Furthermore, we require that the receiver of an INIT chunk MUST enforce these rules by silently discarding an arriving packet with an INIT chunk that is bundled with other chunks or has a non-zero verification tag and contains an INIT-chunk.

New text: (Section 11.3)

It is helpful for some firewalls if they can inspect just the first fragment of a fragmented SCTP packet and unambiguously determine whether it corresponds to an INIT chunk (for further information, please refer to [RFC1858]). Accordingly, we stress the requirements, as stated in Section 3.1, that (1) an INIT chunk MUST NOT be bundled with any other chunk in a packet and (2) a packet containing an INIT chunk MUST have a zero Verification Tag. The receiver of an INIT chunk MUST silently discard the INIT chunk and all further chunks if the INIT chunk is bundled with other chunks or the packet has a non-zero Verification Tag.

This text is in final form and is not further updated in this document.

3.25.3. Solution Description

The new text makes it clear that chunks can be processed from the beginning to the end and that no rollback or prescreening is required.

3.26. Increasing the cwnd in the Congestion Avoidance Phase

3.26.1. Description of the Problem

Section 7.2.2 of [RFC4960] prescribes that cwnd be increased by 1*MTU per RTT if the sender has cwnd or more bytes of data outstanding to the corresponding address in the congestion avoidance phase. However, this is described without normative language. Moreover, Section 7.2.2 of [RFC4960] includes an algorithm that specifies how an implementation can achieve this, but this algorithm is underspecified and actually allows increasing cwnd by more than 1*MTU per RTT.

3.26.2. Text Changes to the Document

Old text: (Section 7.2.2)

When cwnd is greater than ssthresh, cwnd should be incremented by 1*MTU per RTT if the sender has cwnd or more bytes of data outstanding for the corresponding transport address.

New text: (Section 7.2.2)

When cwnd is greater than ssthresh, cwnd SHOULD be incremented by 1*MTU per RTT if the sender has cwnd or more bytes of data outstanding for the corresponding transport address. The basic guidelines for incrementing cwnd during congestion avoidance are as follows:

- SCTP MAY increment cwnd by 1*MTU.
- SCTP SHOULD increment cwnd by 1*MTU once per RTT when the sender has cwnd or more bytes of data outstanding for the corresponding transport address.
- SCTP MUST NOT increment cwnd by more than 1*MTU per RTT.

This text is in final form and is not further updated in this document.

Old text: (Section 7.2.2)

- Whenever cwnd is greater than ssthresh, upon each SACK arrival that advances the Cumulative TSN Ack Point, increase partial_bytes_acked by the total number of bytes of all new chunks acknowledged in that SACK including chunks acknowledged by the new Cumulative TSN Ack and by Gap Ack Blocks.
- When partial_bytes_acked is equal to or greater than cwnd and before the arrival of the SACK the sender had cwnd or more bytes of data outstanding (i.e., before arrival of the SACK, flightsize was greater than or equal to cwnd), increase cwnd by MTU, and reset partial_bytes_acked to (partial_bytes_acked - cwnd).

New text: (Section 7.2.2)

- Whenever cwnd is greater than ssthresh, upon each SACK arrival, increase partial_bytes_acked by the total number of bytes of all new chunks acknowledged in that SACK, including chunks acknowledged by the new Cumulative TSN Ack, by Gap Ack Blocks, and by the number of bytes of duplicated chunks reported in Duplicate TSNs.

- (1) when partial_bytes_acked is greater than cwnd and (2) before the arrival of the SACK the sender had less than cwnd bytes of data outstanding (i.e., before the arrival of the SACK, flightsize was less than cwnd), reset partial_bytes_acked to cwnd.

- (1) when partial_bytes_acked is equal to or greater than cwnd and (2) before the arrival of the SACK the sender had cwnd or more bytes of data outstanding (i.e., before the arrival of the SACK, flightsize was greater than or equal to cwnd), partial_bytes_acked is reset to (partial_bytes_acked - cwnd). Next, cwnd is increased by 1*MTU.

This text has been modified by multiple errata. It includes modifications from Sections 3.12 and 3.22. It is in final form and is not further updated in this document.

3.26.3. Solution Description

The basic guidelines for incrementing cwnd during the congestion avoidance phase are added into Section 7.2.2. The guidelines include the normative language and are aligned with [RFC5681].

The algorithm from Section 7.2.2 is improved and now does not allow increasing cwnd by more than 1*MTU per RTT.

3.27. Refresh of cwnd and ssthresh after Idle Period

3.27.1. Description of the Problem

[RFC4960] prescribes that cwnd per RTO be adjusted if the endpoint does not transmit data on a given transport address. In addition to that, it prescribes that cwnd be set to the initial value after a sufficiently long idle period. The latter is excessive. Moreover, what is considered a sufficiently long idle period is unclear.

[RFC4960] doesn't specify the handling of ssthresh in the idle case. If ssthresh is reduced due to packet loss, ssthresh is never recovered. So, traffic can end up in congestion avoidance all the time, resulting in a low sending rate and bad performance. The problem is even more serious for SCTP: in a multi-homed SCTP association, traffic that switches back to the previously failed primary path will also lead to the situation where traffic ends up in congestion avoidance.

3.27.2. Text Changes to the Document

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---------
Old text: (Section 7.2.1)
---------
```

o The initial cwnd before DATA transmission or after a sufficiently long idle period MUST be set to min(4*MTU, max (2*MTU, 4380 bytes)).

```
---------
New text: (Section 7.2.1)
---------
```

o The initial cwnd before data transmission MUST be set to min(4*MTU, max (2*MTU, 4380 bytes)).

```
---------
Old text: (Section 7.2.1)
---------
```

o When the endpoint does not transmit data on a given transport address, the cwnd of the transport address should be adjusted to max(cwnd/2, 4*MTU) per RTO.

```
---------
New text: (Section 7.2.1)
---------
```

o While the endpoint does not transmit data on a given transport address, the cwnd of the transport address SHOULD be adjusted to max(cwnd/2, 4*MTU) once per RTO. Before the first cwnd adjustment, the ssthresh of the transport address SHOULD be set to the cwnd.

This text is in final form and is not further updated in this document.

3.27.3. Solution Description

A rule about cwnd adjustment after a sufficiently long idle period is removed.

The text is updated to describe the handling of ssthresh. When the idle period is detected, the cwnd value is copied to ssthresh.

3.28. Window Updates after Receiver Window Opens Up

3.28.1. Description of the Problem

The sending of SACK chunks for window updates is only indirectly referenced in Section 6.2 of [RFC4960], which states that an SCTP receiver must not generate more than one SACK for every incoming packet, other than to update the offered window.

However, to avoid performance problems, it is necessary to send the window updates when the receiver window opens up.

3.28.2. Text Changes to the Document

Old text: (Section 6.2)

An SCTP receiver MUST NOT generate more than one SACK for every incoming packet, other than to update the offered window as the receiving application consumes new data.

New text: (Section 6.2)

An SCTP receiver MUST NOT generate more than one SACK for every incoming packet, other than to update the offered window as the receiving application consumes new data. When the window opens up, an SCTP receiver SHOULD send additional SACK chunks to update the window even if no new data is received. The receiver MUST avoid sending a large number of window updates -- in particular, large bursts of them. One way to achieve this is to send a window update only if the window can be increased by at least a quarter of the receive buffer size of the association.

This text is in final form and is not further updated in this document.

3.28.3. Solution Description

The new text makes it clear that additional SACK chunks for window updates should be sent as long as excessive bursts are avoided.

3.29. Path of DATA and Reply Chunks

3.29.1. Description of the Problem

Section 6.4 of [RFC4960] describes the transmission policy for multi-homed SCTP endpoints. However, this policy has the following issues:

- It states that a SACK should be sent to the source address of an incoming DATA. However, it is known that other SACK policies (e.g., always sending SACKs to the primary path) may be more beneficial in some situations.

- Also, it initially states that an endpoint should always transmit DATA chunks to the primary path but then states that the rule for the transmittal of reply chunks should also be followed if the endpoint is bundling DATA chunks together with the reply chunk. The second statement contradicts the first statement. Some implementations were having problems with it and sent DATA chunks bundled with reply chunks to a different destination address than the primary path, causing many gaps.

3.29.2. Text Changes to the Document

Old text: (Section 6.4)

An endpoint SHOULD transmit reply chunks (e.g., SACK, HEARTBEAT ACK, etc.) to the same destination transport address from which it received the DATA or control chunk to which it is replying. This rule should also be followed if the endpoint is bundling DATA chunks together with the reply chunk.

However, when acknowledging multiple DATA chunks received in packets from different source addresses in a single SACK, the SACK chunk may be transmitted to one of the destination transport addresses from which the DATA or control chunks being acknowledged were received.

New text: (Section 6.4)

An endpoint SHOULD transmit reply chunks (e.g., INIT ACK, COOKIE ACK, HEARTBEAT ACK) in response to control chunks to the same destination transport address from which it received the control chunk to which it is replying.

The selection of the destination transport address for packets containing SACK chunks is implementation dependent. However, an endpoint SHOULD NOT vary the destination transport address of a SACK when it receives DATA chunks coming from the same source address.

When acknowledging multiple DATA chunks received in packets from different source addresses in a single SACK, the SACK chunk MAY be transmitted to one of the destination transport addresses from which the DATA or control chunks being acknowledged were received.

This text is in final form and is not further updated in this document.

3.29.3. Solution Description

The SACK transmission policy is left implementation dependent, but the new text now specifies that the policy not vary the destination address of a packet containing a SACK chunk unless there are reasons for not doing so, as varying the destination address may negatively impact RTT measurement.

New text removes a confusing statement that prescribes following the rule for transmittal of reply chunks when the endpoint is bundling DATA chunks together with the reply chunk.

3.30. "Outstanding Data", "Flightsize", and "Data in Flight" Key Terms

3.30.1. Description of the Problem

[RFC4960] uses the key terms "outstanding data", "flightsize", and "data in flight" in formulas and statements, but Section 1.3 ("Key Terms") of [RFC4960] does not provide their definitions. Furthermore, outstanding data does not include DATA chunks that are classified as lost but that have not yet been retransmitted, and there is a paragraph in Section 6.1 of [RFC4960] where this statement is broken.

3.30.2. Text Changes to the Document

Old text: (Section 1.3)

- Congestion window (cwnd): An SCTP variable that limits the data, in number of bytes, a sender can send to a particular destination transport address before receiving an acknowledgement.

...

o Outstanding TSN (at an SCTP endpoint): A TSN (and the associated DATA chunk) that has been sent by the endpoint but for which it has not yet received an acknowledgement.

New text: (Section 1.3)
---

o Congestion window (cwnd): An SCTP variable that limits outstanding data, in number of bytes, that a sender can send to a particular destination transport address before receiving an acknowledgement.

...

o Flightsize: The amount of bytes of outstanding data to a particular destination transport address at any given time.

...

o Outstanding data (or "data outstanding" or "data in flight"): The total amount of the DATA chunks associated with outstanding TSNs. A retransmitted DATA chunk is counted once in outstanding data. A DATA chunk that is classified as lost but that has not yet been retransmitted is not in outstanding data.

o Outstanding TSN (at an SCTP endpoint): A TSN (and the associated DATA chunk) that has been sent by the endpoint but for which it has not yet received an acknowledgement.

This text is in final form and is not further updated in this document.

Old text: (Section 6.1)

C) When the time comes for the sender to transmit, before sending new DATA chunks, the sender MUST first transmit any outstanding DATA chunks that are marked for retransmission (limited by the current cwnd).

New text: (Section 6.1)

C) When the time comes for the sender to transmit, before sending new DATA chunks, the sender MUST first transmit any DATA chunks that are marked for retransmission (limited by the current cwnd).

This text is in final form and is not further updated in this document.

3.30.3. Solution Description

Section 1.3 is corrected to include explanations of the key terms "outstanding data", "data in flight", and "flightsize". Section 6.1 is corrected to now use "any DATA chunks" instead of "any outstanding DATA chunks".

3.31. Degradation of cwnd due to Max.Burst

3.31.1. Description of the Problem

Some implementations were experiencing a degradation of cwnd because of the Max.Burst limit. This was due to misinterpretation of the suggestion in Section 6.1 of [RFC4960] regarding how to use the Max.Burst parameter when calculating the number of packets to transmit.

3.31.2. Text Changes to the Document

```
---------
Old text: (Section 6.1)
---------
```

D) When the time comes for the sender to transmit new DATA chunks, the protocol parameter Max.Burst SHOULD be used to limit the number of packets sent. The limit MAY be applied by adjusting cwnd as follows:

```
if((flightsize + Max.Burst*MTU) < cwnd) cwnd = flightsize +
Max.Burst*MTU
```

Or it MAY be applied by strictly limiting the number of packets emitted by the output routine.

```
---------
New text: (Section 6.1)
---------
```

D) When the time comes for the sender to transmit new DATA chunks, the protocol parameter Max.Burst SHOULD be used to limit the number of packets sent. The limit MAY be applied by adjusting cwnd temporarily, as follows:

```
if ((flightsize + Max.Burst*MTU) < cwnd)
    cwnd = flightsize + Max.Burst*MTU
```

Or, it MAY be applied by strictly limiting the number of packets emitted by the output routine. When calculating the number of packets to transmit, and particularly when using the formula above, cwnd SHOULD NOT be changed permanently.

This text is in final form and is not further updated in this document.

3.31.3. Solution Description

The new text clarifies that cwnd should not be changed when applying the Max.Burst limit. This mitigates packet bursts related to the reception of SACK chunks but not bursts related to an application sending a burst of user messages.

3.32. Reduction of RTO.Initial

3.32.1. Description of the Problem

[RFC4960] uses 3 seconds as the default value for RTO.Initial in accordance with Section 4.2.3.1 of [RFC1122]. [RFC6298] updates [RFC1122] and lowers the initial value of the retransmission timer from 3 seconds to 1 second.

3.32.2. Text Changes to the Document

```
---------
Old text: (Section 15)
---------
```

The following protocol parameters are RECOMMENDED:

```
RTO.Initial - 3 seconds
RTO.Min - 1 second
RTO.Max - 60 seconds
Max.Burst - 4
RTO.Alpha - 1/8
RTO.Beta - 1/4
Valid.Cookie.Life - 60 seconds
Association.Max.Retrans - 10 attempts
Path.Max.Retrans - 5 attempts (per destination address)
Max.Init.Retransmits - 8 attempts
HB.interval - 30 seconds
HB.Max.Burst - 1
```

New text: (Section 15)

The following protocol parameters are RECOMMENDED:

RTO.Initial: 1 second
RTO.Min: 1 second
RTO.Max: 60 seconds
Max.Burst: 4
RTO.Alpha: 1/8
RTO.Beta: 1/4
Valid.Cookie.Life: 60 seconds
Association.Max.Retrans: 10 attempts
Path.Max.Retrans: 5 attempts (per destination address)
Max.Init.Retransmits: 8 attempts
HB.interval: 30 seconds
HB.Max.Burst: 1
SACK.Delay: 200 milliseconds

This text has been modified by multiple errata. It includes modifications from Section 3.24. It is in final form and is not further updated in this document.

3.32.3. Solution Description

The default value for RTO.Initial has been lowered to 1 second to be in tune with [RFC6298].

3.33. Ordering of Bundled SACK and ERROR Chunks

3.33.1. Description of the Problem

When an SCTP endpoint receives a DATA chunk with an invalid stream identifier, it shall acknowledge it by sending a SACK chunk and indicate that the stream identifier was invalid by sending an ERROR chunk. These two chunks may be bundled. However, in the case of bundling, [RFC4960] requires that the ERROR chunk follow the SACK chunk. This restriction regarding the ordering of the chunks is not necessary and might limit interoperability.

3.33.2. Text Changes to the Document

Old text: (Section 6.5)

Every DATA chunk MUST carry a valid stream identifier. If an endpoint receives a DATA chunk with an invalid stream identifier, it shall acknowledge the reception of the DATA chunk following the normal procedure, immediately send an ERROR chunk with cause set to "Invalid Stream Identifier" (see Section 3.3.10), and discard the DATA chunk. The endpoint may bundle the ERROR chunk in the same packet as the SACK as long as the ERROR follows the SACK.

New text: (Section 6.5)

Every DATA chunk MUST carry a valid stream identifier. If an endpoint receives a DATA chunk with an invalid stream identifier, it SHOULD acknowledge the reception of the DATA chunk following the normal procedure, immediately send an ERROR chunk with cause set to "Invalid Stream Identifier" (see Section 3.3.10), and discard the DATA chunk. The endpoint MAY bundle the ERROR chunk and the SACK chunk in the same packet.

This text is in final form and is not further updated in this document.

3.33.3. Solution Description

The unnecessary restriction regarding the ordering of the SACK and ERROR chunks has been removed.

3.34. Undefined Parameter Returned by RECEIVE Primitive

3.34.1. Description of the Problem

[RFC4960] provides a description of an abstract API. In the definition of the RECEIVE primitive, an optional parameter with name "delivery number" is mentioned. However, no definition of this parameter is given in [RFC4960], and the parameter is unnecessary.

3.34.2. Text Changes to the Document

```
---------
Old text: (Section 10.1 G))
---------

G) Receive

Format: RECEIVE(association id, buffer address, buffer size
        [,stream id])
-> byte count [,transport address] [,stream id] [,stream sequence
   number] [,partial flag] [,delivery number] [,payload protocol-id]

---------
New text: (Section 10.1 G))
---------

G) Receive

Format: RECEIVE(association id, buffer address, buffer size
        [,stream id])
-> byte count [,transport address] [,stream id] [,stream sequence
   number] [,partial flag] [,payload protocol-id]

This text is in final form and is not further updated in this
document.
```

3.34.3. Solution Description

The undefined parameter has been removed.

3.35. DSCP Changes

3.35.1. Description of the Problem

The upper layer can change the Differentiated Services Code Point (DSCP) used for packets being sent. Changing the DSCP can result in packets hitting different queues on the path. Therefore, congestion control should be initialized when the DSCP is changed by the upper layer. This is not described in [RFC4960].

3.35.2. Text Changes to the Document

New text: (Section 7.2.5)

7.2.5. Making Changes to Differentiated Services Code Points

> SCTP implementations MAY allow an application to configure the Differentiated Services Code Point (DSCP) used for sending packets. If a DSCP change might result in outgoing packets being queued in different queues, the congestion control parameters for all affected destination addresses MUST be reset to their initial values.

This text is in final form and is not further updated in this document.

Old text: (Section 10.1 M))

Mandatory attributes:

- association id - local handle to the SCTP association.
- protocol parameter list - the specific names and values of the protocol parameters (e.g., Association.Max.Retrans; see Section 15) that the SCTP user wishes to customize.

New text: (Section 10.1 M))

Mandatory attributes:

- association id - local handle to the SCTP association.
- protocol parameter list - the specific names and values of the protocol parameters (e.g., Association.Max.Retrans (see Section 15), or other parameters like the DSCP) that the SCTP user wishes to customize.

This text is in final form and is not further updated in this document.

3.35.3. Solution Description

Text describing the required action for DSCP changes has been added.

3.36. Inconsistent Handling of ICMPv4 and ICMPv6 Messages

3.36.1. Description of the Problem

Appendix C of [RFC4960] describes the handling of ICMPv4 and ICMPv6 messages. The handling of ICMP messages indicating that the port number is unreachable, as described in the enumerated procedures, is not consistent with the description given in [RFC4960] after the procedures. Furthermore, the text explicitly describes the handling of ICMPv6 packets indicating reachability problems but does not do the same for the corresponding ICMPv4 packets.

3.36.2. Text Changes to the Document

```
---------
Old text: (Appendix C)
---------

ICMP3) An implementation MAY ignore any ICMPv4 messages where the
       code does not indicate "Protocol Unreachable" or
       "Fragmentation Needed".

---------
New text: (Appendix C)
---------

ICMP3) An implementation SHOULD ignore any ICMP messages where the
       code indicates "Port Unreachable".

This text is in final form and is not further updated in this
document.

---------
Old text: (Appendix C)
---------

ICMP9) If the ICMPv6 code is "Destination Unreachable", the
       implementation MAY mark the destination into the unreachable
       state or alternatively increment the path error counter.
```

New text: (Appendix C)

ICMP9) If the ICMP type is "Destination Unreachable", the implementation MAY move the destination to the unreachable state or, alternatively, increment the path error counter.

This text has been modified by multiple errata. It is further updated in Section 3.37.

3.36.3. Solution Description

The text has been changed to describe the intended handling of ICMP messages indicating that the port number is unreachable by replacing the third rule. Also, the limitation to ICMPv6 in the ninth rule has been removed.

3.37. Handling of Soft Errors

3.37.1. Description of the Problem

[RFC1122] defines the handling of soft errors and hard errors for TCP. Appendix C of [RFC4960] only deals with hard errors.

3.37.2. Text Changes to the Document

Old text: (Appendix C)

ICMP9) If the ICMPv6 code is "Destination Unreachable", the implementation MAY mark the destination into the unreachable state or alternatively increment the path error counter.

New text: (Appendix C)

ICMP9) If the ICMP type is "Destination Unreachable", the implementation MAY move the destination to the unreachable state or, alternatively, increment the path error counter. SCTP MAY provide information to the upper layer indicating the reception of ICMP messages when reporting a network status change.

This text has been modified by multiple errata. It includes modifications from Section 3.36. It is in final form and is not further updated in this document.

3.37.3. Solution Description

Text has been added allowing SCTP to notify the application in the case of soft errors.

3.38. Honoring cwnd

3.38.1. Description of the Problem

When using the slow start algorithm, SCTP increases the congestion window only when it is being fully utilized. Since SCTP uses DATA chunks and does not use the congestion window to fragment user messages, this requires that some overbooking of the congestion window be allowed.

3.38.2. Text Changes to the Document

Old text: (Section 6.1)

B) At any given time, the sender MUST NOT transmit new data to a given transport address if it has cwnd or more bytes of data outstanding to that transport address.

New text: (Section 6.1)

B) At any given time, the sender MUST NOT transmit new data to a given transport address if it has cwnd + (PMTU - 1) or more bytes of data outstanding to that transport address. If data is available, the sender SHOULD exceed cwnd by up to (PMTU - 1) bytes on a new data transmission if the flightsize does not currently reach cwnd. The breach of cwnd MUST constitute one packet only.

This text is in final form and is not further updated in this document.

Old text: (Section 7.2.1)
---

o Whenever cwnd is greater than zero, the endpoint is allowed to have cwnd bytes of data outstanding on that transport address.

New text: (Section 7.2.1)
---

o Whenever cwnd is greater than zero, the endpoint is allowed to have cwnd bytes of data outstanding on that transport address. A limited overbooking as described in Section 6.1 B) SHOULD be supported.

This text is in final form and is not further updated in this document.

3.38.3. Solution Description

Text was added to clarify how the cwnd limit should be handled.

3.39. Zero Window Probing

3.39.1. Description of the Problem

The text in Section 6.1 of [RFC4960] that describes zero window probing does not clearly address the case where the window is not zero but is too small for the next DATA chunk to be transmitted. Even in this case, zero window probing has to be performed to avoid deadlocks.

3.39.2. Text Changes to the Document

Old text: (Section 6.1)

A) At any given time, the data sender MUST NOT transmit new data to any destination transport address if its peer's rwnd indicates that the peer has no buffer space (i.e., rwnd is 0; see Section 6.2.1). However, regardless of the value of rwnd (including if it is 0), the data sender can always have one DATA chunk in flight to the receiver if allowed by cwnd (see rule B, below). This rule allows the sender to probe for a change in rwnd that the sender missed due to the SACK's having been lost in transit from the data receiver to the data sender.

When the receiver's advertised window is zero, this probe is called a zero window probe. Note that a zero window probe SHOULD only be sent when all outstanding DATA chunks have been cumulatively acknowledged and no DATA chunks are in flight. Zero window probing MUST be supported.

New text: (Section 6.1)

A) At any given time, the data sender MUST NOT transmit new data to any destination transport address if its peer's rwnd indicates that the peer has no buffer space (i.e., rwnd is smaller than the size of the next DATA chunk; see Section 6.2.1). However, regardless of the value of rwnd (including if it is 0), the data sender can always have one DATA chunk in flight to the receiver if allowed by cwnd (see rule B, below). This rule allows the sender to probe for a change in rwnd that the sender missed due to the SACK's having been lost in transit from the data receiver to the data sender.

When the receiver has no buffer space, this probe is called a zero window probe. Note that a zero window probe SHOULD only be sent when all outstanding DATA chunks have been cumulatively acknowledged and no DATA chunks are in flight. Zero window probing MUST be supported.

This text is in final form and is not further updated in this document.

3.39.3. Solution Description

The terminology is used in a cleaner way.

3.40. Updating References regarding ECN

3.40.1. Description of the Problem

For Explicit Congestion Notification (ECN), [RFC4960] refers only to [RFC3168], which has been updated by [RFC8311]. This needs to be reflected in the text when referring to ECN.

3.40.2. Text Changes to the Document

```
---------
Old text: (Appendix A)
---------
```

ECN [RFC3168] describes a proposed extension to IP that details a method to become aware of congestion outside of datagram loss.

```
---------
New text: (Appendix A)
---------
```

ECN as specified in [RFC3168] (updated by [RFC8311]) describes an extension to IP that details a method for becoming aware of congestion outside of datagram loss.

This text is in final form and is not further updated in this document.

```
---------
Old text: (Appendix A)
---------
```

In general, [RFC3168] should be followed with the following exceptions.

```
---------
New text: (Appendix A)
---------
```

In general, [RFC3168] (updated by [RFC8311]) SHOULD be followed, with the following exceptions.

This text is in final form and is not further updated in this document.

Old text: (Appendix A)

[RFC3168] details negotiation of ECN during the SYN and SYN-ACK stages of a TCP connection.

New text: (Appendix A)

[RFC3168] (updated by [RFC8311]) details the negotiation of ECN during the SYN and SYN-ACK stages of a TCP connection.

This text is in final form and is not further updated in this document.

Old text: (Appendix A)

[RFC3168] details a specific bit for a receiver to send back in its TCP acknowledgements to notify the sender of the Congestion Experienced (CE) bit having arrived from the network.

New text: (Appendix A)

[RFC3168] (updated by [RFC8311]) details a specific bit for a receiver to send back in its TCP acknowledgements to notify the sender of the Congestion Experienced (CE) bit that the CE bit has arrived from the network.

This text is in final form and is not further updated in this document.

Old text: (Appendix A)

[RFC3168] details a specific bit for a sender to send in the header of its next outbound TCP segment to indicate to its peer that it has reduced its congestion window.

New text: (Appendix A)

[RFC3168] (updated by [RFC8311]) details a specific bit for a sender to send in the header of its next outbound TCP segment to indicate to its peer that it has reduced its congestion window.

This text is in final form and is not further updated in this document.

3.40.3. Solution Description

References to [RFC8311] have been added. Some wordsmithing was also done while making those updates.

3.41. Host Name Address Parameter Deprecated

3.41.1. Description of the Problem

[RFC4960] defines three types of address parameters to be used with INIT and INIT ACK chunks:

1. IPv4 Address parameters.

2. IPv6 Address parameters.

3. Host Name Address parameters.

The first two parameter types are supported by the SCTP kernel implementations of FreeBSD, Linux, and Solaris, but the third is not. In addition, the first two were successfully tested in all nine interoperability tests for SCTP, but the third has never been successfully tested. Therefore, the Host Name Address parameter should be deprecated.

3.41.2. Text Changes to the Document

Old text: (Section 3.3.2)

Note 3: An INIT chunk MUST NOT contain more than one Host Name Address parameter. Moreover, the sender of the INIT MUST NOT combine any other address types with the Host Name Address in the INIT. The receiver of INIT MUST ignore any other address types if the Host Name Address parameter is present in the received INIT chunk.

New text: (Section 3.3.2)

Note 3: An INIT chunk MUST NOT contain the Host Name Address parameter. The receiver of an INIT chunk containing a Host Name Address parameter MUST send an ABORT and MAY include an "Unresolvable Address" error cause.

This text is in final form and is not further updated in this document.

Old text: (Section 3.3.2.1)

The sender of INIT uses this parameter to pass its Host Name (in place of its IP addresses) to its peer. The peer is responsible for resolving the name. Using this parameter might make it more likely for the association to work across a NAT box.

New text: (Section 3.3.2.1)

The sender of an INIT chunk MUST NOT include this parameter. The usage of the Host Name Address parameter is deprecated.

This text is in final form and is not further updated in this document.

Old text: (Section 3.3.2.1)

Address Type: 16 bits (unsigned integer)

> This is filled with the type value of the corresponding address TLV (e.g., IPv4 = 5, IPv6 = 6, Host name = 11).

New text: (Section 3.3.2.1)

Address Type: 16 bits (unsigned integer)

This is filled with the type value of the corresponding address TLV (e.g., IPv4 = 5, IPv6 = 6). The value indicating the Host Name Address parameter (Host name = 11) MUST NOT be used.

This text is in final form and is not further updated in this document.

Old text: (Section 3.3.3)

Note 3: The INIT ACK chunks MUST NOT contain more than one Host Name Address parameter. Moreover, the sender of the INIT ACK MUST NOT combine any other address types with the Host Name Address in the INIT ACK. The receiver of the INIT ACK MUST ignore any other address types if the Host Name Address parameter is present.

New text: (Section 3.3.3)

Note 3: An INIT ACK chunk MUST NOT contain the Host Name Address parameter. The receiver of INIT ACK chunks containing a Host Name Address parameter MUST send an ABORT and MAY include an "Unresolvable Address" error cause.

This text is in final form and is not further updated in this document.

Old text: (Section 5.1.2)

B) If there is a Host Name parameter present in the received INIT or INIT ACK chunk, the endpoint shall resolve that host name to a list of IP address(es) and derive the transport address(es) of this peer by combining the resolved IP address(es) with the SCTP source port.

The endpoint MUST ignore any other IP Address parameters if they are also present in the received INIT or INIT ACK chunk.

The time at which the receiver of an INIT resolves the host name has potential security implications to SCTP. If the receiver of an INIT resolves the host name upon the reception of the chunk, and the mechanism the receiver uses to resolve the host name involves potential long delay (e.g., DNS query), the receiver may open itself up to resource attacks for the period of time while it is waiting for the name resolution results before it can build the State Cookie and release local resources.

Therefore, in cases where the name translation involves potential long delay, the receiver of the INIT MUST postpone the name resolution till the reception of the COOKIE ECHO chunk from the peer. In such a case, the receiver of the INIT SHOULD build the State Cookie using the received Host Name (instead of destination transport addresses) and send the INIT ACK to the source IP address from which the INIT was received.

The receiver of an INIT ACK shall always immediately attempt to resolve the name upon the reception of the chunk.

The receiver of the INIT or INIT ACK MUST NOT send user data (piggy-backed or stand-alone) to its peer until the host name is successfully resolved.

If the name resolution is not successful, the endpoint MUST immediately send an ABORT with "Unresolvable Address" error cause to its peer. The ABORT shall be sent to the source IP address from which the last peer packet was received.

New text: (Section 5.1.2)

B) If there is a Host Name Address parameter present in the received INIT or INIT ACK chunk, the endpoint MUST immediately send an ABORT and MAY include an "Unresolvable Address" error cause to its peer. The ABORT SHALL be sent to the source IP address from which the last peer packet was received.

This text is in final form and is not further updated in this document.

Old text: (Section 11.2.4.1)

The use of the host name feature in the INIT chunk could be used to flood a target DNS server. A large backlog of DNS queries, resolving the host name received in the INIT chunk to IP addresses, could be accomplished by sending INITs to multiple hosts in a given domain. In addition, an attacker could use the host name feature in an indirect attack on a third party by sending large numbers of INITs to random hosts containing the host name of the target. In addition to the strain on DNS resources, this could also result in large numbers of INIT ACKs being sent to the target. One method to protect against this type of attack is to verify that the IP addresses received from DNS include the source IP address of the original INIT. If the list of IP addresses received from DNS does not include the source IP address of the INIT, the endpoint MAY silently discard the INIT. This last option will not protect against the attack against the DNS.

New text: (Section 11.2.4.1)

Support for the Host Name Address parameter has been removed from the protocol. Endpoints receiving INIT or INIT ACK chunks containing the Host Name Address parameter MUST send an ABORT chunk in response and MAY include an "Unresolvable Address" error cause.

This text is in final form and is not further updated in this document.

3.41.3. Solution Description

The usage of the Host Name Address parameter has been deprecated.

3.42. Conflicting Text regarding the 'Supported Address Types' Parameter

3.42.1. Description of the Problem

Section 5.1.2 of [RFC4960] contains conflicting text regarding the receipt of an SCTP packet containing an INIT chunk sent from an address for which the corresponding address type is not listed in the 'Supported Address Types' parameter. The text states that the association MUST be aborted, but it also states that the association SHOULD be established and there SHOULD NOT be any error indication.

3.42.2. Text Changes to the Document

Old text: (Section 5.1.2)

The sender of INIT may include a 'Supported Address Types' parameter in the INIT to indicate what types of address are acceptable. When this parameter is present, the receiver of INIT (initiate) MUST either use one of the address types indicated in the Supported Address Types parameter when responding to the INIT, or abort the association with an "Unresolvable Address" error cause if it is unwilling or incapable of using any of the address types indicated by its peer.

New text: (Section 5.1.2)

The sender of INIT chunks MAY include a 'Supported Address Types' parameter in the INIT to indicate what types of addresses are acceptable.

This text is in final form and is not further updated in this document.

3.42.3. Solution Description

The conflicting text has been removed.

3.43. Integration of RFC 6096

3.43.1. Description of the Problem

[RFC6096] updates [RFC4960] by adding the "Chunk Flags" registry. This should be integrated into the base specification.

3.43.2. Text Changes to the Document

Old text: (Section 14.1)

14.1. IETF-Defined Chunk Extension

The assignment of new chunk parameter type codes is done through an IETF Consensus action, as defined in [RFC2434]. Documentation of the chunk parameter MUST contain the following information:

a) A long and short name for the new chunk type.

b) A detailed description of the structure of the chunk, which MUST conform to the basic structure defined in Section 3.2.

c) A detailed definition and description of the intended use of each field within the chunk, including the chunk flags if any.

d) A detailed procedural description of the use of the new chunk type within the operation of the protocol.

The last chunk type (255) is reserved for future extension if necessary.

New text: (Section 14.1)

14.1. IETF-Defined Chunk Extension

The assignment of new chunk type codes is done through an IETF Review action, as defined in [RFC8126]. Documentation for a new chunk MUST contain the following information:

a) A long and short name for the new chunk type.

b) A detailed description of the structure of the chunk, which MUST conform to the basic structure defined in Section 3.2.

c) A detailed definition and description of the intended use of each field within the chunk, including the chunk flags (if any). Defined chunk flags will be used as initial entries in the chunk flags table for the new chunk type.

d) A detailed procedural description of the use of the new chunk type within the operation of the protocol.

The last chunk type (255) is reserved for future extension if necessary.

For each new chunk type, IANA creates a registration table for the chunk flags of that type. The procedure for registering particular chunk flags is described in Section 14.2.

This text has been modified by multiple errata. It includes modifications from Section 3.3. It is in final form and is not further updated in this document.

New text: (Section 14.2)

14.2. New IETF Chunk Flags Registration

The assignment of new chunk flags is done through an RFC Required action, as defined in [RFC8126]. Documentation for the chunk flags MUST contain the following information:

a) A name for the new chunk flag.

b) A detailed procedural description of the use of the new chunk flag within the operation of the protocol. It MUST be considered that implementations not supporting the flag will send '0' on transmit and just ignore it on receipt.

IANA selects a chunk flags value. This MUST be one of 0x01, 0x02, 0x04, 0x08, 0x10, 0x20, 0x40, or 0x80, which MUST be unique within the chunk flag values for the specific chunk type.

This text is in final form and is not further updated in this document.

Please note that Sections 14.2, 14.3, 14.4, and 14.5 as shown in [RFC4960] will need to be renumbered when [RFC4960] is updated.

3.43.3. Solution Description

[RFC6096] has been integrated, and the reference has been updated to [RFC8126].

3.44. Integration of RFC 6335

3.44.1. Description of the Problem

[RFC6335] updates [RFC4960] by updating procedures for the "Service Name and Transport Protocol Port Number Registry". This should be integrated into the base specification. Also, the "Guidelines for Writing an IANA Considerations Section in RFCs" reference needs to be changed to [RFC8126].

3.44.2. Text Changes to the Document

Old text: (Section 14.5)

SCTP services may use contact port numbers to provide service to unknown callers, as in TCP and UDP. IANA is therefore requested to open the existing Port Numbers registry for SCTP using the following rules, which we intend to mesh well with existing Port Numbers registration procedures. An IESG-appointed Expert Reviewer supports IANA in evaluating SCTP port allocation requests, according to the procedure defined in [RFC2434].

Port numbers are divided into three ranges. The Well Known Ports are those from 0 through 1023, the Registered Ports are those from 1024 through 49151, and the Dynamic and/or Private Ports are those from 49152 through 65535. Well Known and Registered Ports are intended for use by server applications that desire a default contact point on a system. On most systems, Well Known Ports can only be used by system (or root) processes or by programs executed by privileged users, while Registered Ports can be used by ordinary user processes or programs executed by ordinary users. Dynamic and/or Private Ports are intended for temporary use, including client-side ports, out-of-band negotiated ports, and application testing prior to registration of a dedicated port; they MUST NOT be registered.

The Port Numbers registry should accept registrations for SCTP ports in the Well Known Ports and Registered Ports ranges. Well Known and Registered Ports SHOULD NOT be used without registration. Although in some cases -- such as porting an application from TCP to SCTP -- it may seem natural to use an SCTP port before registration completes, we emphasize that IANA will not guarantee registration of particular Well Known and Registered Ports. Registrations should be requested as early as possible.

Each port registration SHALL include the following information:

- A short port name, consisting entirely of letters (A-Z and a-z), digits (0-9), and punctuation characters from "-_+./*" (not including the quotes).
- The port number that is requested for registration.
- A short English phrase describing the port's purpose.
- Name and contact information for the person or entity performing the registration, and possibly a reference to a document defining the port's use. Registrations coming from IETF working groups need only name the working group, but indicating a contact person is recommended.

Registrants are encouraged to follow these guidelines when submitting a registration.

- A port name SHOULD NOT be registered for more than one SCTP port number.
- A port name registered for TCP MAY be registered for SCTP as well. Any such registration SHOULD use the same port number as the existing TCP registration.
- Concrete intent to use a port SHOULD precede port registration. For example, existing TCP ports SHOULD NOT be registered in advance of any intent to use those ports for SCTP.

New text: (Section 14.5)

SCTP services can use contact port numbers to provide service to unknown callers, as in TCP and UDP. IANA is therefore requested to open the existing "Service Name and Transport Protocol Port Number Registry" for SCTP using the following rules, which we intend to mesh well with existing port-number registration procedures. An IESG-appointed expert reviewer supports IANA in evaluating SCTP port allocation requests, according to the procedure defined in [RFC8126]. The details of this process are defined in [RFC6335].

This text is in final form and is not further updated in this document.

3.44.3. Solution Description

[RFC6335] has been integrated, and the reference has been updated to [RFC8126].

3.45. Integration of RFC 7053

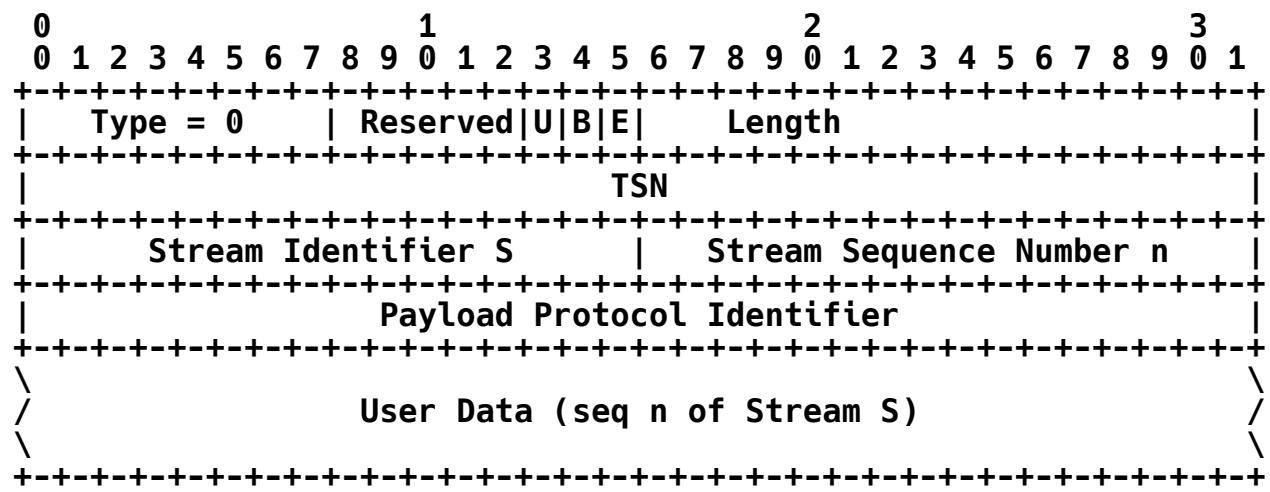
3.45.1. Description of the Problem

[RFC7053] updates [RFC4960] by adding the I bit to the DATA chunk. This should be integrated into the base specification.

3.45.2. Text Changes to the Document

Old text: (Section 3.3.1)

The following format MUST be used for the DATA chunk:

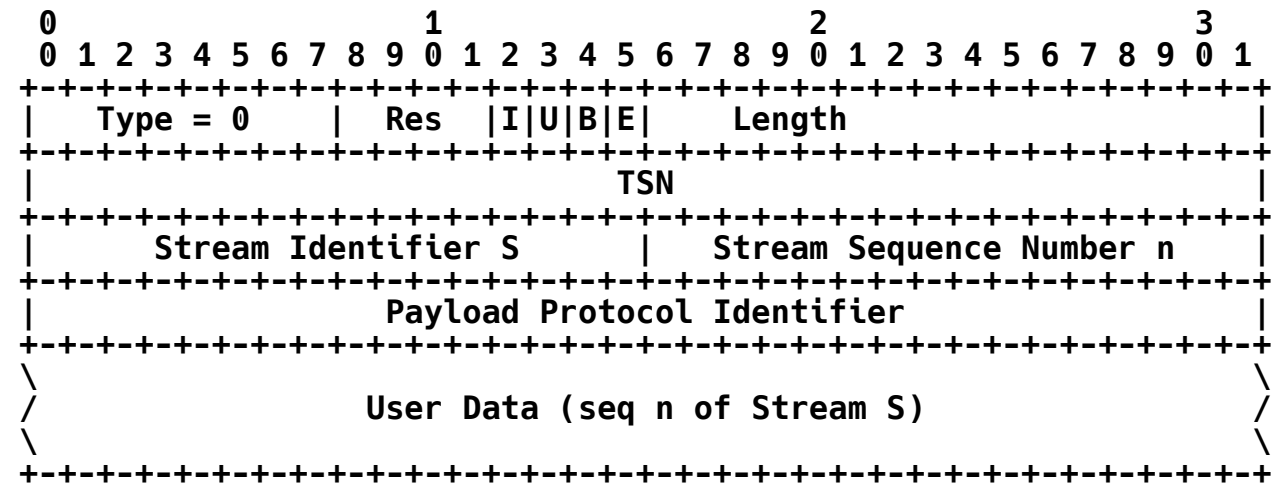


Reserved: 5 bits

Should be set to all '0's and ignored by the receiver.

New text: (Section 3.3.1)

The following format MUST be used for the DATA chunk:



Res: 4 bits

SHOULD be set to all '0's and ignored by the receiver.

I bit: 1 bit

The (I)mmediate bit MAY be set by the sender whenever the sender of a DATA chunk can benefit from the corresponding SACK chunk being sent back without delay. See Section 4 of [RFC7053] for a discussion of the benefits.

This text is in final form and is not further updated in this document.

New text: (Append to Section 6.1)

Whenever the sender of a DATA chunk can benefit from the corresponding SACK chunk being sent back without delay, the sender MAY set the I bit in the DATA chunk header. Please note that why the sender has set the I bit is irrelevant to the receiver.

Reasons for setting the I bit include, but are not limited to, the following (see Section 4 of [RFC7053] for a discussion of the benefits):

- The application requests that the I bit of the last DATA chunk of a user message be set when providing the user message to the SCTP implementation (see Section 7).
- The sender is in the SHUTDOWN-PENDING state.
- The sending of a DATA chunk fills the congestion or receiver window.

This text is in final form and is not further updated in this document.

Old text: (Section 6.2)

Note: The SHUTDOWN chunk does not contain Gap Ack Block fields. Therefore, the endpoint should use a SACK instead of the SHUTDOWN chunk to acknowledge DATA chunks received out of order.

New text: (Section 6.2)

Note: The SHUTDOWN chunk does not contain Gap Ack Block fields. Therefore, the endpoint SHOULD use a SACK instead of the SHUTDOWN chunk to acknowledge DATA chunks received out of order.

Upon receipt of an SCTP packet containing a DATA chunk with the I bit set, the receiver SHOULD NOT delay the sending of the corresponding SACK chunk, i.e., the receiver SHOULD immediately respond with the corresponding SACK chunk.

Please note that this change is only about adding a paragraph.

This text is in final form and is not further updated in this document.

Old text: (Section 10.1 E))

E) Send

Format: SEND(association id, buffer address, byte count [,context]
[,stream id] [,life time] [,destination transport address]
[,unordered flag] [,no-bundle flag] [,payload protocol-id])
-> result

New text: (Section 10.1 E))

E) Send

Format: SEND(association id, buffer address, byte count [,context]
[,stream id] [,life time] [,destination transport address]
[,unordered flag] [,no-bundle flag] [,payload protocol-id]
[,sack-immediately])
-> result

This text is in final form and is not further updated in this document.

New text: (Append optional parameter in item E) of Section 10.1)
---

o sack-immediately flag - set the I bit on the last DATA chunk used for the user message to be transmitted.

This text is in final form and is not further updated in this document.

3.45.3. Solution Description

[RFC7053] has been integrated.

3.46. CRC32c Code Improvements

3.46.1. Description of the Problem

The code given for the CRC32c computations uses types such as "long", which may have different lengths on different operating systems or processors. Therefore, the code needs to be changed, so that it uses specific types such as uint32_t.

Some syntax errors and a comment also need to be fixed.

We remind the reader that per Section 3.10.2 of this document most of Appendix C of RFC 4960 will be moved to Appendix B in the bis document (thus the "Old text: (Appendix C)" and "New text: (Appendix B)" items in this section).

3.46.2. Text Changes to the Document

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Old text: (Appendix C)
---------

/*****************************************************************/
/* Note Definition for Ross Williams table generator would   */
/* be: TB_WIDTH=4, TB_POLLY=0x1EDC6F41, TB_REVER=TRUE        */
/* For Mr. Williams direct calculation code use the settings */
/* cm_width=32, cm_poly=0x1EDC6F41, cm_init=0xFFFFFFFF,      */
/* cm_refin=TRUE, cm_refot=TRUE, cm_xorort=0x00000000        */
/*****************************************************************/

/* Example of the crc table file */
#ifndef __crc32cr_table_h__
#define __crc32cr_table_h__

#define CRC32C_POLY 0x1EDC6F41
#define CRC32C(c,d) (c=(c>>8)^crc_c[(c^(d))&0xFF])

unsigned long  crc_c[256] =
{
0x00000000L, 0xF26B8303L, 0xE13B70F7L, 0x1350F3F4L,
0xC79A971FL, 0x35F1141CL, 0x26A1E7E8L, 0xD4CA64EBL,
0x8AD958CFL, 0x78B2DBCCL, 0x6BE22838L, 0x9989AB3BL,
0x4D43CFD0L, 0xBF284CD3L, 0xAC78BF27L, 0x5E133C24L,
0x105EC76FL, 0xE235446CL, 0xF165B798L, 0x030E349BL,
0xD7C45070L, 0x25AFD373L, 0x36FF2087L, 0xC494A384L,
0x9A879FA0L, 0x68EC1CA3L, 0x7BBCEF57L, 0x89D76C54L,
0x5D1D08BFL, 0xAF768BBCL, 0xBC267848L, 0x4E4DFB4BL,
0x20BD8EDEL, 0xD2D60DDDL, 0xC186FE29L, 0x33ED7D2AL,
0xE72719C1L, 0x154C9AC2L, 0x061C6936L, 0xF477EA35L,
0xAA64D611L, 0x580F5512L, 0x4B5FA6E6L, 0xB93425E5L,
0x6DFE410EL, 0x9F95C20DL, 0x8CC531F9L, 0x7EAEB2FAL,
0x30E349B1L, 0xC288CAB2L, 0xD1D83946L, 0x23B3BA45L,

0xF779DEAEL, 0x05125DADL, 0x1642AE59L, 0xE4292D5AL,
0xBA3A117EL, 0x4851927DL, 0x5B016189L, 0xA96AE28AL,
0x7DA08661L, 0x8FCB0562L, 0x9C9BF696L, 0x6EF07595L,
0x417B1DBCL, 0xB3109EBFL, 0xA0406D4BL, 0x522BEE48L,
0x86E18AA3L, 0x748A09A0L, 0x67DAFA54L, 0x95B17957L,
0xCBA24573L, 0x39C9C670L, 0x2A993584L, 0xD8F2B687L,
0x0C38D26CL, 0xFE53516FL, 0xED03A29BL, 0x1F682198L,
0x5125DAD3L, 0xA34E59D0L, 0xB01EAA24L, 0x42752927L,
0x96BF4DCCL, 0x64D4CECFL, 0x77843D3BL, 0x85EFBE38L,
0xDBFC821CL, 0x2997011FL, 0x3AC7F2EBL, 0xC8AC71E8L,
0x1C661503L, 0xEE0D9600L, 0xFD5D65F4L, 0x0F36E6F7L,
```

```
   0x61C69362L, 0x93AD1061L, 0x80FDE395L, 0x72966096L,
   0xA65C047DL, 0x5437877EL, 0x4767748AL, 0xB50CF789L,
   0xEB1FCBADL, 0x197448AEL, 0x0A24BB5AL, 0xF84F3859L,
   0x2C855CB2L, 0xDEEEDFB1L, 0xCDBE2C45L, 0x3FD5AF46L,
   0x7198540DL, 0x83F3D70EL, 0x90A324FAL, 0x62C8A7F9L,
   0xB602C312L, 0x44694011L, 0x5739B3E5L, 0xA55230E6L,
   0xFB410CC2L, 0x092A8FC1L, 0x1A7A7C35L, 0xE811FF36L,
   0x3CDB9BDDL, 0xCEB018DEL, 0xDDE0EB2AL, 0x2F8B6829L,
   0x82F63B78L, 0x709DB87BL, 0x63CD4B8FL, 0x91A6C88CL,
   0x456CAC67L, 0xB7072F64L, 0xA457DC90L, 0x563C5F93L,
   0x082F63B7L, 0xFA44E0B4L, 0xE9141340L, 0x1B7F9043L,
   0xCFB5F4A8L, 0x3DDE77ABL, 0x2E8E845FL, 0xDCE5075CL,
   0x92A8FC17L, 0x60C37F14L, 0x73938CE0L, 0x81F80FE3L,
   0x55326B08L, 0xA759E80BL, 0xB4091BFFL, 0x466298FCL,
   0x1871A4D8L, 0xEA1A27DBL, 0xF94AD42FL, 0x0B21572CL,
   0xDFEB33C7L, 0x2D80B0C4L, 0x3ED04330L, 0xCCBBC033L,
   0xA24BB5A6L, 0x502036A5L, 0x4370C551L, 0xB11B4652L,
   0x65D122B9L, 0x97BAA1BAL, 0x84EA524EL, 0x7681D14DL,
   0x2892ED69L, 0xDAF96E6AL, 0xC9A99D9EL, 0x3BC21E9DL,
   0xEF087A76L, 0x1D63F975L, 0x0E330A81L, 0xFC588982L,
   0xB21572C9L, 0x407EF1CAL, 0x532E023EL, 0xA145813DL,
   0x758FE5D6L, 0x87E466D5L, 0x94B49521L, 0x66DF1622L,
   0x38CC2A06L, 0xCAA7A905L, 0xD9F75AF1L, 0x2B9CD9F2L,
   0xFF56BD19L, 0x0D3D3E1AL, 0x1E6DCDEEL, 0xEC064EEDL,
   0xC38D26C4L, 0x31E6A5C7L, 0x22B65633L, 0xD0DDD530L,
   0x0417B1DBL, 0xF67C32D8L, 0xE52CC12CL, 0x1747422FL,
   0x49547E0BL, 0xBB3FFD08L, 0xA86F0EFCL, 0x5A048DFFL,
   0x8ECEE914L, 0x7CA56A17L, 0x6FF599E3L, 0x9D9E1AE0L,
   0xD3D3E1ABL, 0x21B862A8L, 0x32E8915CL, 0xC083125FL,
   0x144976B4L, 0xE622F5B7L, 0xF5720643L, 0x07198540L,
   0x590AB964L, 0xAB613A67L, 0xB831C993L, 0x4A5A4A90L,
   0x9E902E7BL, 0x6CFBAD78L, 0x7FAB5E8CL, 0x8DC0DD8FL,
   0xE330A81AL, 0x115B2B19L, 0x020BD8EDL, 0xF0605BEEL,
   0x24AA3F05L, 0xD6C1BC06L, 0xC5914FF2L, 0x37FACCF1L,
   0x69E9F0D5L, 0x9B8273D6L, 0x88D28022L, 0x7AB90321L,
   0xAE7367CAL, 0x5C18E4C9L, 0x4F48173DL, 0xBD23943EL,
   0xF36E6F75L, 0x0105EC76L, 0x12551F82L, 0xE03E9C81L,

   0x34F4F86AL, 0xC69F7B69L, 0xD5CF889DL, 0x27A40B9EL,
   0x79B737BAL, 0x8BDCB4B9L, 0x988C474DL, 0x6AE7C44EL,
   0xBE2DA0A5L, 0x4C4623A6L, 0x5F16D052L, 0xAD7D5351L,
   };

   #endif
```

```
---------
New text: (Appendix B)
---------

<CODE BEGINS>
/*****************************************************************/
/* Note: The definitions for Ross Williams's table generator    */
/* would be TB_WIDTH=4, TB_POLY=0x1EDC6F41, TB_REVER=TRUE.      */
/* For Mr. Williams's direct calculation code, use the settings */
/* cm_width=32, cm_poly=0x1EDC6F41, cm_init=0xFFFFFFFF,         */
/* cm_refin=TRUE, cm_refot=TRUE, cm_xorot=0x00000000.           */
/*****************************************************************/

/* Example of the crc table file */
#ifndef __crc32cr_h__
#define __crc32cr_h__

#define CRC32C_POLY 0x1EDC6F41UL
#define CRC32C(c,d) (c=(c>>8)^crc_c[(c^(d))&0xFF])

uint32_t crc_c[256] =
{
0x00000000UL, 0xF26B8303UL, 0xE13B70F7UL, 0x1350F3F4UL,
0xC79A971FUL, 0x35F1141CUL, 0x26A1E7E8UL, 0xD4CA64EBUL,
0x8AD958CFUL, 0x78B2DBCCUL, 0x6BE22838UL, 0x9989AB3BUL,
0x4D43CFD0UL, 0xBF284CD3UL, 0xAC78BF27UL, 0x5E133C24UL,
0x105EC76FUL, 0xE235446CUL, 0xF165B798UL, 0x030E349BUL,
0xD7C45070UL, 0x25AFD373UL, 0x36FF2087UL, 0xC494A384UL,
0x9A879FA0UL, 0x68EC1CA3UL, 0x7BBCEF57UL, 0x89D76C54UL,
0x5D1D08BFUL, 0xAF768BBCUL, 0xBC267848UL, 0x4E4DFB4BUL,
0x20BD8EDEUL, 0xD2D60DDDUL, 0xC186FE29UL, 0x33ED7D2AUL,
0xE72719C1UL, 0x154C9AC2UL, 0x061C6936UL, 0xF477EA35UL,
0xAA64D611UL, 0x580F5512UL, 0x4B5FA6E6UL, 0xB93425E5UL,
0x6DFE410EUL, 0x9F95C20DUL, 0x8CC531F9UL, 0x7EAEB2FAUL,
0x30E349B1UL, 0xC288CAB2UL, 0xD1D83946UL, 0x23B3BA45UL,
0xF779DEAEUL, 0x05125DADUL, 0x1642AE59UL, 0xE4292D5AUL,
0xBA3A117EUL, 0x4851927DUL, 0x5B016189UL, 0xA96AE28AUL,
0x7DA08661UL, 0x8FCB0562UL, 0x9C9BF696UL, 0x6EF07595UL,
0x417B1DBCUL, 0xB3109EBFUL, 0xA0406D4BUL, 0x522BEE48UL,
0x86E18AA3UL, 0x748A09A0UL, 0x67DAFA54UL, 0x95B17957UL,
0xCBA24573UL, 0x39C9C670UL, 0x2A993584UL, 0xD8F2B687UL,
0x0C38D26CUL, 0xFE53516FUL, 0xED03A29BUL, 0x1F682198UL,
0x5125DAD3UL, 0xA34E59D0UL, 0xB01EAA24UL, 0x42752927UL,
0x96BF4DCCUL, 0x64D4CECFUL, 0x77843D3BUL, 0x85EFBE38UL,
0xDBFC821CUL, 0x2997011FUL, 0x3AC7F2EBUL, 0xC8AC71E8UL,
0x1C661503UL, 0xEE0D9600UL, 0xFD5D65F4UL, 0x0F36E6F7UL,
0x61C69362UL, 0x93AD1061UL, 0x80FDE395UL, 0x72966096UL,
0xA65C047DUL, 0x5437877EUL, 0x4767748AUL, 0xB50CF789UL,
```

```
   0xEB1FCBADUL, 0x197448AEUL, 0x0A24BB5AUL, 0xF84F3859UL,
   0x2C855CB2UL, 0xDEEEDFB1UL, 0xCDBE2C45UL, 0x3FD5AF46UL,
   0x7198540DUL, 0x83F3D70EUL, 0x90A324FAUL, 0x62C8A7F9UL,
   0xB602C312UL, 0x44694011UL, 0x5739B3E5UL, 0xA55230E6UL,
   0xFB410CC2UL, 0x092A8FC1UL, 0x1A7A7C35UL, 0xE811FF36UL,
   0x3CDB9BDDUL, 0xCEB018DEUL, 0xDDE0EB2AUL, 0x2F8B6829UL,
   0x82F63B78UL, 0x709DB87BUL, 0x63CD4B8FUL, 0x91A6C88CUL,
   0x456CAC67UL, 0xB7072F64UL, 0xA457DC90UL, 0x563C5F93UL,
   0x082F63B7UL, 0xFA44E0B4UL, 0xE9141340UL, 0x1B7F9043UL,
   0xCFB5F4A8UL, 0x3DDE77ABUL, 0x2E8E845FUL, 0xDCE5075CUL,
   0x92A8FC17UL, 0x60C37F14UL, 0x73938CE0UL, 0x81F80FE3UL,
   0x55326B08UL, 0xA759E80BUL, 0xB4091BFFUL, 0x466298FCUL,
   0x1871A4D8UL, 0xEA1A27DBUL, 0xF94AD42FUL, 0x0B21572CUL,
   0xDFEB33C7UL, 0x2D80B0C4UL, 0x3ED04330UL, 0xCCBBC033UL,
   0xA24BB5A6UL, 0x502036A5UL, 0x4370C551UL, 0xB11B4652UL,
   0x65D122B9UL, 0x97BAA1BAUL, 0x84EA524EUL, 0x7681D14DUL,
   0x2892ED69UL, 0xDAF96E6AUL, 0xC9A99D9EUL, 0x3BC21E9DUL,
   0xEF087A76UL, 0x1D63F975UL, 0x0E330A81UL, 0xFC588982UL,
   0xB21572C9UL, 0x407EF1CAUL, 0x532E023EUL, 0xA145813DUL,
   0x758FE5D6UL, 0x87E466D5UL, 0x94B49521UL, 0x66DF1622UL,
   0x38CC2A06UL, 0xCAA7A905UL, 0xD9F75AF1UL, 0x2B9CD9F2UL,
   0xFF56BD19UL, 0x0D3D3E1AUL, 0x1E6DCDEEUL, 0xEC064EEDUL,
   0xC38D26C4UL, 0x31E6A5C7UL, 0x22B65633UL, 0xD0DDD530UL,
   0x0417B1DBUL, 0xF67C32D8UL, 0xE52CC12CUL, 0x1747422FUL,
   0x49547E0BUL, 0xBB3FFD08UL, 0xA86F0EFCUL, 0x5A048DFFUL,
   0x8ECEE914UL, 0x7CA56A17UL, 0x6FF599E3UL, 0x9D9E1AE0UL,
   0xD3D3E1ABUL, 0x21B862A8UL, 0x32E8915CUL, 0xC083125FUL,
   0x144976B4UL, 0xE622F5B7UL, 0xF5720643UL, 0x07198540UL,
   0x590AB964UL, 0xAB613A67UL, 0xB831C993UL, 0x4A5A4A90UL,
   0x9E902E7BUL, 0x6CFBAD78UL, 0x7FAB5E8CUL, 0x8DC0DD8FUL,
   0xE330A81AUL, 0x115B2B19UL, 0x020BD8EDUL, 0xF0605BEEUL,
   0x24AA3F05UL, 0xD6C1BC06UL, 0xC5914FF2UL, 0x37FACCF1UL,
   0x69E9F0D5UL, 0x9B8273D6UL, 0x88D28022UL, 0x7AB90321UL,
   0xAE7367CAUL, 0x5C18E4C9UL, 0x4F48173DUL, 0xBD23943EUL,
   0xF36E6F75UL, 0x0105EC76UL, 0x12551F82UL, 0xE03E9C81UL,
   0x34F4F86AUL, 0xC69F7B69UL, 0xD5CF889DUL, 0x27A40B9EUL,
   0x79B737BAUL, 0x8BDCB4B9UL, 0x988C474DUL, 0x6AE7C44EUL,
   0xBE2DA0A5UL, 0x4C4623A6UL, 0x5F16D052UL, 0xAD7D5351UL,
   };

   #endif
```

This text has been modified by multiple errata. It includes modifications from Section 3.10. It is in final form and is not further updated in this document.

```
---------
Old text: (Appendix C)
---------

/* Example of table build routine */

#include <stdio.h>
#include <stdlib.h>

#define OUTPUT_FILE   "crc32cr.h"
#define CRC32C_POLY    0x1EDC6F41L
FILE *tf;
unsigned long
reflect_32 (unsigned long b)
{
  int i;
  unsigned long rw = 0L;

  for (i = 0; i < 32; i++){
      if (b & 1)
        rw |= 1 << (31 - i);
      b >>= 1;
  }
  return (rw);
}

unsigned long
build_crc_table (int index)
{
  int i;
  unsigned long rb;

  rb = reflect_32 (index);

  for (i = 0; i < 8; i++){
      if (rb & 0x80000000L)
       rb = (rb << 1) ^ CRC32C_POLY;
      else
       rb <<= 1;
  }
  return (reflect_32 (rb));
}

main ()

{
  int i;
```

```
    printf ("\nGenerating CRC-32c table file <%s>\n",
    OUTPUT_FILE);
    if ((tf = fopen (OUTPUT_FILE, "w")) == NULL){
        printf ("Unable to open %s\n", OUTPUT_FILE);
        exit (1);
    }
    fprintf (tf, "#ifndef __crc32cr_table_h__\n");
    fprintf (tf, "#define __crc32cr_table_h__\n\n");
    fprintf (tf, "#define CRC32C_POLY 0x%08lX\n",
    CRC32C_POLY);
    fprintf (tf,
    "#define CRC32C(c,d) (c=(c>>8)^crc_c[(c^(d))&0xFF])\n");
    fprintf (tf, "\nunsigned long  crc_c[256] =\n{\n");
    for (i = 0; i < 256; i++){
        fprintf (tf, "0x%08lXL, ", build_crc_table (i));
        if ((i & 3) == 3)
          fprintf (tf, "\n");
    }
    fprintf (tf, "};\n\n#endif\n");

    if (fclose (tf) != 0)
      printf ("Unable to close <%s>." OUTPUT_FILE);
    else
      printf ("\nThe CRC-32c table has been written to <%s>.\n",
        OUTPUT_FILE);
  }

  ---------
  New text: (Appendix B)
  ---------

  /* Example of table build routine */

  #include <stdio.h>
  #include <stdlib.h>

  #define OUTPUT_FILE   "crc32cr.h"
  #define CRC32C_POLY    0x1EDC6F41UL

  static FILE *tf;

  static uint32_t
  reflect_32(uint32_t b)
  {
    int i;
    uint32_t rw = 0UL;

    for (i = 0; i < 32; i++) {
```

```
        if (b & 1)
          rw |= 1 << (31 - i);
        b >>= 1;
    }
    return (rw);
  }

  static uint32_t
  build_crc_table (int index)
  {
    int i;
    uint32_t rb;

    rb = reflect_32(index);

    for (i = 0; i < 8; i++) {
        if (rb & 0x80000000UL)
         rb = (rb << 1) ^ (uint32_t)CRC32C_POLY;
        else
         rb <<= 1;
    }
    return (reflect_32(rb));
  }

  int
  main (void)
  {
    int i;

    printf("\nGenerating CRC32c table file <%s>.\n",
    OUTPUT_FILE);
    if ((tf = fopen(OUTPUT_FILE, "w")) == NULL) {
        printf("Unable to open %s.\n", OUTPUT_FILE);
        exit (1);
    }
    fprintf(tf, "#ifndef __crc32cr_h__\n");
    fprintf(tf, "#define __crc32cr_h__\n\n");
    fprintf(tf, "#define CRC32C_POLY 0x%08XUL\n",
      (uint32_t)CRC32C_POLY);
    fprintf(tf,
      "#define CRC32C(c,d) (c=(c>>8)^crc_c[(c^(d))&0xFF])\n");
    fprintf(tf, "\nuint32_t crc_c[256] =\n{\n");
    for (i = 0; i < 256; i++) {
        fprintf(tf, "0x%08XUL,", build_crc_table (i));
        if ((i & 3) == 3)
```

```
          fprintf(tf, "\n");
        else
          fprintf(tf, " ");
    }
    fprintf(tf, "};\n\n#endif\n");

    if (fclose(tf) != 0)
      printf("Unable to close <%s>.\n", OUTPUT_FILE);
    else
      printf("\nThe CRC32c table has been written to <%s>.\n",
        OUTPUT_FILE);
  }
```

This text has been modified by multiple errata. It includes modifications from Section 3.10. It is in final form and is not further updated in this document.

Old text: (Appendix C)

```
/* Example of crc insertion */

#include "crc32cr.h"

unsigned long
generate_crc32c(unsigned char *buffer, unsigned int length)
{
  unsigned int i;
  unsigned long crc32 = ~0L;
  unsigned long result;
  unsigned char byte0,byte1,byte2,byte3;

  for (i = 0; i < length; i++){
      CRC32C(crc32, buffer[i]);
  }

  result = ~crc32;

  /*  result now holds the negated polynomial remainder;
   *  since the table and algorithm is "reflected" [williams95].
   *  That is, result has the same value as if we mapped the message
   *  to a polynomial, computed the host-bit-order polynomial
   *  remainder, performed final negation, then did an end-for-end
   *  bit-reversal.
   *  Note that a 32-bit bit-reversal is identical to four inplace
   *  8-bit reversals followed by an end-for-end byteswap.
   *  In other words, the bytes of each bit are in the right order,
```

```
     *  but the bytes have been byteswapped.  So we now do an explicit
     *  byteswap.  On a little-endian machine, this byteswap and
     *  the final ntohl cancel out and could be elided.
     */

    byte0 = result & 0xff;
    byte1 = (result>>8) & 0xff;
    byte2 = (result>>16) & 0xff;
    byte3 = (result>>24) & 0xff;
    crc32 = ((byte0 << 24) |
             (byte1 << 16) |
             (byte2 << 8)  |
             byte3);
    return ( crc32 );
  }

  int
  insert_crc32(unsigned char *buffer, unsigned int length)
  {
    SCTP_message *message;
    unsigned long crc32;
    message = (SCTP_message *) buffer;
    message->common_header.checksum = 0L;
    crc32 = generate_crc32c(buffer,length);
    /* and insert it into the message */
    message->common_header.checksum = htonl(crc32);
    return 1;
  }

  int
  validate_crc32(unsigned char *buffer, unsigned int length)
  {
    SCTP_message *message;
    unsigned int i;
    unsigned long original_crc32;
    unsigned long crc32 = ~0L;

    /* save and zero checksum */
    message = (SCTP_message *) buffer;
    original_crc32 = ntohl(message->common_header.checksum);
    message->common_header.checksum = 0L;
    crc32 = generate_crc32c(buffer,length);
    return ((original_crc32 == crc32)? 1 : -1);
  }
```

```
   ---------
   New text: (Appendix B)
   ---------

   /* Example of crc insertion */

   #include "crc32cr.h"

   uint32_t
   generate_crc32c(unsigned char *buffer, unsigned int length)
   {
     unsigned int i;
     uint32_t crc32 = 0xffffffffUL;
     uint32_t result;
     uint8_t byte0, byte1, byte2, byte3;

     for (i = 0; i < length; i++) {
         CRC32C(crc32, buffer[i]);
     }

     result = ~crc32;

     /*  result now holds the negated polynomial remainder,
      *  since the table and algorithm are "reflected" [williams95].
      *  That is, result has the same value as if we mapped the message
      *  to a polynomial, computed the host-bit-order polynomial
      *  remainder, performed final negation, and then did an
      *  end-for-end bit-reversal.
      *  Note that a 32-bit bit-reversal is identical to four in-place
      *  8-bit bit-reversals followed by an end-for-end byteswap.
      *  In other words, the bits of each byte are in the right order,
      *  but the bytes have been byteswapped.  So, we now do an explicit
      *  byteswap.  On a little-endian machine, this byteswap and
      *  the final ntohl cancel out and could be elided.
      */

     byte0 = result & 0xff;
     byte1 = (result>>8) & 0xff;
     byte2 = (result>>16) & 0xff;
     byte3 = (result>>24) & 0xff;
     crc32 = ((byte0 << 24) |
              (byte1 << 16) |
              (byte2 << 8)  |
              byte3);
     return (crc32);
   }

   int
```

```
insert_crc32(unsigned char *buffer, unsigned int length)
{
  SCTP_message *message;
  uint32_t crc32;
  message = (SCTP_message *) buffer;
  message->common_header.checksum = 0UL;
  crc32 = generate_crc32c(buffer,length);
  /* and insert it into the message */
  message->common_header.checksum = htonl(crc32);
  return 1;
}

int
validate_crc32(unsigned char *buffer, unsigned int length)
{
  SCTP_message *message;
  unsigned int i;
  uint32_t original_crc32;
  uint32_t crc32;

  /* save and zero checksum */
  message = (SCTP_message *)buffer;
  original_crc32 = ntohl(message->common_header.checksum);
  message->common_header.checksum = 0L;
  crc32 = generate_crc32c(buffer, length);
  return ((original_crc32 == crc32)? 1 : -1);
}
<CODE ENDS>
```

This text has been modified by multiple errata. It includes modifications from Sections 3.5 and 3.10. It is in final form and is not further updated in this document.

3.46.3. Solution Description

The code was changed to use platform-independent types.

3.47. Clarification of Gap Ack Blocks in SACK Chunks

3.47.1. Description of the Problem

The Gap Ack Blocks in the SACK chunk are intended to be isolated. However, this is not mentioned with normative text.

This issue was reported as part of an errata for [RFC4960] with Errata ID 5202.

3.47.2. Text Changes to the Document

Old text: (Section 3.3.4)

The SACK also contains zero or more Gap Ack Blocks. Each Gap Ack Block acknowledges a subsequence of TSNs received following a break in the sequence of received TSNs. By definition, all TSNs acknowledged by Gap Ack Blocks are greater than the value of the Cumulative TSN Ack.

New text: (Section 3.3.4)

The SACK also contains zero or more Gap Ack Blocks. Each Gap Ack Block acknowledges a subsequence of TSNs received following a break in the sequence of received TSNs. The Gap Ack Blocks SHOULD be isolated. This means that the TSN just before each Gap Ack Block and the TSN just after each Gap Ack Block have not been received. By definition, all TSNs acknowledged by Gap Ack Blocks are greater than the value of the Cumulative TSN Ack.

This text is in final form and is not further updated in this document.

Old text: (Section 3.3.4)

Gap Ack Blocks:

> These fields contain the Gap Ack Blocks. They are repeated for each Gap Ack Block up to the number of Gap Ack Blocks defined in the Number of Gap Ack Blocks field. All DATA chunks with TSNs greater than or equal to (Cumulative TSN Ack + Gap Ack Block Start) and less than or equal to (Cumulative TSN Ack + Gap Ack Block End) of each Gap Ack Block are assumed to have been received correctly.

New text: (Section 3.3.4)

Gap Ack Blocks:

These fields contain the Gap Ack Blocks. They are repeated for each Gap Ack Block up to the number of Gap Ack Blocks defined in the Number of Gap Ack Blocks field. All DATA chunks with TSNs greater than or equal to (Cumulative TSN Ack + Gap Ack Block Start) and less than or equal to (Cumulative TSN Ack + Gap Ack Block End) of each Gap Ack Block are assumed to have been received correctly. Gap Ack Blocks SHOULD be isolated. This means that the DATA chunks with TSNs equal to (Cumulative TSN Ack + Gap Ack Block Start - 1) and (Cumulative TSN Ack + Gap Ack Block End + 1) have not been received.

This text is in final form and is not further updated in this document.

3.47.3. Solution Description

Normative text describing the intended usage of Gap Ack Blocks has been added.

3.48. Handling of SSN Wraparounds

3.48.1. Description of the Problem

The Stream Sequence Number (SSN) is used for preserving the ordering of user messages within each SCTP stream. The SSN is limited to 16 bits. Therefore, multiple wraparounds of the SSN might happen within the current send window. To allow the receiver to deliver ordered user messages in the correct sequence, the sender should limit the number of user messages per stream.

3.48.2. Text Changes to the Document

Old text: (Section 6.1)

Note: The data sender SHOULD NOT use a TSN that is more than 2**31 - 1 above the beginning TSN of the current send window.

New text: (Section 6.1)

Note: The data sender SHOULD NOT use a TSN that is more than
2**31 - 1 above the beginning TSN of the current send window.
Note: For each stream, the data sender SHOULD NOT have more than
2**16 - 1 ordered user messages in the current send window.

This text is in final form and is not further updated in this
document.

3.48.3. Solution Description

The data sender is required to limit the number of ordered user
messages within the current send window.

3.49. Update to RFC 2119 Boilerplate Text

3.49.1. Description of the Problem

The text to be used to refer to the terms ("key words") defined in
[RFC2119] has been updated by [RFC8174]. This needs to be integrated
into the base specification.

3.49.2. Text Changes to the Document

Old text: (Section 2)

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].

New text: (Section 2)

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.

This text is in final form and is not further updated in this
document.

3.49.3. Solution Description

The text has been updated to the text specified in [RFC8174].

3.50. Removal of Text (Previously Missed in RFC 4960)

3.50.1. Description of the Problem

When integrating the changes to Section 7.2.4 of [RFC2960] as described in Section 2.8.2 of [RFC4460], some text was not removed and is therefore still in [RFC4960].

3.50.2. Text Changes to the Document

Old text: (Section 7.2.4)

A straightforward implementation of the above keeps a counter for each TSN hole reported by a SACK. The counter increments for each consecutive SACK reporting the TSN hole. After reaching 3 and starting the Fast-Retransmit procedure, the counter resets to 0. Because cwnd in SCTP indirectly bounds the number of outstanding TSN's, the effect of TCP Fast Recovery is achieved automatically with no adjustment to the congestion control window size.

New text: (Section 7.2.4)

This text is in final form and is not further updated in this document.

3.50.3. Solution Description

The text has finally been removed.

4. IANA Considerations

Section 3.44 of this document suggests new text that would update the "Service Name and Transport Protocol Port Number Registry" for SCTP to be consistent with [RFC6335].

IANA has confirmed that it is OK to make the proposed text change in an upcoming Standards Track document that will update [RFC4960]. IANA is not asked to perform any other action, and this document does not request that IANA make a change to any registry.

5. Security Considerations

This document does not add any security considerations to those given in [RFC4960].

6. References

6.1. Normative References

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6.2. Informative References

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[RFC6096] Tuexen, M. and R. Stewart, "Stream Control Transmission Protocol (SCTP) Chunk Flags Registration", RFC 6096, DOI 10.17487/RFC6096, January 2011, <https://www.rfc-editor.org/info/rfc6096>.

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[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>.

[RFC7053] Tuexen, M., Ruengeler, I., and R. Stewart, "SACK-IMMEDIATELY Extension for the Stream Control Transmission Protocol", RFC 7053, DOI 10.17487/RFC7053, November 2013, <https://www.rfc-editor.org/info/rfc7053>.

[RFC8126] Cotton, M., Leiba, B., and T. Narten, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 8126, DOI 10.17487/RFC8126, June 2017, <https://www.rfc-editor.org/info/rfc8126>.

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