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M. Tuexen
Muenster Univ. of Applied Sciences
R. Stewart
P. Lei
Cisco Systems, Inc.
E. Rescorla
RTFM, Inc.

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Authenticated Chunks for the Stream Control Transmission Protocol (SCTP)

Status of This Memo

Abstract

This document describes a new chunk type, several parameters, and procedures for the Stream Control Transmission Protocol (SCTP). This new chunk type can be used to authenticate SCTP chunks by using shared keys between the sender and receiver. The new parameters are used to establish the shared keys.

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1. Introduction

SCTP uses 32-bit verification tags to protect itself against blind attackers. These values are not changed during the lifetime of an SCTP association.

Looking at new SCTP extensions, there is the need to have a method of proving that an SCTP chunk(s) was really sent by the original peer that started the association and not by a malicious attacker.

Using Transport Layer Security (TLS), as defined in RFC 3436 [6], does not help because it only secures SCTP user data.

Therefore, an SCTP extension that provides a mechanism for deriving shared keys for each association is presented. These association shared keys are derived from endpoint pair shared keys, which are configured and might be empty, and data that is exchanged during the SCTP association setup.

The extension presented in this document allows an SCTP sender to authenticate chunks using shared keys between the sender and receiver. The receiver can then verify that the chunks are sent from the sender and not from a malicious attacker (as long as the attacker does not know an association shared key).

The extension described in this document places the result of a Hashed Message Authentication Code (HMAC) computation before the data covered by that computation. Placing it at the end of the packet would have required placing a control chunk after DATA chunks in case of authenticating DATA chunks. This would break the rule that control chunks occur before DATA chunks in SCTP packets. It should also be noted that putting the result of the HMAC computation after the data being covered would not allow sending the packet during the computation of the HMAC because the result of the HMAC computation is needed to compute the CRC32C checksum of the SCTP packet, which is placed in the common header of the SCTP packet.

The SCTP extension for Dynamic Address Reconfiguration (ADD-IP) requires the usage of the extension described in this document. The SCTP Partial Reliability Extension (PR-SCTP) can be used in conjunction with the extension described in this document.

2. Conventions

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL", when they appear in this document, are to be interpreted as described in RFC 2119 [3].

3. New Parameter Types

This section defines the new parameter types that will be used to negotiate the authentication during association setup. Table 1 illustrates the new parameter types.

Parameter Type	Parameter Name
0x8002	Random Parameter (RANDOM)
0x8003	Chunk List Parameter (CHUNKS)
0x8004	Requested HMAC Algorithm Parameter (HMAC-ALGO)

Table 1

Note that the parameter format requires the receiver to ignore the parameter and continue processing if the parameter is not understood. This is accomplished (as described in RFC 2960 [5], Section 3.2.1.) by the use of the upper bits of the parameter type.

3.1. Random Parameter (RANDOM)

This parameter is used to carry a random number of an arbitrary length.

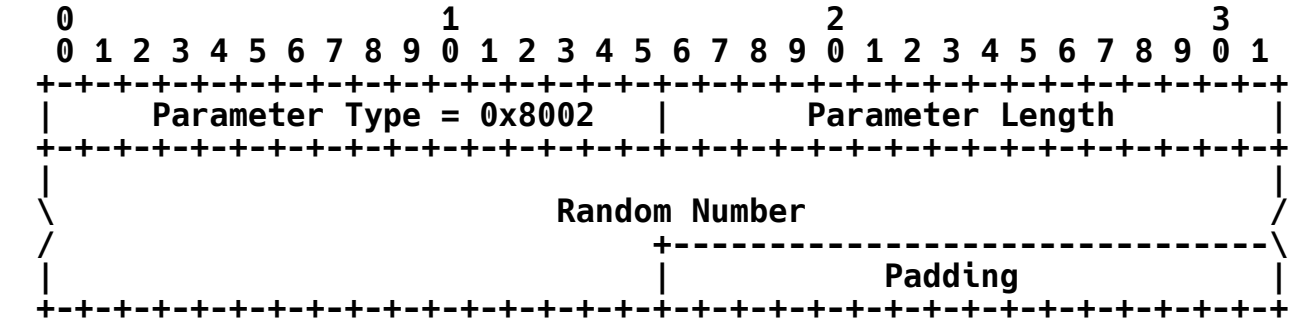

Figure 1

Parameter Type: 2 bytes (unsigned integer)
This value MUST be set to 0x8002.

Parameter Length: 2 bytes (unsigned integer)
This value is the length of the Random Number in bytes plus 4.

Random Number: n bytes (unsigned integer)
This value represents an arbitrary Random Number in network byte order.

Padding: 0, 1, 2, or 3 bytes (unsigned integer)
If the length of the Random Number is not a multiple of 4 bytes, the sender MUST pad the parameter with all zero bytes to make the parameter 32-bit aligned. The Padding MUST NOT be longer than 3 bytes and it MUST be ignored by the receiver.

The RANDOM parameter MUST be included once in the INIT or INIT-ACK chunk, if the sender wants to send or receive authenticated chunks, to provide a 32-byte Random Number. For 32-byte Random Numbers, the Padding is empty.

3.2. Chunk List Parameter (CHUNKS)

This parameter is used to specify which chunk types are required to be authenticated before being sent by the peer.

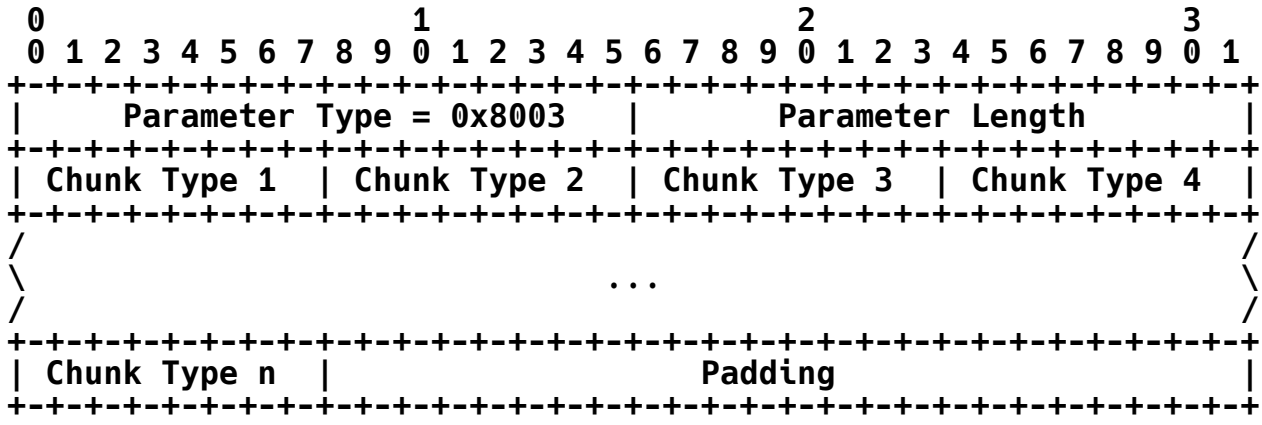

Figure 2

Parameter Type: 2 bytes (unsigned integer)
This value MUST be set to 0x8003.

Parameter Length: 2 bytes (unsigned integer)
This value is the number of listed Chunk Types plus 4.

Chunk Type n: 1 byte (unsigned integer)
Each Chunk Type listed is required to be authenticated when sent by the peer.

Padding: 0, 1, 2, or 3 bytes (unsigned integer)
If the number of Chunk Types is not a multiple of 4, the sender MUST pad the parameter with all zero bytes to make the parameter 32-bit aligned. The Padding MUST NOT be longer than 3 bytes and it MUST be ignored by the receiver.

The CHUNKS parameter MUST be included once in the INIT or INIT-ACK chunk if the sender wants to receive authenticated chunks. Its maximum length is 260 bytes.

The chunk types for INIT, INIT-ACK, SHUTDOWN-COMPLETE, and AUTH chunks MUST NOT be listed in the CHUNKS parameter. However, if a CHUNKS parameter is received then the types for INIT, INIT-ACK, SHUTDOWN-COMPLETE, and AUTH chunks MUST be ignored.

3.3. Requested HMAC Algorithm Parameter (HMAC-ALGO)

This parameter is used to list the HMAC Identifiers the peer MUST use.

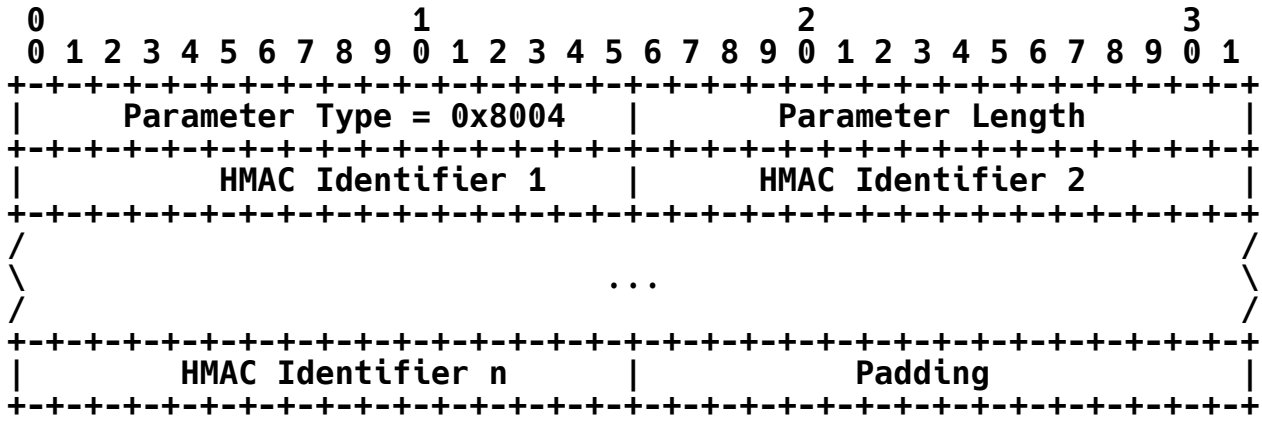

Figure 3

Parameter Type: 2 bytes (unsigned integer)
This value MUST be set to 0x8004.

Parameter Length: 2 bytes (unsigned integer)
This value is the number of HMAC Identifiers multiplied by 2, plus 4.

HMAC Identifier n: 2 bytes (unsigned integer)
The values expressed are a list of HMAC Identifiers that may be used by the peer. The values are listed by preference, with respect to the sender, where the first HMAC Identifier listed is the one most preferable to the sender.

Padding: 0 or 2 bytes (unsigned integer)
If the number of HMAC Identifiers is not even, the sender MUST pad the parameter with all zero bytes to make the parameter 32-bit aligned. The Padding MUST be 0 or 2 bytes long and it MUST be ignored by the receiver.

The HMAC-ALGO parameter MUST be included once in the INIT or INIT-ACK chunk if the sender wants to send or receive authenticated chunks.

Table 2 shows the currently defined values for HMAC Identifiers.

HMAC Identifier	Message Digest Algorithm
0	Reserved
1	SHA-1 defined in [8]
2	Reserved
3	SHA-256 defined in [8]

Table 2

Every endpoint supporting SCTP chunk authentication MUST support the HMAC based on the SHA-1 algorithm.

4. New Error Cause

This section defines a new error cause that will be sent if an AUTH chunk is received with an unsupported HMAC Identifier. Table 3 illustrates the new error cause.

Cause Code	Error Cause Name
0x0105	Unsupported HMAC Identifier

Table 3

4.1. Unsupported HMAC Identifier Error Cause

This error cause is used to indicate that an AUTH chunk has been received with an unsupported HMAC Identifier.

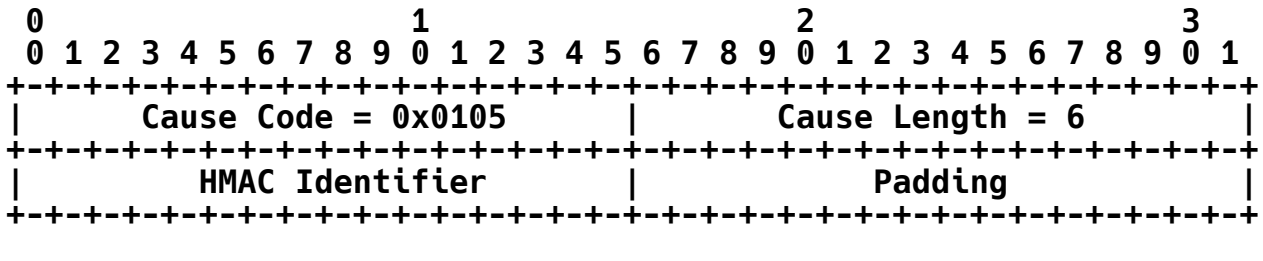

Figure 4

Cause Code: 2 bytes (unsigned integer)
This value MUST be set to 0x0105.

Cause Length: 2 bytes (unsigned integer)
This value MUST be set to 6.

HMAC Identifier: 2 bytes (unsigned integer)
This value is the HMAC Identifier which is not supported.

Padding: 2 bytes (unsigned integer)
The sender MUST pad the error cause with all zero bytes to make the cause 32-bit aligned. The Padding MUST be 2 bytes long and it MUST be ignored by the receiver.

5. New Chunk Type

This section defines the new chunk type that will be used to authenticate chunks. Table 4 illustrates the new chunk type.

Chunk Type	Chunk Name
0x0F	Authentication Chunk (AUTH)

Table 4

It should be noted that the AUTH-chunk format requires the receiver to ignore the chunk if it is not understood and silently discard all chunks that follow. This is accomplished (as described in RFC 2960 [5], Section 3.2.) by the use of the upper bits of the chunk type.

5.1. Authentication Chunk (AUTH)

This chunk is used to hold the result of the HMAC calculation.

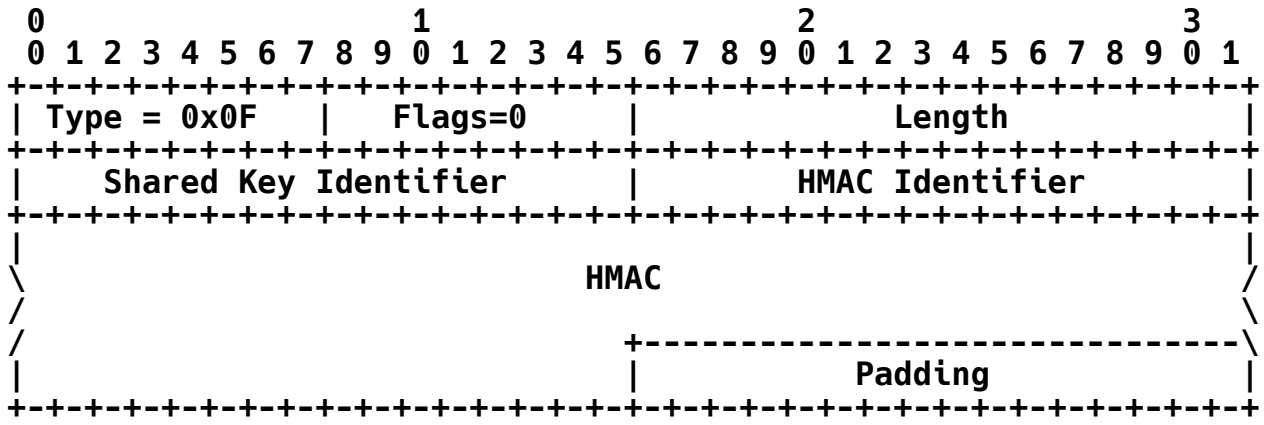

Figure 5

Type: 1 byte (unsigned integer)
This value MUST be set to 0x0F for all AUTH-chunks.

Flags: 1 byte (unsigned integer)
SHOULD be set to zero on transmit and MUST be ignored on receipt.

Length: 2 bytes (unsigned integer)
This value holds the length of the HMAC in bytes plus 8.

Shared Key Identifier: 2 bytes (unsigned integer)
This value describes which endpoint pair shared key is used.

HMAC Identifier: 2 bytes (unsigned integer)
This value describes which message digest is being used. Table 2 shows the currently defined values.

HMAC: n bytes (unsigned integer)
This holds the result of the HMAC calculation.

Padding: 0, 1, 2, or 3 bytes (unsigned integer)
If the length of the HMAC is not a multiple of 4 bytes, the sender MUST pad the chunk with all zero bytes to make the chunk 32-bit aligned. The Padding MUST NOT be longer than 3 bytes and it MUST be ignored by the receiver.

The control chunk AUTH MUST NOT appear more than once in an SCTP packet. All control and data chunks that are placed after the AUTH chunk in the packet are sent in an authenticated way. Those chunks placed in a packet before the AUTH chunk are not authenticated. Please note that DATA chunks can not appear before control chunks in an SCTP packet.

6. Procedures

6.1. Establishment of an Association Shared Key

An SCTP endpoint willing to receive or send authenticated chunks MUST send one RANDOM parameter in its INIT or INIT-ACK chunk. The RANDOM parameter MUST contain a 32-byte Random Number. The Random Number should be generated in accordance with RFC 4086 [7]. If the Random Number is not 32 bytes, the association MUST be aborted. The ABORT chunk SHOULD contain the error cause 'Protocol Violation'. In case of INIT collision, the rules governing the handling of this Random Number follow the same pattern as those for the Verification Tag, as explained in Section 5.2.4 of RFC 2960 [5]. Therefore, each endpoint knows its own Random Number and the peer's Random Number after the association has been established.

An SCTP endpoint has a list of chunks it only accepts if they are received in an authenticated way. This list is included in the INIT and INIT-ACK, and MAY be omitted if it is empty. Since this list does not change during the lifetime of the SCTP endpoint there is no problem in case of INIT collision.

Each SCTP endpoint MUST include in the INIT and INIT-ACK a HMAC-ALGO parameter containing a list of HMAC Identifiers it requests the peer to use. The receiver of an HMAC-ALGO parameter SHOULD use the first listed algorithm it supports. The HMAC algorithm based on SHA-1 MUST be supported and included in the HMAC-ALGO parameter. An SCTP endpoint MUST NOT change the parameters listed in the HMAC-ALGO parameter during the lifetime of the endpoint.

Both endpoints of an association MAY have endpoint pair shared keys that are byte vectors and pre-configured or established by another mechanism. They are identified by the Shared Key Identifier. For each endpoint pair shared key, an association shared key is computed. If there is no endpoint pair shared key, only one association shared key is computed by using an empty byte vector as the endpoint pair shared key.

The RANDOM parameter, the CHUNKS parameter, and the HMAC-ALGO parameter sent by each endpoint are concatenated as byte vectors. These parameters include the parameter type, parameter length, and the parameter value, but padding is omitted; all padding MUST be removed from this concatenation before proceeding with further computation of keys. Parameters that were not sent are simply omitted from the concatenation process. The resulting two vectors are called the two key vectors.

From the endpoint pair shared keys and the key vectors, the association shared keys are computed. This is performed by selecting the numerically smaller key vector and concatenating it to the endpoint pair shared key, and then concatenating the numerically larger key vector to that. If the key vectors are equal as numbers but differ in length, then the concatenation order is the endpoint shared key, followed by the shorter key vector, followed by the longer key vector. Otherwise, the key vectors are identical, and may be concatenated to the endpoint pair key in any order. The concatenation is performed on byte vectors, and all numerical comparisons use network byte order to convert the key vectors to a number. The result of the concatenation is the association shared key.

6.2. Sending Authenticated Chunks

Endpoints MUST send all requested chunks that have been authenticated where this has been requested by the peer. The other chunks MAY be sent whether or not they have been authenticated. If endpoint pair shared keys are used, one of them MUST be selected for authentication.

To send chunks in an authenticated way, the sender MUST include these chunks after an AUTH chunk. This means that a sender MUST bundle chunks in order to authenticate them.

If the endpoint has no endpoint pair shared key for the peer, it MUST use Shared Key Identifier zero with an empty endpoint pair shared key. If there are multiple endpoint shared keys the sender selects one and uses the corresponding Shared Key Identifier.

The sender MUST calculate the Message Authentication Code (MAC) (as described in RFC 2104 [2]) using the hash function H as described by the HMAC Identifier and the shared association key K based on the endpoint pair shared key described by the Shared Key Identifier. The 'data' used for the computation of the AUTH-chunk is given by the AUTH chunk with its HMAC field set to zero (as shown in Figure 6) followed by all the chunks that are placed after the AUTH chunk in the SCTP packet.

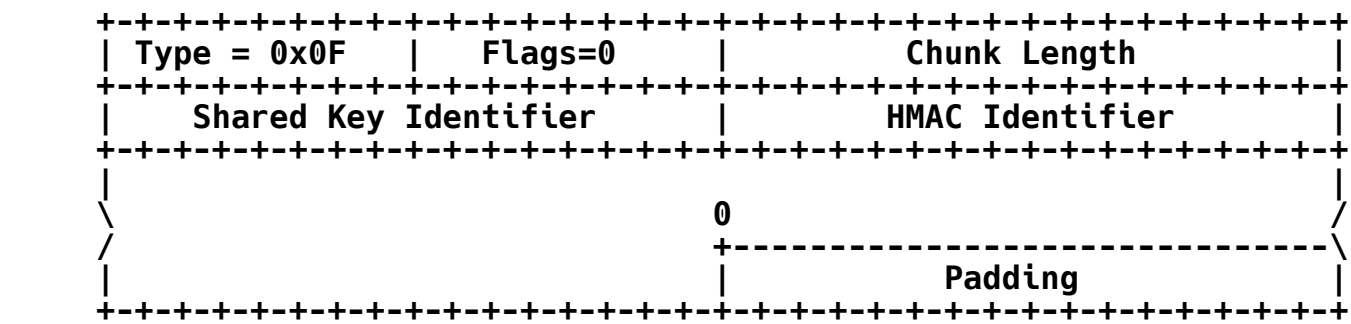

Figure 6

Please note that all fields are in network byte order and that the field that will contain the complete HMAC is filled with zeroes. The length of the field shown as zero is the length of the HMAC described by the HMAC Identifier. The padding of all chunks being authenticated MUST be included in the HMAC computation.

The sender fills the HMAC into the HMAC field and sends the packet.

6.3. Receiving Authenticated Chunks

The receiver has a list of chunk types that it expects to be received only after an AUTH-chunk. This list has been sent to the peer during the association setup. It MUST silently discard these chunks if they are not placed after an AUTH chunk in the packet.

The receiver MUST use the HMAC algorithm indicated in the HMAC Identifier field. If this algorithm was not specified by the receiver in the HMAC-ALGO parameter in the INIT or INIT-ACK chunk during association setup, the AUTH chunk and all the chunks after it MUST be discarded and an ERROR chunk SHOULD be sent with the error cause defined in Section 4.1.

If an endpoint with no shared key receives a Shared Key Identifier other than 0, it MUST silently discard all authenticated chunks. If the endpoint has at least one endpoint pair shared key for the peer, it MUST use the key specified by the Shared Key Identifier if a key has been configured for that Shared Key Identifier. If no endpoint pair shared key has been configured for that Shared Key Identifier, all authenticated chunks MUST be silently discarded.

The receiver now performs the same calculation as described for the sender based on Figure 6. If the result of the calculation is the

same as given in the HMAC field, all the chunks following the AUTH chunk are processed. If the field does not match the result of the calculation, all the chunks following the AUTH chunk MUST be silently discarded.

It should be noted that if the receiver wants to tear down an association in an authenticated way only, the handling of malformed packets should not result in tearing down the association.

An SCTP implementation has to maintain state for each SCTP association. In the following, we call this data structure the SCTP transmission control block (STCB).

When an endpoint requires COOKIE-ECHO chunks to be authenticated, some special procedures have to be followed because the reception of a COOKIE-ECHO chunk might result in the creation of an SCTP association. If a packet arrives containing an AUTH chunk as a first chunk, a COOKIE-ECHO chunk as the second chunk, and possibly more chunks after them, and the receiver does not have an STCB for that packet, then authentication is based on the contents of the COOKIE-ECHO chunk. In this situation, the receiver MUST authenticate the chunks in the packet by using the RANDOM parameters, CHUNKS parameters and HMAC_ALGO parameters obtained from the COOKIE-ECHO chunk, and possibly a local shared secret as inputs to the authentication procedure specified in Section 6.3. If authentication fails, then the packet is discarded. If the authentication is successful, the COOKIE-ECHO and all the chunks after the COOKIE-ECHO MUST be processed. If the receiver has an STCB, it MUST process the AUTH chunk as described above using the STCB from the existing association to authenticate the COOKIE-ECHO chunk and all the chunks after it.

If the receiver does not find an STCB for a packet containing an AUTH chunk as the first chunk and does not find a COOKIE-ECHO chunk as the second chunk, it MUST use the chunks after the AUTH chunk to look up an existing association. If no association is found, the packet MUST be considered as out of the blue. The out of the blue handling MUST be based on the packet without taking the AUTH chunk into account. If an association is found, it MUST process the AUTH chunk using the STCB from the existing association as described earlier.

Requiring ABORT chunks and COOKIE-ECHO chunks to be authenticated makes it impossible for an attacker to bring down or restart an association as long as the attacker does not know the association shared key. But it should also be noted that if an endpoint accepts ABORT chunks only in an authenticated way, it may take longer to detect that the peer is no longer available. If an endpoint accepts COOKIE-ECHO chunks only in an authenticated way, the restart

procedure does not work, because the restarting endpoint most likely does not know the association shared key of the old association to be restarted. However, if the restarting endpoint does know the old association shared key, he can successfully send the COOKIE-ECHO chunk in a way that it is accepted by the peer by using this old association shared key for the packet containing the AUTH chunk. After this operation, both endpoints have to use the new association shared key.

If a server has an endpoint pair shared key with some clients, it can request the COOKIE_ECHO chunk to be authenticated and can ensure that only associations from clients with a correct endpoint pair shared key are accepted.

Furthermore, it is important that the cookie contained in an INIT-ACK chunk and in a COOKIE-ECHO chunk MUST NOT contain any endpoint pair shared keys.

7. Examples

This section gives examples of message exchanges for association setup.

The simplest way of using the extension described in this document is given by the following message exchange.

```
    ---------- INIT[RANDOM; CHUNKS; HMAC-ALGO] ---------->
    <------- INIT-ACK[RANDOM; CHUNKS; HMAC-ALGO] ---------
    -------------------- COOKIE-ECHO -------------------->
    <-------------------- COOKIE-ACK ---------------------
```

Please note that the CHUNKS parameter is optional in the INIT and INIT-ACK.

If the server wants to receive DATA chunks in an authenticated way, the following message exchange is possible:

```
    ---------- INIT[RANDOM; CHUNKS; HMAC-ALGO] ---------->
    <------- INIT-ACK[RANDOM; CHUNKS; HMAC-ALGO] ---------
    --------------- COOKIE-ECHO; AUTH; DATA ------------->
    <----------------- COOKIE-ACK; SACK ------------------
```

Please note that if the endpoint pair shared key depends on the client and the server, and is only known by the upper layer, this message exchange requires an upper layer intervention between the processing of the COOKIE-ECHO chunk and the processing of the AUTH and DATA chunk at the server side. This intervention may be realized by a COMMUNICATION-UP notification followed by the presentation of

the endpoint pair shared key by the upper layer to the SCTP stack, see for example Section 10 of RFC 2960 [5]. If this intervention is not possible due to limitations of the API (for example, the socket API), the server might discard the AUTH and DATA chunk, making a retransmission of the DATA chunk necessary. If the same endpoint pair shared key is used for multiple endpoints and does not depend on the client, this intervention might not be necessary.

8. IANA Considerations

This document (RFC 4895) is the reference for all registrations described in this section. All registrations need to be listed in the document available at SCTP-parameters [9]. The changes are described below.

8.1. A New Chunk Type

A chunk type for the AUTH chunk has been assigned by IANA. IANA has assigned the value (15), as given in Table 4. An additional line has been added in the "CHUNK TYPES" table of SCTP-parameters [9]:

CHUNK TYPES

ID Value	Chunk Type	Reference
15	Authentication Chunk (AUTH)	[RFC4895]

8.2. Three New Parameter Types

Parameter types have been assigned for the RANDOM, CHUNKS, and HMAC-ALGO parameter by IANA. The values are as given in Table 1. This required two modifications to the "CHUNK PARAMETER TYPES" tables in SCTP-parameters [9]: the first is the addition of three new lines to the "INIT Chunk Parameter Types" table:

Chunk Parameter Type	Value
Random	32770 (0x8002)
Chunk List	32771 (0x8003)
Requested HMAC Algorithm Parameter	32772 (0x8004)

The second required change is the addition of the same three lines to the to the "INIT ACK Chunk Parameter Types" table.

8.3. A New Error Cause

An error cause for the Unsupported HMAC Identifier error cause has been assigned. The value (261) has been assigned as in Table 3.

This requires an additional line of the "CAUSE CODES" table in SCTP-parameters [9]:

VALUE	CAUSE CODE	REFERENCE
261 (0x0105)	Unsupported HMAC Identifier	[RFC4895]

8.4. A New Table for HMAC Identifiers

HMAC Identifiers have to be maintained by IANA. Four initial values have been assigned by IANA as described in Table 2. This required a new table "HMAC IDENTIFIERS" in SCTP-parameters [9]:

HMAC Identifier	Message Digest Algorithm	REFERENCE
0	Reserved	[RFC4895]
1	SHA-1	[RFC4895]
2	Reserved	[RFC4895]
3	SHA-256	[RFC4895]

For registering a new HMAC Identifier with IANA, in this table, a request has to be made to assign such a number. This number must be unique and a message digest algorithm usable with the HMAC defined in RFC 2104 [2] MUST be specified. The "Specification Required" policy of RFC 2434 [4] MUST be applied.

9. Security Considerations

Without using endpoint shared keys, this extension only protects against modification or injection of authenticated chunks by attackers who did not capture the initial handshake setting up the SCTP association.

If an endpoint pair shared key is used, even a true man in the middle cannot inject chunks, which are required to be authenticated, even if he intercepts the initial message exchange. The endpoint also knows that it is accepting authenticated chunks from a peer who knows the endpoint pair shared key.

The establishment of endpoint pair shared keys is out of the scope of this document. Other mechanisms can be used, like using TLS or manual configuration.

When an endpoint accepts COOKIE-ECHO chunks only in an authenticated way the restart procedure does not work. Neither an attacker nor a restarted endpoint not knowing the association shared key can perform an restart. However, if the association shared key is known, it is possible to restart the association.

Because SCTP already has a built-in mechanism that handles the reception of duplicated chunks, the presented solution makes use of this functionality and does not provide a method to avoid replay attacks by itself. Of course, this only works within each SCTP association. Therefore, a separate shared key is used for each SCTP association to handle replay attacks covering multiple SCTP associations.

Each endpoint presenting a list of more than one element in the HMAC-ALGO parameter must be prepared for the peer using the weakest algorithm listed.

When an endpoint pair uses non-NULL endpoint pair shared keys and one of the endpoints still accepts a NULL key, an attacker who captured the initial handshake can still inject or modify authenticated chunks by using the NULL key.

10. Acknowledgments

The authors wish to thank David Black, Sascha Grau, Russ Housley, Ivan Arias Rodriguez, Irene Ruengeler, and Magnus Westerlund for their invaluable comments.

11. Normative References

[1] Rivest, R., "The MD5 Message-Digest Algorithm", RFC 1321, April 1992.

[2] Krawczyk, H., Bellare, M., and R. Canetti, "HMAC: Keyed-Hashing for Message Authentication", RFC 2104, February 1997.

[3] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[4] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 2434, October 1998.

[5] Stewart, R., Xie, Q., Morneault, K., Sharp, C., Schwarzbauer, H., Taylor, T., Rytina, I., Kalla, M., Zhang, L., and V. Paxson, "Stream Control Transmission Protocol", RFC 2960, October 2000.

[6] Jungmaier, A., Rescorla, E., and M. Tuexen, "Transport Layer Security over Stream Control Transmission Protocol", RFC 3436, December 2002.

[7] Eastlake, D., Schiller, J., and S. Crocker, "Randomness Requirements for Security", BCP 106, RFC 4086, June 2005.

[8] National Institute of Standards and Technology, "Secure Hash Standard", FIPS PUB 180-2, August 2002, <http://csrc.nist.gov/publications/fips/fips180-2/fips180-2.pdf>.

[9] <http://www.iana.org/assignments/sctp-parameters>

Authors' Addresses

Michael Tuexen
Muenster Univ. of Applied Sciences
Stegerwaldstr. 39
48565 Steinfurt
Germany

EMail: tuexen@fh-muenster.de

Randall R. Stewart
Cisco Systems, Inc.
4875 Forest Drive
Suite 200
Columbia, SC 29206
USA

EMail: rrs@cisco.com

Peter Lei
Cisco Systems, Inc.
8735 West Higgins Road
Suite 300
Chicago, IL 60631
USA

Phone:
EMail: peterlei@cisco.com

Eric Rescorla
RTFM, Inc.
2064 Edgewood Drive
Palo Alto, CA 94303
USA

Phone: +1 650-320-8549
EMail: ekr@rtfm.com

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