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**RFC 4960 Errata and Issues**  
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Abstract

This document is a compilation of issues found since the publication of [RFC4960](#) in September 2007 based on experience with implementing, testing, and using SCTP along with the suggested fixes. This document provides deltas to [RFC4960](#) and is organized in a time based way. The issues are listed in the order they were brought up. Because some text is changed several times the last delta in the text is the one which should be applied. In addition to the delta a description of the problem and the details of the solution are also provided.

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## [1](#). Introduction

This document contains a compilation of all defects found up until the publishing of this document for [[RFC4960](#)] specifying the Stream Control Transmission Protocol (SCTP). 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 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 similar to [[RFC4460](#)].

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

- o The problem description,
- o The text quoted from [[RFC4960](#)],
- o The replacement text that should be placed into an upcoming BIS document,
- o A description of the solution.

Note that when reading this document one must use care to assure that a field or item is not updated further on within the document. Each section should be applied in sequence to the original [[RFC4960](#)] since this document is a historical record of the sequential changes that have been found necessary at various inter-op events and through discussion on the list.



## **2. Conventions**

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 [[RFC2119](#)].

## **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 [Section 8.2](#) and [Section 8.3 of \[RFC4960\]](#) in an Inconsistent way. Whereas [Section 8.2](#) describes that a path is marked inactive when the path error counter exceeds the threshold, [Section 8.3](#) says 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 of reachability of this destination address. After this, the endpoint should continue HEARTBEAT on this destination address but should stop increasing the counter.



**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 NOT send a SHUTDOWN in response to a ULP request, and should discard subsequent ULP shutdown requests.

**3.2.3. Solution Description**

The text never intended the SCTP endpoint to 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 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 [[RFC2434](#)]. Documentation of the chunk type MUST contain the following information:

**[3.3.3.](#) Solution Description**

Refer to chunk types as intended.

**[3.4.](#) Variable Parameters for INIT Chunks**

**[3.4.1.](#) Description of the Problem**

Newlines in wrong places break the layout of the table of variable parameters for the INIT chunk in [Section 3.3.2 of \[RFC4960\]](#).

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	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	

**[3.4.3.](#) Solution Description**

Fix the formatting of the table.

**[3.5.](#) CRC32c Sample Code on 64-bit Platforms**

**[3.5.1.](#) Description of the Problem**

The sample code for computing the CRC32c 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 the ones using 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;
```

### **[3.5.3.](#) Solution Description**

Use 0xffffffffL instead of ~0L which 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 shall 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 which currently is used for data transfer. Unacknowledged HEARTBEAT chunks observed on paths different from the path currently used for data transfer shall not increment the association error counter, as this could lead to association closure even if the path which currently is used for data transfer is available (but idle).

### **[3.6.3.](#) Solution Description**

A more refined handling for 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 [[RFC0813](#)]. The algorithm can be similar to the one described in [Section 4.2.3.4 of \[RFC1122\]](#).

### **[3.7.3](#). Solution Description**

Last paragraph of [Section 6.1](#) A) removed as 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)  
 -----

```

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)

```

**[3.8.3](#). Solution Description**

Change the figure 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.

**[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  $TSN = 0$ .

-----  
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.



-----  
Old text: ([Section 6.7](#), Figure 9)  
-----

```

Endpoint A                                Endpoint Z {App
sends 3 messages; strm 0} DATA [TSN=6,Strm=0,Seq=2] -----
-----> (ack delayed) (Start T3-rtx timer)

DATA [TSN=7,Strm=0,Seq=3] -----> X (lost)

DATA [TSN=8,Strm=0,Seq=4] -----> (gap detected,
                                     immediately send ack)
                                     /----- SACK [TSN Ack=6,Block=1,
                                     /           Start=2,End=2]
                                     <-----/ (remove 6 from out-queue,
and mark 7 as "1" missing report)

```

-----  
New text: ([Section 6.7](#), Figure 9)  
-----

```

Endpoint A                                Endpoint Z
{App sends 3 messages; strm 0}
DATA [TSN=6,Strm=0,Seq=2] -----> (ack delayed)
(Start T3-rtx timer)

DATA [TSN=7,Strm=0,Seq=3] -----> X (lost)

DATA [TSN=8,Strm=0,Seq=4] -----> (gap detected,
                                     immediately send ack)
                                     /----- SACK [TSN Ack=6,Block=1,
                                     /           Strt=2,End=2]
                                     <-----/
(remove 6 from out-queue,
and mark 7 as "1" missing report)

```



-----  
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 than 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.

-----  
Old text: ([Section 10.1](#))  
-----

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](#))  
-----

0) Receive Unacknowledged Message

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



-----  
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".

-----  
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 path MTU discovery.

-----  
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 one to which the INIT ACK was sent.



-----

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)

```

-----

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.



-----

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).

### **[3.9.3.](#) Solution Description**

Typos 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 appears at the end of [Appendix C](#), which deals with ICMP handling.

### **[3.10.2.](#) Text Changes to the Document**

Move the sample code related to CRC32c computation and its explanation from the end of [Appendix C](#) to the end of [Appendix B](#).



**3.10.3. Solution Description**

Text 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 detecting from SACK but the same is missed for 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

**3.11.3. Solution Description**

Specify 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 \[RFC4960\]](#) is unclear about the 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 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`), `partial_bytes_acked` is reset to `(partial_bytes_acked - cwnd)`. Next, `cwnd` is increased by `MTU`.

### **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**

[Section 8.1](#) and [Section 8.3 of \[RFC4960\]](#) prescribe that the receiver of a HEARTBEAT ACK must reset the association overall error counter. 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 shall 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.

-----

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 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 counter (as defined in [Section 8.1](#)).



### [3.13.3.](#) Solution Description

The new text provides a possibility to not reset the association overall error counter when a HEARTBEAT ACK is received if there are valid reasons for it.

## [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 where original data was sent to. If the primary path has been changed and original data was sent there before the fast retransmit, the implementation MAY send it to the new primary path.

### [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) of [\[RFC4960\], Section 7.2.4](#), 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 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.

**[3.15.3.](#) Solution Description**

The new text explicitly specifies to send only the first packet in the Fast Recovery phase disregarding cwnd limitations.

**[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, use a higher requirements level, since not following the advice may result in performance problems.

### **[3.16.2.](#) Text Changes to the Document**

-----  
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., to the size of the largest possible advertised window).

### **[3.16.3.](#) Solution Description**

Use the same value as suggested in [[RFC5681](#)], [Section 3.1](#), as an appropriate initial value. Furthermore use the same requirements level.

## **[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 is automatically CONFIRMED. This however is unclear if only addresses in the request to initiate association establishment are considered or any addresses provided by the upper layer in any requests (e.g. in 'Set Primary').

### **[3.17.2.](#) Text Changes to the Document**



-----

Old text: ([Section 5.4](#))

-----

- 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 is automatically considered to be CONFIRMED.

### **[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](#) does not specify how many packets are allowed to be sent after T3-rtx timer expiration if more than one packet fit into cwnd. At the same time, [Section 7.2.3](#) has the 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 acknowledgment. It makes the text inconsistent.

### **[3.18.2.](#) Text Changes to the Document**



-----

Old text: ([Section 7.2.1](#))

-----

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

-----

New text: ([Section 7.2.1](#))

-----

- o 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.

### **[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 case of an INIT received in the COOKIE-WAIT state [[RFC4960](#)] prescribes to send an INIT ACK to the same destination address to which the original INIT has been sent. This text does not address the possibility of the upper layer to provide 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 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.

### **[3.19.3.](#) Solution Description**

The new text requires sending INIT ACK to the destination address that is passed by the upper layer and reported in the incoming INIT. If the source address of the INIT fulfills it then 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. But receiving new packets from the peer does not guarantee peer's accessibility and, if the destination address becomes unreachable during zero window probing, SCTP cannot get a changed rwnd until it switches the destination address for probes.



### [3.20.2.](#) Text Changes to the Document

-----  
Old text: ([Section 6.1](#))  
-----

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](#))  
-----

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 MAY keep its window closed for an indefinite time. Refer to [Section 6.2](#) on the receiver behavior when it advertises a zero window.

### [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](#)

### [3.21.1.](#) Description of the Problem

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

### [3.21.2.](#) Text Changes to the Document

-----  
Old text: ([Section 10.1](#))  
-----

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

```

...

- 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) 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

```

...

- 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.

```

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

```

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]

```

...

- o 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) 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]

...

- o 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.

-----

Old text: ([Section 10.1](#))

-----

N) Receive Unsent Message

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

...

- o 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) Receive Unsent Message

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



...

- o 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.

-----

Old text: ([Section 10.1](#))

-----

0) Receive Unacknowledged Message

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

...

- o 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](#))

-----

0) Receive Unacknowledged Message

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

...

- o 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.



### **[3.21.3.](#) Solution Description**

The normative language is removed from [Section 10](#).

## **[3.22.](#) Increase of `partial_bytes_acked` in Congestion Avoidance**

### **[3.22.1.](#) Description of the Problem**

Two issues have been discovered with the `partial_bytes_acked` handling described in [Section 7.2.2 of \[RFC4960\]](#):

- o 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` although these TSNs were successfully received by the peer.
- o Duplicate TSNs are not considered in `partial_bytes_acked` although they confirm that the DATA chunks were successfully received by the peer.

### **[3.22.2.](#) Text Changes to the Document**

-----  
Old text: ([Section 7.2.2](#))  
-----

- o 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](#))  
-----

- o 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.

### **[3.22.3.](#) Solution Description**

Now `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.](#) Inconsistency in Notifications Handling**

#### **[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. E.g. [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 while [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.

This makes the text inconsistent.

#### **[3.23.2.](#) Text Changes to the Document**

The following change is based on the change described in [Section 3.6.](#)



-----  
Old text: ([Section 8.1](#))  
-----

An endpoint shall 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 which currently is used for data transfer. Unacknowledged HEARTBEAT chunks observed on paths different from the path currently used for data transfer shall not increment the association error counter, as this could lead to association closure even if the path which currently is 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 shall 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 MAY 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.

-----  
New text: ([Section 8.1](#))  
-----

An endpoint shall 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 which currently is used for data transfer. Unacknowledged HEARTBEAT chunks observed on paths different from the path currently used for data transfer shall not increment the association error counter, as this could lead to association closure even if the path which currently is 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 shall 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.

The following changes are based on [[RFC4960](#)].



-----

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 shall 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 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.

-----

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 of reachability of this destination address. After this, the endpoint should continue HEARTBEAT on this destination address but should stop increasing the counter.

-----

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 counter (as defined in [Section 8.1](#)).

-----

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).

-----

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).

### **[3.23.3.](#) Solution Description**

The inconsistencies are removed by using consistently 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, defining a name for this parameter and listing it in the table of protocol parameters in [Section 15 of \[RFC4960\]](#) is 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.

-----  
Old text: ([Section 15](#))  
-----

The following protocol parameters are RECOMMENDED:

RT0.Initial - 3 seconds  
RT0.Min - 1 second  
RT0.Max - 60 seconds  
Max.Burst - 4  
RT0.Alpha - 1/8  
RT0.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:

RT0.Initial - 3 seconds  
RT0.Min - 1 second  
RT0.Max - 60 seconds  
Max.Burst - 4



RT0.Alpha - 1/8  
 RT0.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

**[3.24.3.](#) Solution Description**

The parameter was given a name 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 the receiver of a packet must discard it while processing the chunks of the packet. It is unclear whether the receiver has to rollback state changes already performed while processing the packet or not.

The intention of [[RFC4960](#)] is to process an incoming packet chunk by chunk and do not perform any prescreening of chunks in the received packet so the receiver must only discard a chunk causing discard and 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'.

-----  
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, 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 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.

### **[3.25.3](#). Solution Description**

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

## **[3.26](#). CWND Increase in Congestion Avoidance Phase**

### **[3.26.1](#). Description of the Problem**

[RFC4960] in [Section 7.2.2](#) prescribes to increase cwnd by 1\*MTU per RTT if the sender has cwnd or more bytes of outstanding data to the corresponding address in the Congestion Avoidance phase. However,



this is described without normative language. Moreover, [Section 7.2.2](#) includes an algorithm how an implementation can achieve it 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:

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

-----  
Old text: ([Section 7.2.2](#))

- 
- o 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.
  - 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 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.
- o When `partial_bytes_acked` is greater than `cwnd` and before the arrival of the SACK the sender had less bytes of data outstanding than `cwnd` (i.e., before arrival of the SACK, `flightsize` was less than `cwnd`), reset `partial_bytes_acked` to `cwnd`.
- 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`), `partial_bytes_acked` is reset to `(partial_bytes_acked - cwnd)`. Next, `cwnd` is increased by MTU.

### **[3.26.3.](#) Solution Description**

The basic guidelines for incrementing `cwnd` during 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 to not allow increasing `cwnd` by more than  $1 * \text{MTU}$  per RTT.

### **[3.27.](#) Refresh of `cwnd` and `ssthresh` after Idle Period**

#### **[3.27.1.](#) Description of the Problem**

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

[RFC4960] doesn't specify the handling of `ssthresh` in the idle case. If `ssthresh` is reduced due to a 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 because in a multi-homed SCTP association traffic switch 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

-----  
Old text: ([Section 7.2.1](#))  
-----

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

-----  
New text: ([Section 7.2.1](#))  
-----

- o The initial cwnd before DATA transmission MUST be set to  $\min(4*MTU, \max(2*MTU, 4380 \text{ bytes}))$ .

-----  
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  $\max(\text{cwnd}/2, 4*MTU)$  per RTO.

-----  
New 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  $\max(\text{cwnd}/2, 4*MTU)$  per RTO. At the first cwnd adjustment, the ssthresh of the transport address should be adjusted to the cwnd.

### [3.27.3.](#) Solution Description

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

The text is updated to refresh ssthresh after the idle period. When the idle period is detected, the cwnd value is stored to the ssthresh value.

### [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 [\[RFC4960\], Section 6.2](#), where it is stated that an SCTP receiver must not generate more than one SACK for every incoming packet, other than to update the offered window.

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

### **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 large burst of window updates.

### **3.28.3. Solution Description**

The new text makes 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, there are the following issues with it:

- o 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. sending SACKs always to the primary path) may be more beneficial in some situations.

- o Initially it states that an endpoint should always transmit DATA chunks to the primary path. Then it states that the rule for transmittal of reply chunks should also be followed if the endpoint is bundling DATA chunks together with the reply chunk which contradicts with the first statement to always transmit DATA chunks to the primary path. Some implementations were having problems with it and sent DATA chunks bundled with reply chunks to a different destination address than the primary path that caused 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, etc.) 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 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.



### **[3.29.3.](#) Solution Description**

The SACK transmission policy is left implementation dependent but it is specified to not vary the destination address of a packet containing a SACK chunk unless there are reasons for it as it may negatively impact RTT measurement.

A confusing statement that prescribes to follow the rule for transmittal of reply chunks when the endpoint is bundling DATA chunks together with the reply chunk is removed.

### **[3.30.](#) Outstanding Data, Flightsize and Data In Flight Key Terms**

#### **[3.30.1.](#) Description of the Problem**

[RFC4960] uses outstanding data, flightsize and data in flight key terms in formulas and statements but their definitions are not provided in [Section 1.3](#). Furthermore, outstanding data does not include DATA chunks which are classified as lost but which has not been retransmitted yet 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](#))  
-----

- o 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 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.
- 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 which is classified as lost but which has not been retransmitted yet is not in outstanding data.

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

-----

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).

### **[3.30.3.](#) Solution Description**

Now [Section 1.3](#), Key Terms, includes explanations of outstanding data, data in flight and flightsize key terms. [Section 6.1](#) is corrected to properly use the outstanding data term.

## **[3.31.](#) CWND Degradation 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 [[RFC4960](#)], [Section 6.1](#), on 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 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 using the formula above, cwnd SHOULD NOT be changed.

### **[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 RT0.Initial**

### **[3.32.1.](#) Description of the Problem**

[RFC4960] uses 3 seconds as the default value for RT0.Initial in accordance with [Section 4.3.2.1 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:

RT0.Initial - 3 seconds  
RT0.Min - 1 second  
RT0.Max - 60 seconds  
Max.Burst - 4  
RT0.Alpha - 1/8  
RT0.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

-----  
New text: ([Section 15](#))  
-----

The following protocol parameters are RECOMMENDED:

RT0.Initial - 1 second  
RT0.Min - 1 second  
RT0.Max - 60 seconds  
Max.Burst - 4  
RT0.Alpha - 1/8  
RT0.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

### **[3.32.3.](#) Solution Description**

The value RT0.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, [[RFC4960](#)] requires in case of bundling that the ERROR chunk follows the SACK chunk. This restriction of the ordering is not necessary and might only 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 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 and the SACK Chunk in the same packet.

#### **[3.33.3.](#) Solution Description**

The unnecessary restriction regarding the ordering of the SACK and ERROR chunk 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) 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) 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]

### **[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. A change of the DSCP can result in packets hitting different queues on the path and therefore the 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](#))  
-----

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.

-----  
Old text: ([Section 10.1](#))  
-----

M) Set Protocol Parameters

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

This primitive allows the local SCTP to customize the protocol parameters.

Mandatory attributes:

- o association id - local handle to the SCTP association.
- o 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.

-----  
Old text: ([Section 10.1](#))  
-----

M) Set Protocol Parameters

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

This primitive allows the local SCTP to customize the protocol parameters.



Mandatory attributes:

- o association id - local handle to the SCTP association.
- o 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.

### **[3.35.3](#). Solution Description**

Text describing the required action on 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 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:  
-----

ICMP3) An implementation SHOULD ignore any ICMPv4 messages where the code indicates "Port Unreachable".

-----  
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:  
-----

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

### **[3.36.3.](#) Solution Description**

The text has been changed to not limit the processing of ICMPv4 packets with type "Destination Unreachable" by rewording the third rule. Furthermore, remove in the ninth rule the limitation to ICMPv6.

## **[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)

-----  
ICMP8) If the ICMP type is "Destination Unreachable", the implementation MAY mark the destination into the unreachable state or alternatively increment the path error counter.

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

-----  
ICMP8) If the ICMP type is "Destination Unreachable", the implementation MAY mark the destination into 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.

**[3.37.3.](#) Solution Description**

Text has been added allowing the Sctp to notify the application in 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 is 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.

-----

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 B) of [Section 6.1](#) should be supported.

### **[3.38.3](#). Solution Description**

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

### **[3.39](#). Zero Window Probing**

#### **[3.39.1](#). Description of the Problem**

The text describing zero window probing was not clearly handling the case where the window was not zero, but 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.

### **[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**

[RFC4960] refers for ECN only to [[RFC3168](#)], which will be updated by [[I-D.ietf-tsvwg-ecn-experimentation](#)]. This needs to be reflected 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 [[I-D.ietf-tsvwg-ecn-experimentation](#)] describes a proposed extension to IP that details a method to become aware of congestion outside of datagram loss.

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

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

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

In general, [[RFC3168](#)] updated by [[I-D.ietf-tsvwg-ecn-experimentation](#)] should be followed with the following exceptions.

-----  
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 [[I-D.ietf-tsvwg-ecn-experimentation](#)] details negotiation of ECN during the SYN and SYN-ACK stages of a TCP connection.

-----

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 [[I-D.ietf-tsvwg-ecn-experimentation](#)] 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.

-----

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 [[I-D.ietf-tsvwg-ecn-experimentation](#)] 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.

**[3.40.3. Solution Description](#)**

References to [[I-D.ietf-tsvwg-ecn-experimentation](#)] have been added.



**[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 are supported by the SCTP kernel implementations of FreeBSD, Linux and Solaris, but the third one is not. In addition, the first two were successfully tested in all nine interoperability tests for SCTP, but the third one 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 an Host Name Address parameter MUST send an ABORT and MAY include an Error Cause indicating an Unresolvable Address.

-----  
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.

-----

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.

-----

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 an Host Name Address parameter MUST send an ABORT and MAY include an Error Cause indicating an Unresolvable Address.

-----

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 parameter present in the received INIT or INIT ACK chunk, the endpoint MUST immediately send an ABORT and MAY include an Error Cause indicating an Unresolvable Address to its peer. The ABORT shall be sent to the source IP address from which the last peer packet was received.

-----



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](#))

-----

The support of 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 Error Cause indicating an Unresolvable Address.

### **[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**

When receiving 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, there is conflicting text in [Section 5.1.2 of \[RFC4960\]](#). It is stated that the association MUST be aborted and also 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 may include a 'Supported Address Types' parameter in the INIT to indicate what types of address are acceptable.

### **[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 a 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 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 [[RFC5226](#)]. Documentation of 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 of \[\[RFC4960\]\(#\)\]](#);
- c) A detailed definition and description of 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 the following [Section 14.2](#).

-----  
 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 [[RFC5226](#)]. Documentation of 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.

Please note that Sections [14.2](#), [14.3](#), [14.4](#), and [14.5](#) need to be renumbered.

### **[3.43.3](#). Solution Description**

[RFC6096] was integrated.

## **[3.44](#). Integration of [RFC 6335](#)**

### **[3.44.1](#). Description of the Problem**

[RFC6335] updates [[RFC4960](#)] by updating Procedures for the Port Numbers Registry. This should be integrated into the base specification. While there, update the reference to the RFC giving guidelines for writing IANA sections 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:

- o A short port name, consisting entirely of letters (A-Z and a-z), digits (0-9), and punctuation characters from "-\_+./\*" (not including the quotes).
- o The port number that is requested for registration.
- o A short English phrase describing the port's purpose.
- o 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.

- o A port name SHOULD NOT be registered for more than one SCTP port number.
- o 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.
- o 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.

-----





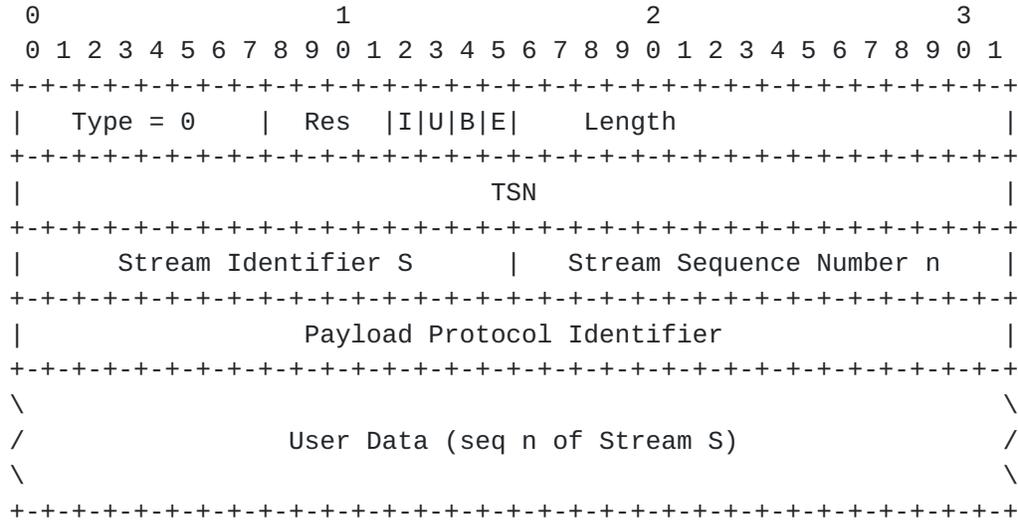


Should be set to all '0's and ignored by the receiver.

-----

New text: ([Section 3.3.1](#))

-----



Res: 4 bits

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

I bit: 1 bit

The (I)mmmediate 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 [[RFC7053](#)] for a discussion about

-----

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 (see [Section 4 of \[RFC7053\]](#) for the benefits):

- o The application requests to set the I bit of the last DATA chunk of a user message when providing the user message to the SCTP implementation (see [Section 7](#)).



- o The sender is in the SHUTDOWN-PENDING state.
- o The sending of a DATA chunk fills the congestion or receiver window.

-----  
 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.

-----  
 Old text: ([Section 10.1](#))  
 -----

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) 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

-----

New text: (Append optional parameter in Subsection E of [Section 10.1](#))

-----

- o sack immediately - set the I bit on the last DATA chunk used for sending buffer.

Please note that the change in [Section 6.2](#) is only about adding a paragraph.

### [3.45.3.](#) Solution Description

[RFC7053] was integrated.

## [3.46.](#) CRC32c Code Improvements

### [3.46.1.](#) Description of the Problem

The code given for the CRC32c computations uses types like long which may have different length on different operating systems or processors. Therefore the code is changed to use specific types like uint32\_t.

While there, fix also some syntax errors.

### [3.46.2.](#) Text Changes to the Document

-----

Old text: (Appendix B)

-----

```
/* 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,  
0x96BF4DCCCL, 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, 0xCCBCC033L,  
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,  
0x8ECEEE914L, 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)
```

```
-----
```

```
/* 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, 0xD2D60DDFUL, 0xC186FE29UL, 0x33ED7D2AUL,  
0xE72719C1UL, 0x154C9AC2UL, 0x061C6936UL, 0xF477EA35UL,  
0xAA64D611UL, 0x580F5512UL, 0x4B5FA6E6UL, 0xB93425E5UL,  
0x6DFE410EUL, 0x9F95C20DUL, 0x8CC531F9UL, 0x7EAE2FAUL,  
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, 0xD9F96E6AUL, 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,  
0x8ECEEE914UL, 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
```



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

/* 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 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_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>.", OUTPUT_FILE);
else
    printf("\nThe CRC-32c table has been written to <%s>.\n",
        OUTPUT_FILE);
}

-----
Old text: (Appendix B)
-----

/* 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"

unsigned long
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 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;
    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);
}
```

### **[3.46.3.](#) Solution Description**

The code was changed to use platform independent types.

## **[4.](#) IANA Considerations**

This document does not require any actions from IANA.

## **[5.](#) Security Considerations**

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

## **[6.](#) Acknowledgments**

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