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The SEED Cipher Algorithm and Its Use  
with the Secure Real-Time Transport Protocol (SRTP)

Abstract

This document describes the use of the SEED block cipher algorithm in the Secure Real-time Transport Protocol (SRTP) for providing confidentiality for Real-time Transport Protocol (RTP) traffic and for the control traffic for RTP, the Real-time Transport Control Protocol (RTCP).

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## 1. Introduction

This document describes the use of the SEED [RFC4269] block cipher algorithm in the Secure Real-time Transport Protocol (SRTP) [RFC3711] for providing confidentiality for Real-time Transport Protocol (RTP) [RFC3550] traffic and for the control traffic for RTP, the Real-time Transport Control Protocol (RTCP) [RFC3550].

### 1.1. SEED

SEED is a symmetric encryption algorithm that was developed by the Korea Information Security Agency (KISA) and a group of experts, beginning in 1998. The input/output block size of SEED is 128-bit and the key length is also 128-bit. SEED has the 16-round Feistel structure. A 128-bit input is divided into two 64-bit blocks and the right 64-bit block is an input to the round function with a 64-bit subkey generated from the key scheduling.

SEED is easily implemented in various software and hardware because it is designed to increase the efficiency of memory storage and the simplicity of generating keys without degrading the security of the algorithm. In particular, it can be effectively adopted in a computing environment that has restricted resources such as mobile devices, smart cards, and so on.

SEED is a national industrial association standard [TTASSEED] and is widely used in South Korea for electronic commerce and financial services operated on wired and wireless PKI.

The algorithm specification and object identifiers are described in [RFC4269]. The SEED homepage, <http://seed.kisa.or.kr/eng/main.jsp>, contains a wealth of information about SEED, including detailed specification, evaluation report, test vectors, and so on.

### 1.2. Terminology

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].

### 1.3. Definitions

|| concatenation  
XOR exclusive or

## 2. Cryptographic Transforms

All symmetric block cipher algorithms share common characteristics, including mode, key size, weak keys, and block size. The following sections contain descriptions of the relevant characteristics of SEED.

SEED does not have any restrictions for modes of operation that are used with this block cipher. We define three modes of running SEED: (1) SEED in counter mode, (2) SEED in counter mode with CBC-MAC (CCM), and (3) SEED in Galois/Counter Mode (GCM).

### 2.1. Counter

Section 4.1.1 of [RFC3711] defines AES counter mode encryption, which that document refers to as AES-CM. SEED counter mode is defined in a similar manner and is denoted as SEED-CTR. The plaintext inputs to the block cipher are formed as in AES-CM, and the block cipher outputs are processed as in AES-CM. The only difference in the processing is that SEED-CTR uses SEED as the underlying encryption primitive. When SEED-CTR is used, it MUST be used only in conjunction with an authentication function.

#### 2.1.1. Message Authentication/Integrity: HMAC-SHA1

HMAC-SHA1 [RFC2104], as defined in Section 4.2.1 of [RFC3711], SHALL be the default message-authentication code to be used with SEED-CTR. The default session-authentication key length SHALL be 160 bits, the default authentication tag length SHALL be 80 bits, and the SRTP\_PREFIX\_LENGTH SHALL be zero for HMAC-SHA1. For SRTP, smaller values are NOT RECOMMENDED but MAY be used after careful consideration of the issues discussed in Sections 7.5 and 9.5 of [RFC3711].

### 2.2. Counter with CBC-MAC (CCM)

CCM [RFC3610] is a generic authenticate-and-encrypt block cipher mode. In this specification, CCM used with the SEED block cipher is denoted as SEED-CCM.

Section 3.3 of [RFC3711] defines procedures to construct or to authenticate and decrypt SRTP packets. For SEED-CCM, however, the sender performs Step 7 before Step 5 and the receiver performs the second half of Step 5 (verification) after Step 6. This means that authentication is performed on the plaintext rather than the ciphertext. This applies equally to SRTCP.

All SRTP packets MUST be authenticated and encrypted. Unlike SRTP, Secure Real-time Transport Control Protocol (SRTCP) packet encryption is optional (but authentication is mandatory). A sender can select which packets to encrypt and indicates this choice with a 1-bit encryption flag (located in the leftmost bit of the 32-bit word that contains the SRTCP index).

SEED-CCM has two parameters:

- M M indicates the size of the authentication tag. In SRTP, a full 80-bit authentication tag SHOULD be used and implementation of this specification MUST support M values of 10 octets.
- L L indicates the size of the length field in octets. The number of octets in the nonce MUST be 12, i.e., L is 3.

SEED-CCM has four inputs:

#### Key

A single key is used to calculate the authentication tag (using CBC-MAC) and to perform payload encryption using counter mode. SEED only supports a key size of 128 bits.

#### Nonce

The size of the nonce depends on the value selected for the parameter L. It is 15-L octets. L equals 3, and hence the nonce size equals 12 octets.

#### Plaintext

In the case of SRTP, the payload of the RTP packet, the RTP padding, and the RTP pad count field (if the latter two fields are present) are treated as plaintext.

In the case of SRTCP, when the encryption flag is set to 1, the Encrypted Portion described in Fig.2 of [RFC3711] is treated as plaintext. When the encryption flag is set to 0, the plaintext is zero-length.

#### Additional Authentication Data (AAD)

In the case of SRTP, the header of the RTP packet, including the contributing source (CSRC) identifier (if present) and the RTP header extension (if present), is considered AAD.

In the case of SRTCP, when the encryption flag is set to 0, the Authentication Portion described in Fig.2 of [RFC3711] is treated as AAD. When the encryption flag is set to 1, the first 8 octets, the encryption flag, and the SRTCP index are treated as AAD.

SEED-CCM accepts these four inputs and returns a ciphertext field.

### 2.3. Galois/Counter Mode (GCM)

GCM is a block cipher mode of operation providing both confidentiality and data origin authentication [GCM]. GCM used with the SEED block cipher is denoted as SEED-GCM.

SEED-GCM has four inputs: a key, a plaintext, a nonce, and the additional authenticated data (AAD), all described in Section 2.2.

The bit length of the tag, denoted  $t$ , is 12, and an authentication tag with a length of 12 octets (96 bits) is used.

## 3. Nonce Format for CCM and GCM

### 3.1. Nonce for SRTP

The nonce for SRTP SHALL be formed in the following way:

$$\text{Nonce} = (16 \text{ bits of zeroes} \parallel \text{SSRC} \parallel \text{ROC} \parallel \text{SEQ}) \text{ XOR Salt}$$

The 4-octet SSRC and the 2-octet SEQ SHALL be taken from the RTP header. The 4-octet ROC is from the cryptographic context. The 12-octet Salt SHALL be produced by the SRTP key derivation function.

### 3.2. Nonce for SRTCP

The nonce for SRTCP SHALL be formed in the following way:

$$\text{Nonce} = (16 \text{ bits of zeroes} \parallel \text{SSRC} \parallel 16 \text{ bits of zeroes} \parallel \text{SRTCP index}) \text{ XOR Salt}$$

The 4-octet SSRC SHALL be taken from the RTCP header and the 31-bit SRTCP index (packed zero-filled and right-justified into a 4-octet field) is from each packet. The 12-octet Salt SHALL be produced by the SRTP key derivation function.

#### 4. Key Derivation: SEED-CTR PRF

Section 4.3.3 of [RFC3711] defines the AES-128 counter mode key derivation function, which it refers to as "AES-CM PRF". The SEED-CTR PRF is defined in a similar manner, but with each invocation of AES replaced with an invocation of SEED.

The currently defined PRF, keyed by the 128-bit master key, has input block size  $m = 128$  and can produce  $n$ -bit outputs for  $n$  up to  $2^{23}$ . SEED-PRF<sub>n</sub>( $k_{\text{master}}$ ,  $x$ ) SHALL be SEED in counter mode, as described in Section 2.1; it SHALL be applied to key  $k_{\text{master}}$ , have IV equal to  $(x \cdot 2^{16})$ , and have the output keystream truncated to the first  $n$  (leftmost) bits.

#### 5. Mandatory-to-Implement Transforms

"Mandatory-to-implement" means conformance to this specification, and that Table 1 in this document does not supercede a similar table in Section 5 of [RFC3711]. An RTP implementation that supports SEED MUST implement the modes listed in Table 1 of this document.

|                      | mandatory-to-implement | optional           |
|----------------------|------------------------|--------------------|
| encryption           | SEED-CTR               | SEED-CCM, SEED-GCM |
| message integrity    | HMAC-SHA1              | SEED-CCM, SEED-GCM |
| key derivation (PRF) | SEED-CTR               | -                  |

Table 1: Mandatory-to-implement and optional transforms in SRTP and SRTCP

#### 6. Security Considerations

No security problem has been found on SEED. SEED is secure against all known attacks, including differential cryptanalysis, linear cryptanalysis, and related key attacks. The best known attack is only an exhaustive search for the key. For further security considerations, the reader is encouraged to read [SEED-EVAL].

See [RFC3610] and [GCM] for security considerations regarding the CCM and GCM Modes of Operation, respectively. In the context of SRTP, the procedures in [RFC3711] ensure the critical property of non-reuse of counter values.

## 7. IANA Considerations

[RFC4568] defines SRTP "crypto suites". In order to allow the Session Description Protocol (SDP) to signal the use of the algorithms defined in this document, IANA has registered the following crypto suites into the subregistry for SRTP crypto suites under the Media Stream Transports of the SDP Security Descriptions:

```
SEED_CTR_128_HMAC_SHA1_80
SEED_128_CCM_80
SEED_128_GCM_96
```

## 8. Acknowledgements

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## 9. References

### 9.1. Normative References

- [GCM] Dworkin, M., "NIST Special Publication 800-38D: Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC", U.S. National Institute of Standards and Technology, <http://csrc.nist.gov/publications/nistpubs/800-38D/SP-800-38D.pdf>
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- [RFC4269] Lee, H., Lee, S., Yoon, J., Cheon, D., and J. Lee, "The SEED Encryption Algorithm", RFC 4269, December 2005.
- [RFC4568] Andreasen, F., Baugher, M., and D. Wing, "Session Description Protocol (SDP) Security Descriptions for Media Streams", RFC 4568, July 2006.
- [TTASSEED] Telecommunications Technology Association (TTA), South Korea, "128-bit Symmetric Block Cipher (SEED)", TTAS.KO-12.0004/R1, December 2005, (In Korean)  
<http://www.tta.or.kr/English/index.jsp>.

## 9.2. Informative References

- [SEED-EVAL] KISA, "Self Evaluation Report",  
<http://seed.kisa.or.kr/eng/main.jsp>

## Appendix A. Test Vectors

All values are in hexadecimal.

## A.1. SEED-CTR Test Vectors

|                        |   |
|------------------------|---|
| Session Key:           | 0c5ffd37a11edc42c325287fc0604f2e  |
| Rollover Counter:      | 00000000  |
| Sequence Number:       | 315e  |
| SSRC:                  | 20e8f5eb  |
| Authentication Key:    | f93563311b354748c978913795530631  |
| Session Salt:          | cd3a7c42c671e0067a2a2639b43a  |
| Initialization Vector: | cd3a7c42e69915ed7a2a263985640000  |
| RTP Payload:           | f57af5fd4ae19562976ec57a5a7ad55a<br>5af5c5e5c5fdf5c55ad57a4a7272d572<br>62e9729566ed66e97ac54a4a5a7ad5e1<br>5ae5fdd5fd5ac5d56ae56ad5c572d54a<br>e54ac55a956afd6aed5a4ac562957a95<br>16991691d572fd14e97ae962ed7a9f4a<br>955af572e162f57a956666e17aelf54a<br>95f566d54a66e16e4afd6a9f7aelfc5c5<br>5ae5d56afde916c5e94a6ec56695e14a<br>fde1148416e94ad57ac5146ed59d1cc5 |
| Encrypted RTP Payload: | df5a89291e7e383e9beff765e691a737<br>49c9e33139ad3001cd8da73ad07f69a2<br>805a70358b5c7c8c60ed359f95cf5e08<br>f713c53ff7b808250d79a19ccb8d1073<br>4e3cb72ed1f0a4e85b002b248049ab07<br>63dbe571bec52cf9153fdf2019e421ef<br>779cd6f4bd1c8211da8c272e2fce4393<br>4b9eabb87362510f254149f992599036<br>f5e43102327db1ac5e78adc4f66546ed<br>7abfb5a4db320fb7b9c52a61bc554e44  |
| Authentication Tag:    | a5cdaa4d9edc53763855  |

## A.2. SEED-CCM Test Vectors

Key: 974bee725d44fc3992267b284c3c6750

Rollover Counter: 00000000

Sequence Number: 315e

SSRC: 20e8f5eb

Nonce: 000020e8f5eb00000000315e

Payload: f57af5fd4ae19562976ec57a5a7ad55a  
5af5c5e5c5fdf5c55ad57a4a7272d572  
62e9729566ed66e97ac54a4a5a7ad5e1  
5ae5fdd5fd5ac5d56ae56ad5c572d54a  
e54ac55a956afd6aed5a4ac562957a95  
16991691d572fd14e97ae962ed7a9f4a  
955af572e162f57a956666e17aelf54a  
95f566d54a66e16e4afd6a9f7aelfc5c5  
5ae5d56afde916c5e94a6ec56695e14a  
fde1148416e94ad57ac5146ed59d1cc5

AAD: 8008315ebf2e6fe020e8f5eb

Encrypted RTP Payload: 486843a881df215a8574650ddabf5dbb  
2650f06f51252bccae4012899d6d71e  
30c64dad5ead5d8ba65ffe9d79aaf30d  
c9e6334490c07e7533d704114a9006ec  
b3b3bff59ecf585485bc0bd286ed434c  
fd684d19a1ad514ca5f37b71d93288c0  
7cf4d5e9b83db8becc8c692a7279b6a9  
ac62ba970fc54f46dcc926d434c0b5ad  
8678fbf0e7a03037924dae342ef64fa6  
5b8eaea260fecb477a57e3919c5dab82

Authentication Tag: b0a8274cf6a8bb6cc466

## A.3. SEED-GCM Test Vectors

Key: e91e5e75da65554a48181f3846349562

Rollover Counter: 00000000

Sequence Number: 315e

SSRC: 20e8f5eb

Nonce: 000020e8f5eb00000000315e

Payload: f57af5fd4ae19562976ec57a5a7ad55a  
5af5c5e5c5fdf5c55ad57a4a7272d572  
62e9729566ed66e97ac54a4a5a7ad5e1  
5ae5fdd5fd5ac5d56ae56ad5c572d54a  
e54ac55a956afd6aed5a4ac562957a95  
16991691d572fd14e97ae962ed7a9f4a  
955af572e162f57a956666e17aelf54a  
95f566d54a66e16e4afd6a9f7aelfc5c5  
5ae5d56afde916c5e94a6ec56695e14a  
fde1148416e94ad57ac5146ed59d1cc5

AAD: 8008315ebf2e6fe020e8f5eb

Encrypted RTP Payload: 8a5363682c6b1bbf13c0b09cf747a551  
2543cb2f129b8bd0e92dfadf735cda8f  
88c4bbf90288f5e58d20c4f1bb0d5844  
6ea009103ee57ba99cdeabaaa18d4a9a  
05ddb46e7e5290a5a2284fe50b1f6fe9  
ad3f1348c354181e85b24f1a552a1193  
cf0e13eed5ab95ae854fb4f5b0edb2d3  
ee5eb238c8f4bfb136b2eb6cd7876042  
0680ce1879100014f140a15e07e70133  
ed9cbb6d57b75d574acb0087eefbac99

Authentication Tag: 36cd9ae602be3ee2cd8d5d9d

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