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Additional Cryptographic Algorithms For Use With TCP-AO
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Abstract

RFC5926 creates a list of cryptographic algorithms that can be used with TCP-AO. This document expands that list, adding two Message Authentication Code (MAC) algorithms, HMAC-SHA256-128 and KMAC256-128. For each MAC algorithm, a corresponding Key Derivation Function (KDF) is also added.

The MAC algorithms described by this document produce 128-bit (i.e., 16-byte) MACs. When 16-byte MACs are encoded in TCP-AO, the TCP-AO consumes 20 bytes. This does not challenge TCP's 40-byte option size limitation.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on 4 December 2026.

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1. Introduction

[RFC5926] creates a list of cryptographic algorithms that can be used with TCP-AO [RFC5925]. This document expands that list, adding two Message Authentication Code (MAC) algorithms, HMAC-SHA256-128 and KMAC256-128. For each MAC algorithm, a corresponding Key Derivation Function (KDF) is also added.

The MAC algorithms described by this document produce 128-bit (i.e., 16-byte) MACs. When 16-byte MACs are encoded in TCP-AO, the TCP-AO consumes 20 bytes. This does not challenge TCP's [RFC9293] 40-byte option size limitation.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Algorithm Classes

[RFC5925] requires the following cryptographic algorithm classes:

* Key Derivation Functions (KDFs)

* MAC Algorithms

Section 3.1 of this document addresses KDFs while Section 3.2 addresses MAC algorithms.

3.1. Key Derivation Functions (KDFs)

A KDF converts Input Keying Material (IKM) into cryptographically secure Output Keying Material (OKM). In the case of TCP-AO, a KDF converts an administratively assigned Master_Key into a Traffic_Key.

KDFs have the following interface:

* Traffic_Key = KDF_alg(Master_Key, Context, Output_Length)

where:

* KDF_alg is the KDF algorithm being used.

* Master_Key is a variable length pre-shared key (PSK).

* Context is binary string containing information related to the TCP connection, as defined in [RFC5925], Section 5.2.

* Output_Length is the desired length of the Traffic_Key. In this document, the Output_Length is always equal to 256 bits.

This document defines two KDFs:

* HKDF-SHA256

* KMAC256-KDF

Section 3.1.1 of this document describes HKDF-SHA256 while Section 3.1.2 describes KMAC256-KDF.

3.1.1. HKDF-SHA256

HKDF-SHA256 is as described in [RFC5869]. HKDF-SHA256 executes in the following stages:

* Extract

* Expand

The interface to the Extract stage is:

* PRK = HKDF-Extract(salt, IKM)

where:

* PRK is a Pseudo-random key, to be used in the Expand stage.

* salt is an all-zero byte string whose length equals 32 bytes.

* IKM is the Master_Key argument provided to the KDF interface.

According to [RFC5869], the goal of the extract stage is to concentrate the possibly dispersed entropy of the input keying material into a short, but cryptographically strong pseudorandom key. Implementations MUST execute the extract stage.

The interface to the Expand stage is:

* OKM = HKDF-Expand(PRK, info, L)

where:

* OKM is the Traffic_Key.

* PRK is the value produced by the Extract stage.

* info is the Context argument provided to the KDF interface.

* L is equal to 32 bytes.

The expand stage expands the pseudorandom key to the desired length. The output key length depend on the specific cryptographic algorithms for which the keys are needed. Implementations MUST execute the expand stage.

3.1.2. KMAC256-KDF

KMAC256-KDF is as described in [DOI.10.6028_NIST.SP.800-185] and [DOI.10.6028_NIST.SP.800-56Cr2]. So, the interface to KMAC256-KDF as described in [DOI.10.6028_NIST.SP.800-56Cr2]:

* OKM = KMAC256(Z, salt, x, H_outputBits, S)

where:

* Z is is the Master_Key argument provided to the KDF interface.

* salt is an all-zero byte string whose length equals 132 bytes.

* x is the Context argument provided to the KDF interface.

* H_outputBits is equal to 256 bits.

* S is the byte string 01001011 || 01000100 || 01000110, which represents the sequence of characters "K", "D," and "F" in 8-bit ASCII.

3.2. MAC Algorithms

Each MAC algorithm defined for TCP-AO has the following fixed elements as part of its definition:

* KDF_Alg is the name of the KDF algorithm used to generate the Traffic_Key.

* Key_Length is the length of the Traffic_Key used in this MAC, measured in bits. In this document, the Key_Length is always 256 bits.

* MAC_Length is the desired length of the MAC to be produced by the algorithm. In this document, the MAC_Length is always 128 bits.

MACs computed for TCP-AO have the following interface:

* MAC = MAC_alg(Traffic_Key, Message)

where:

* MAC is the value to be encoded in TCP-AO.

* MAC_alg is MAC Algorithm used.

* Traffic_Key is the result of KDF.

* Message is the message to be authenticated, as specified in [RFC5925], Section 5.1.

3.2.1. The Use of HMAC-SHA256-128

The three fixed elements for HMAC-SHA256-128 are:

* KDF_Alg: HKDF-SHA256.

* Key_Length: 256 bits.

* MAC_Length: 128 bits.

For:

* MAC = MAC_alg (Traffic_Key, Message)

HMAC-SHA256-128 for TCP-AO has the following values:

* MAC is the value to be encoded in TCP-AO.

* MAC_alg is HMAC-SHA256.

* Traffic_Key is the result of the KDF.

* Message is the message to be authenticated, as specified in [RFC5925], Section 5.1.

3.2.2. The Use of KMAC256-128

The three fixed elements for KMAC256-128 are:

* KDF_Alg: KMAC256-KDF

* Key_Length: 256 bits.

* MAC_Length: 128 bits.

For:

* MAC = MAC_alg (Traffic_Key, Message)

KMAC256-128 for TCP-AO has the following values:

* MAC is the value to be encoded in TCP-AO.

* MAC_alg is KMAC256.

* Traffic_Key is the result of the KDF.

* Message is the message to be authenticated, as specified in [RFC5925], Section 5.1.

4. Security Considerations

This document inherits all of the security considerations of [RFC5869], [RFC5925], [RFC8702], and [RFC9688].

The security of cryptography-based systems depends on both the strength of the cryptographic algorithms chosen and the strength of the keys used with those algorithms. The security also depends on the engineering of the protocol used by the system to ensure that there are no non-cryptographic ways to bypass the security of the overall system.

Master_Keys SHOULD have at least 256 bits of entropy. This document RECOMMENDS that operators use Master_Keys generated by a cryptographic random number generator, or similar. However, it is understood that they may not do so.

TCP-AO Master Key Tuples MUST be rotated at a rate commensurate with the strength of the cryptographic algorithms.

5. IANA Considerations

IANA is requested to add the following entries to the "Cryptographic Algorithms for TCP-AO Registration" (https://www.iana.org/assignments/tcp-parameters/tcp-parameters.xhtml#tcp-parameters-3).

Algorithm	Reference
HMAC-SHA256-128	This Document
KMAC256-128	This Document

Table 1: IANA Actions

6. Acknowledgements

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7. Normative References

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[RFC9688] Housley, R., "Use of the SHA3 One-Way Hash Functions in the Cryptographic Message Syntax (CMS)", RFC 9688, DOI 10.17487/RFC9688, November 2024, <https://www.rfc-editor.org/rfc/rfc9688>.

Appendix A. Test Vectors

This appendix provides test vectors to validate the correct implementation of TCP-AO and the cryptographic algorithms defined in this document. It includes the specification of all endpoint parameters to generate the variety of TCP segments covered by different keys and MAC coverage, i.e., both the default case and the variant where TCP options are ignored for middlebox traversal.

A.1. Input Test Vectors

Input test vectors are as described in Section 3 of [RFC9235].

A.2. IPv4 HMAC-SHA256-128 Output Test Vectors

In the following sections, all values are indicated as 2-digit hexadecimal values with spacing per line representing the contents of 16 consecutive bytes, as is typical for data dumps. The IP/TCP data indicates the entire IP packet, including the TCP segment and its options (whether covered by TCP-AO or not, as indicated), including TCP-AO.

A.2.1. HMAC-SHA256-128 (Default - Covers TCP Options)

A.2.1.1. Send (Client) SYN (Covers Options)

Client ISN = 0xfbfbab5a

Send_SYN_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 4c dd 0f 40 00 ff 06 bf 6b 0a 0b 0c 0d
ac 1b 1c 1d e9 d7 00 b3 fb fb ab 5a 00 00 00 00
e0 02 ff ff ca c4 00 00 02 04 05 b4 01 03 03 08
04 02 08 0a 00 15 5a b7 00 00 00 00 1d 10 3d 54
2e e4 37 c6 f8 ed e6 d7 c4 d6 02 e7
```

MAC:

TBD

A.2.1.2. Receive (Server) SYN-ACK (Covers Options)

Server ISN = 0x11c14261

Receive_SYN_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 4c 65 06 40 00 ff 06 37 75 ac 1b 1c 1d
0a 0b 0c 0d 00 b3 e9 d7 11 c1 42 61 fb fb ab 5b
e0 12 ff ff 37 76 00 00 02 04 05 b4 01 03 03 08
04 02 08 0a 84 a5 0b eb 00 15 5a b7 1d 10 54 3d
ee ab 0f e2 4c 30 10 81 51 16 b3 be
```

MAC:

TBD

A.2.1.3. Send (Client) Non-SYN (Covers Options)

Send_other_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 87 36 a1 40 00 ff 06 65 9f 0a 0b 0c 0d
ac 1b 1c 1d e9 d7 00 b3 fb fb ab 5b 11 c1 42 62
c0 18 01 04 a1 62 00 00 01 01 08 0a 00 15 5a c1
84 a5 0b eb 1d 10 3d 54 70 64 cf 99 8c c6 c3 15
c2 c2 e2 bf ff ff ff ff ff ff ff ff ff ff ff ff
ff ff ff ff 00 43 01 04 da bf 00 b4 0a 0b 0c 0d
26 02 06 01 04 00 01 00 01 02 02 80 00 02 02 02
00 02 02 42 00 02 06 41 04 00 00 da bf 02 08 40
06 00 64 00 01 01 00
```

MAC:

TBD

A.2.1.4. Receive (Server) Non-SYN (Covers Options)

Receive_other_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 87 1f a9 40 00 ff 06 7c 97 ac 1b 1c 1d
0a 0b 0c 0d 00 b3 e9 d7 11 c1 42 62 fb fb ab 9e
c0 18 01 00 40 0c 00 00 01 01 08 0a 84 a5 0b f5
00 15 5a c1 1d 10 54 3d a6 3f 0e cb bb 2e 63 5c
95 4d ea c7 ff ff ff ff ff ff ff ff ff ff ff ff
ff ff ff ff 00 43 01 04 da c0 00 b4 ac 1b 1c 1d
26 02 06 01 04 00 01 00 01 02 02 80 00 02 02 02
00 02 02 42 00 02 06 41 04 00 00 da c0 02 08 40
06 00 64 00 01 01 00
```

MAC:

TBD

A.2.2. HMAC-SHA256-128 (Omits TCP Options)

A.2.2.1. Send (Client) SYN (Omits Options)

Client ISN = 0xcb0efbee

Send_SYN_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 4c 53 99 40 00 ff 06 48 e2 0a 0b 0c 0d
ac 1b 1c 1d ff 12 00 b3 cb 0e fb ee 00 00 00 00
e0 02 ff ff 54 1f 00 00 02 04 05 b4 01 03 03 08
04 02 08 0a 00 02 4c ce 00 00 00 00 1d 10 3d 54
80 af 3c fe b8 53 68 93 7b 8f 9e c2
```

MAC:

TBD

A.2.2.2. Receive (Server) SYN-ACK (Omits Options)

Server ISN = 0xacd5b5e1

Receive_SYN_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 4c 32 84 40 00 ff 06 69 f7 ac 1b 1c 1d
0a 0b 0c 0d 00 b3 ff 12 ac d5 b5 e1 cb 0e fb ef
e0 12 ff ff 38 8e 00 00 02 04 05 b4 01 03 03 08
04 02 08 0a 57 67 72 f3 00 02 4c ce 1d 10 54 3d
09 30 6f 9a ce a6 3a 8c 68 cb 9a 70
```

MAC:

TBD

A.2.2.3. Send (Client) Non-SYN (Omits Options)

Send_other_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 87 a8 f5 40 00 ff 06 f3 4a 0a 0b 0c 0d
ac 1b 1c 1d ff 12 00 b3 cb 0e fb ef ac d5 b5 e2
c0 18 01 04 6c 45 00 00 01 01 08 0a 00 02 4c ce
57 67 72 f3 1d 10 3d 54 71 06 08 cc 69 6c 03 a2
71 c9 3a a5 ff ff ff ff ff ff ff ff ff ff ff ff
ff ff ff ff 00 43 01 04 da bf 00 b4 0a 0b 0c 0d
26 02 06 01 04 00 01 00 01 02 02 80 00 02 02 02
00 02 02 42 00 02 06 41 04 00 00 da bf 02 08 40
06 00 64 00 01 01 00
```

MAC:

TBD

A.2.2.4. Receive (Server) Non-SYN (Omits Options)

Receive_other_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 87 54 37 40 00 ff 06 48 09 ac 1b 1c 1d
0a 0b 0c 0d 00 b3 ff 12 ac d5 b5 e2 cb 0e fc 32
c0 18 01 00 46 b6 00 00 01 01 08 0a 57 67 72 f3
00 02 4c ce 1d 10 54 3d 97 76 6e 48 ac 26 2d e9
ae 61 b4 f9 ff ff ff ff ff ff ff ff ff ff ff ff
ff ff ff ff 00 43 01 04 da c0 00 b4 ac 1b 1c 1d
26 02 06 01 04 00 01 00 01 02 02 80 00 02 02 02
00 02 02 42 00 02 06 41 04 00 00 da c0 02 08 40
06 00 64 00 01 01 00
```

MAC:

TBD

A.3. IPv4 KMAC256-128 Output Test Vectors

In the following sections, all values are indicated as 2-digit hexadecimal values with spacing per line representing the contents of 16 consecutive bytes, as is typical for data dumps. The IP/TCP data indicates the entire IP packet, including the TCP segment and its options (whether covered by TCP-AO or not, as indicated), including TCP-AO.

A.3.1. KMAC256-128 (Default - Covers TCP Options)

A.3.1.1. Send (Client) SYN (Covers Options)

Client ISN = 0x787a1ddf

Send_SYN_traffic_key:

TBD

IP/TCP:

```
45 e0 00 4c 7b 9f 40 00 ff 06 20 dc 0a 0b 0c 0d
ac 1b 1c 1d c4 fa 00 b3 78 7a 1d df 00 00 00 00
e0 02 ff ff 5a 0f 00 00 02 04 05 b4 01 03 03 08
04 02 08 0a 00 01 7e d0 00 00 00 00 1d 10 3d 54
e4 77 e9 9c 80 40 76 54 98 e5 50 91
```

MAC:

TBD

A.3.1.2. Receive (Server) SYN-ACK (Covers Options)

Server ISN = 0xfadd6de9

Receive_SYN_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 4c 4b ad 40 00 ff 06 50 ce ac 1b 1c 1d
0a 0b 0c 0d 00 b3 c4 fa fa dd 6d e9 78 7a 1d e0
e0 12 ff ff f3 f2 00 00 02 04 05 b4 01 03 03 08
04 02 08 0a 93 f4 e9 e8 00 01 7e d0 1d 10 54 3d
d6 ad a7 bc 4c dd 53 6d 17 69 db 5f
```

MAC:

TBD

A.3.1.3. Send (Client) Non-SYN (Covers Options)

Send_other_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 87 fb 4f 40 00 ff 06 a0 f0 0a 0b 0c 0d
ac 1b 1c 1d c4 fa 00 b3 78 7a 1d e0 fa dd 6d ea
c0 18 01 04 95 05 00 00 01 01 08 0a 00 01 7e d0
93 f4 e9 e8 1d 10 3d 54 77 41 27 42 fa 4d c4 33
ef f0 97 3e ff ff ff ff ff ff ff ff ff ff ff ff
ff ff ff ff 00 43 01 04 da bf 00 b4 0a 0b 0c 0d
26 02 06 01 04 00 01 00 01 02 02 80 00 02 02 02
00 02 02 42 00 02 06 41 04 00 00 da bf 02 08 40
06 00 64 00 01 01 00
```

MAC:

TBD

A.3.1.4. Receive (Server) Non-SYN (Covers Options)

Receive_other_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 87 b9 14 40 00 ff 06 e3 2b ac 1b 1c 1d
0a 0b 0c 0d 00 b3 c4 fa fa dd 6d ea 78 7a 1e 23
c0 18 01 00 e7 db 00 00 01 01 08 0a 93 f4 e9 e8
00 01 7e d0 1d 10 54 3d f6 d9 65 a7 83 82 a7 48
45 f7 2d ac ff ff ff ff ff ff ff ff ff ff ff ff
ff ff ff ff 00 43 01 04 da c0 00 b4 ac 1b 1c 1d
26 02 06 01 04 00 01 00 01 02 02 80 00 02 02 02
00 02 02 42 00 02 06 41 04 00 00 da c0 02 08 40
06 00 64 00 01 01 00
```

MAC:

TBD

A.3.2. KMAC256-128 (Omits TCP Options)

A.3.2.1. Send (Client) SYN (Omits Options)

Client ISN = 0x389bed71

Send_SYN_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 4c f2 2e 40 00 ff 06 aa 4c 0a 0b 0c 0d
ac 1b 1c 1d da 1c 00 b3 38 9b ed 71 00 00 00 00
e0 02 ff ff 70 bf 00 00 02 04 05 b4 01 03 03 08
04 02 08 0a 00 01 85 e1 00 00 00 00 1d 10 3d 54
c4 4e 60 cb 31 f7 c0 b1 de 3d 27 49
```

MAC:

TBD

A.3.2.2. Receive (Server) SYN-ACK (Omits Options)

Server ISN = 0xd3844a6f

Receive_SYN_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 4c 6c c0 40 00 ff 06 2f bb ac 1b 1c 1d
0a 0b 0c 0d 00 b3 da 1c d3 84 4a 6f 38 9b ed 72
e0 12 ff ff e4 45 00 00 02 04 05 b4 01 03 03 08
04 02 08 0a ce 45 98 38 00 01 85 e1 1d 10 54 3d
3a 6a bb 20 7e 49 b1 be 71 36 db 90
```

MAC:

TBD

A.3.2.3. Send (Client) Non-SYN (Omits Options)

Send_other_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 87 ee 91 40 00 ff 06 ad ae 0a 0b 0c 0d
ac 1b 1c 1d da 1c 00 b3 38 9b ed 72 d3 84 4a 70
c0 18 01 04 88 51 00 00 01 01 08 0a 00 01 85 e1
ce 45 98 38 1d 10 3d 54 75 85 e9 e9 d5 c3 ec 85
7b 96 f8 37 ff ff ff ff ff ff ff ff ff ff ff ff
ff ff ff ff 00 43 01 04 da bf 00 b4 0a 0b 0c 0d
26 02 06 01 04 00 01 00 01 02 02 80 00 02 02 02
00 02 02 42 00 02 06 41 04 00 00 da bf 02 08 40
06 00 64 00 01 01 00
```

MAC:

TBD

A.3.2.4. Receive (Server) Non-SYN (Omits Options)

Receive_other_traffic_key:

TBD

IPv4/TCP:

```
45 e0 00 87 6a 21 40 00 ff 06 32 1f ac 1b 1c 1d
0a 0b 0c 0d 00 b3 da 1c d3 84 4a 70 38 9b ed 72
c0 18 01 00 04 49 00 00 01 01 08 0a ce 45 98 38
00 01 85 e1 1d 10 54 3d 5c 04 0f d9 23 33 04 76
5c 09 82 f4 ff ff ff ff ff ff ff ff ff ff ff ff
ff ff ff ff 00 43 01 04 da c0 00 b4 ac 1b 1c 1d
26 02 06 01 04 00 01 00 01 02 02 80 00 02 02 02
00 02 02 42 00 02 06 41 04 00 00 da c0 02 08 40
06 00 64 00 01 01 00
```

MAC:

TBD

A.4. IPv6 HMAC-SHA256-128 Output Test Vectors

A.4.1. HMAC-SHA256-128 (Default - Covers TCP Options)

A.4.1.1. Send (Client) SYN (Covers Options)

Client ISN = 0x176a833f

Send_SYN_traffic_key:

TBD

IPv6/TCP:

```
6e 08 91 dc 00 38 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 f7 e4 00 b3 17 6a 83 3f
00 00 00 00 e0 02 ff ff 47 21 00 00 02 04 05 a0
01 03 03 08 04 02 08 0a 00 41 d0 87 00 00 00 00
1d 10 3d 54 90 33 ec 3d 73 34 b6 4c 5e dd 03 9f
```

MAC:

TBD

A.4.1.2. Receive (Server) SYN-ACK (Covers Options)

Server ISN = 0x3f51994b

Receive_SYN_traffic_key:

TBD

IPv6/TCP:

```
6e 01 00 9e 00 38 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 00 b3 f7 e4 3f 51 99 4b
17 6a 83 40 e0 12 ff ff bf ec 00 00 02 04 05 a0
01 03 03 08 04 02 08 0a bd 33 12 9b 00 41 d0 87
1d 10 54 3d f1 cb a3 46 c3 52 61 63 f7 1f 1f 55
```

MAC:

TBD

A.4.1.3. Send (Client) Non-SYN (Covers Options)

Send_other_traffic_key:

TBD

IPv6/TCP:

```
6e 08 91 dc 00 73 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 f7 e4 00 b3 17 6a 83 40
3f 51 99 4c c0 18 01 00 32 9c 00 00 01 01 08 0a
00 41 d0 91 bd 33 12 9b 1d 10 3d 54 bf 08 05 fe
b4 ac 7b 16 3d 6f cd f2 ff ff ff ff ff ff ff ff
ff ff ff ff ff ff ff ff 00 43 01 04 fd e8 00 b4
01 01 01 79 26 02 06 01 04 00 01 00 01 02 02 80
00 02 02 02 00 02 02 42 00 02 06 41 04 00 00 fd
e8 02 08 40 06 00 64 00 01 01 00
```

MAC:

TBD

A.4.1.4. Receive (Server) Non-SYN (Covers Options)

Receive_other_traffic_key:

TBD

IPv6/TCP:

```
6e 01 00 9e 00 73 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 00 b3 f7 e4 3f 51 99 4c
17 6a 83 83 c0 18 01 00 ee 6e 00 00 01 01 08 0a
bd 33 12 a5 00 41 d0 91 1d 10 54 3d 6c 48 12 5c
11 33 5b ab 9a 07 a7 97 ff ff ff ff ff ff ff ff
ff ff ff ff ff ff ff ff 00 43 01 04 fd e8 00 b4
01 01 01 7a 26 02 06 01 04 00 01 00 01 02 02 80
00 02 02 02 00 02 02 42 00 02 06 41 04 00 00 fd
e8 02 08 40 06 00 64 00 01 01 00
```

MAC:

TBD

A.4.2. HMAC-SHA256-128 (Omits TCP Options)

A.4.2.1. Send (Client) SYN (Omits Options)

Client ISN = 0x020c1e69

Send_SYN_traffic_key:

TBD

IPv6/TCP:

```
6e 07 8f cd 00 38 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 c6 cd 00 b3 02 0c 1e 69
00 00 00 00 e0 02 ff ff a4 1a 00 00 02 04 05 a0
01 03 03 08 04 02 08 0a 00 9d b9 5b 00 00 00 00
1d 10 3d 54 88 56 98 b0 53 0e d4 d5 a1 5f 83 46
```

MAC:

TBD

A.4.2.2. Receive (Server) SYN-ACK (Omits Options)

Server ISN = 0xeba3734d

Receive_SYN_traffic_key:

TBD

IPv6/TCP:

```
6e 0a 7e 1f 00 38 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 00 b3 c6 cd eb a3 73 4d
02 0c 1e 6a e0 12 ff ff 77 4d 00 00 02 04 05 a0
01 03 03 08 04 02 08 0a 5e c9 9b 70 00 9d b9 5b
1d 10 54 3d 3c 54 6b ad 97 43 f1 2d f8 b8 01 0d
```

MAC:

TBD

A.4.2.3. Send (Client) Non-SYN (Omits Options)

Send_other_traffic_key:

TBD

IPv6/TCP:

```
6e 07 8f cd 00 73 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 c6 cd 00 b3 02 0c 1e 6a
eb a3 73 4e c0 18 01 00 83 e6 00 00 01 01 08 0a
00 9d b9 65 5e c9 9b 70 1d 10 3d 54 48 bd 09 3b
19 24 e0 01 19 2f 5b f0 ff ff ff ff ff ff ff ff
ff ff ff ff ff ff ff ff 00 43 01 04 fd e8 00 b4
01 01 01 79 26 02 06 01 04 00 01 00 01 02 02 80
00 02 02 02 00 02 02 42 00 02 06 41 04 00 00 fd
e8 02 08 40 06 00 64 00 01 01 00
```

MAC:

TBD

A.4.2.4. Receive (Server) Non-SYN (Omits Options)

Receive_other_traffic_key:

TBD

IPv6/TCP:

```
6e 0a 7e 1f 00 73 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 00 b3 c6 cd eb a3 73 4e
02 0c 1e ad c0 18 01 00 71 6a 00 00 01 01 08 0a
5e c9 9b 7a 00 9d b9 65 1d 10 54 3d 55 9a 81 94
45 b4 fd e9 8d 9e 13 17 ff ff ff ff ff ff ff ff
ff ff ff ff ff ff ff ff 00 43 01 04 fd e8 00 b4
01 01 01 7a 26 02 06 01 04 00 01 00 01 02 02 80
00 02 02 02 00 02 02 42 00 02 06 41 04 00 00 fd
e8 02 08 40 06 00 64 00 01 01 00
```

MAC:

TBD

A.5. IPv6 KMAC256-128 Output Test Vectors

A.5.1. KMAC256-128 (Default - Covers TCP Options)

A.5.1.1. Send (Client) SYN (Covers Options)

Client ISN = 0x193cccec

Send_SYN_traffic_key:

TBD

IP/TCP:

```
6e 04 a7 06 00 38 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 f8 5a 00 b3 19 3c cc ec
00 00 00 00 e0 02 ff ff de 5d 00 00 02 04 05 a0
01 03 03 08 04 02 08 0a 13 e4 ab 99 00 00 00 00
1d 10 3d 54 59 b5 88 10 74 81 ac 6d c3 92 70 40
```

MAC:

TBD

A.5.1.2. Receive (Server) SYN-ACK (Covers Options)

Server ISN = 0xa6744ecb

Receive_SYN_traffic_key:

TBD

IPv6/TCP:

```
6e 06 15 20 00 38 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 00 b3 f8 5a a6 74 4e cb
19 3c cc ed e0 12 ff ff ea bb 00 00 02 04 05 a0
01 03 03 08 04 02 08 0a 71 da ab c8 13 e4 ab 99
1d 10 54 3d dc 28 43 a8 4e 78 a6 bc fd c5 ed 80
```

MAC:

TBD

A.5.1.3. Send (Client) Non-SYN (Covers Options)

Send_other_traffic_key:

TBD

IPv6/TCP:

```
6e 04 a7 06 00 73 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 f8 5a 00 b3 19 3c cc ed
a6 74 4e cc c0 18 01 00 32 80 00 00 01 01 08 0a
13 e4 ab a3 71 da ab c8 1d 10 3d 54 7b 6a 45 5c
0d 4f 5f 01 83 5b aa b3 ff ff ff ff ff ff ff ff
ff ff ff ff ff ff ff ff 00 43 01 04 fd e8 00 b4
01 01 01 79 26 02 06 01 04 00 01 00 01 02 02 80
00 02 02 02 00 02 02 42 00 02 06 41 04 00 00 fd
e8 02 08 40 06 00 64 00 01 01 00
```

MAC:

TBD

A.5.1.4. Receive (Server) Non-SYN (Covers Options)

Receive_other_traffic_key:

TBD

IPv6/TCP:

```
6e 06 15 20 00 73 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 00 b3 f8 5a a6 74 4e cc
19 3c cd 30 c0 18 01 00 52 f4 00 00 01 01 08 0a
71 da ab d3 13 e4 ab a3 1d 10 54 3d c1 06 9b 7d
fd 3d 69 3a 6d f3 f2 89 ff ff ff ff ff ff ff ff
ff ff ff ff ff ff ff ff 00 43 01 04 fd e8 00 b4
01 01 01 7a 26 02 06 01 04 00 01 00 01 02 02 80
00 02 02 02 00 02 02 42 00 02 06 41 04 00 00 fd
e8 02 08 40 06 00 64 00 01 01 00
```

MAC:

TBD

A.5.2. KMAC256-128 (Omits TCP Options)

A.5.2.1. Send (Client) SYN (Omits Options)

Client ISN = 0xb01da74a

Send_SYN_traffic_key:

TBD

IPv6/TCP:

```
6e 09 3d 76 00 38 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 f2 88 00 b3 b0 1d a7 4a
00 00 00 00 e0 02 ff ff 75 ff 00 00 02 04 05 a0
01 03 03 08 04 02 08 0a 14 27 5b 3b 00 00 00 00
1d 10 3d 54 3d 45 b4 34 2d e8 bb 15 30 84 78 98
```

MAC:

TBD

A.5.2.2. Receive (Server) SYN-ACK (Omits Options)

Server ISN = 0xa6246145

Receive_SYN_traffic_key:

TBD

IPv6/TCP:

```
6e 0c 60 0a 00 38 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 00 b3 f2 88 a6 24 61 45
b0 1d a7 4b e0 12 ff ff a7 0c 00 00 02 04 05 a0
01 03 03 08 04 02 08 0a 17 82 24 5b 14 27 5b 3b
1d 10 54 3d 1d 01 f6 c8 7c 6f 93 ac ff a9 d4 b5
```

MAC:

TBD

A.5.2.3. Send (Client) Non-SYN (Omits Options)

Send_other_traffic_key:

TBD

IPv6/TCP:

```
6e 09 3d 76 00 73 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 f2 88 00 b3 b0 1d a7 4b
a6 24 61 46 c0 18 01 00 c3 6d 00 00 01 01 08 0a
14 27 5b 4f 17 82 24 5b 1d 10 3d 54 29 0c f4 14
cc b4 7a 33 32 76 e7 f8 ff ff ff ff ff ff ff ff
ff ff ff ff ff ff ff ff 00 43 01 04 fd e8 00 b4
01 01 01 79 26 02 06 01 04 00 01 00 01 02 02 80
00 02 02 02 00 02 02 42 00 02 06 41 04 00 00 fd
e8 02 08 40 06 00 64 00 01 01 00
```

MAC:

TBD

A.5.2.4. Receive (Server) Non-SYN (Omits Options)

Receive_other_traffic_key:

TBD

IPv6/TCP:

```
6e 0c 60 0a 00 73 06 40 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 02 fd 00 00 00 00 00 00 00
00 00 00 00 00 00 00 01 00 b3 f2 88 a6 24 61 46
b0 1d a7 8e c0 18 01 00 34 51 00 00 01 01 08 0a
17 82 24 65 14 27 5b 4f 1d 10 54 3d 99 51 5f fc
d5 40 34 99 f6 19 fd 1b ff ff ff ff ff ff ff ff
ff ff ff ff ff ff ff ff 00 43 01 04 fd e8 00 b4
01 01 01 7a 26 02 06 01 04 00 01 00 01 02 02 80
00 02 02 02 00 02 02 42 00 02 06 41 04 00 00 fd
e8 02 08 40 06 00 64 00 01 01 00
```

MAC:

TBD

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