

A 224-bit One-way Hash Function: SHA-224

Status of this Memo

This memo provides information for the Internet community. It does not specify an Internet standard of any kind. Distribution of this memo is unlimited.

Copyright Notice

Copyright (C) The Internet Society (2004).

Abstract

This document specifies a 224-bit one-way hash function, called SHA-224. SHA-224 is based on SHA-256, but it uses a different initial value and the result is truncated to 224 bits.

1. Introduction

This document specifies a 224-bit one-way hash function, called SHA-224. The National Institute of Standards and Technology (NIST) announced the FIPS 180-2 Change Notice on February 28, 2004 which specifies the SHA-224 one-way hash function. One-way hash functions are also known as message digests. SHA-224 is based on SHA-256, the 256-bit one-way hash function already specified by NIST [SHA2]. Computation of a SHA-224 hash value is two steps. First, the SHA-256 hash value is computed, except that a different initial value is used. Second, the resulting 256-bit hash value is truncated to 224 bits.

NIST is developing guidance on cryptographic key management, and NIST recently published a draft for comment [NISTGUIDE]. Five security levels are discussed in the guidance: 80, 112, 128, 192, and 256 bits of security. One-way hash functions are available for all of these levels except one. SHA-224 fills this void. SHA-224 is a one-way hash function that provides 112 bits of security, which is the generally accepted strength of Triple-DES [3DES].

This document makes the SHA-224 one-way hash function specification available to the Internet community, and it publishes the object identifiers for use in ASN.1-based protocols.

1.1. Usage Considerations

Since SHA-224 is based on SHA-256, roughly the same amount of effort is consumed to compute a SHA-224 or a SHA-256 digest message digest value. Even though SHA-224 and SHA-256 have roughly equivalent computational complexity, SHA-224 is an appropriate choice for a one-way hash function that provides 112 bits of security. The use of a different initial value ensures that a truncated SHA-256 message digest value cannot be mistaken for a SHA-224 message digest value computed on the same data.

Some usage environments are sensitive to every octet that is transmitted. In these cases, the smaller (by 4 octets) message digest value provided by SHA-224 is important.

These observations lead to the following guidance:

- * When selecting a suite of cryptographic algorithms that all offer 112 bits of security strength, SHA-224 is an appropriate choice for one-way hash function.
- * When terseness is not a selection criteria, the use of SHA-256 is a preferred alternative to SHA-224.

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 [STDWORDS].

2. SHA-224 Description

SHA-224 may be used to compute a one-way hash value on a message whose length less than 2^{64} bits.

SHA-224 makes use of SHA-256 [SHA2]. To compute a one-way hash value, SHA-256 uses a message schedule of sixty-four 32-bit words, eight 32-bit working variables, and produces a hash value of eight 32-bit words.

The function is defined in the exact same manner as SHA-256, with the following two exceptions:

First, for SHA-224, the initial hash value of the eight 32-bit working variables, collectively called H, shall consist of the following eight 32-bit words (in hex):

```
H_0 = c1059ed8      H_4 = ffc00b31
H_1 = 367cd507      H_5 = 68581511
H_2 = 3070dd17      H_6 = 64f98fa7
H_3 = f70e5939      H_7 = befa4fa4
```

Second, SHA-224 simply makes use of the first seven 32-bit words in the SHA-256 result, discarding the remaining 32-bit words in the SHA-256 result. That is, the final value of H is used as follows, where `||` denotes concatenation:

```
H_0 || H_1 || H_2 || H_3 || H_4 || H_5 || H_6
```

3. Test Vectors

This section includes three test vectors. These test vectors can be used to test implementations of SHA-224.

3.1. Test Vector #1

Let the message to be hashed be the 24-bit ASCII string "abc", which is equivalent to the following binary string:

```
01100001 01100010 01100011
```

The SHA-224 hash value (in hex):

```
23097d22 3405d822 8642a477 bda255b3 2aadbce4 bda0b3f7 e36c9da7
```

3.2. Test Vector #2

Let the message to be hashed be the 448-bit ASCII string "abcdbcdecdefdefgefghfghighijhijkijklklmklmnlmnomnopnopq".

The SHA-224 hash value is (in hex):

```
75388b16 512776cc 5dba5da1 fd890150 b0c6455c b4f58b19 52522525
```

3.3. Test Vector #3

Let the message to be hashed be the binary-coded form of the ASCII string which consists of 1,000,000 repetitions of the character "a".

The SHA-224 hash value is (in hex):

```
20794655 980c91d8 bbb4c1ea 97618a4b f03f4258 1948b2ee 4ee7ad67
```

4. Object Identifier

NIST has assigned an ASN.1 [X.208-88, X.209-88] object identifier for SHA-224. Some protocols use object identifiers to name one-way hash functions. One example is CMS [CMS]. Implementations of such protocols that make use of SHA-224 MUST use the following object identifier.

```
id-sha224 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
    country(16) us(840) organization(1) gov(101)
    csor(3) nistalgorithm(4) hashalgs(2) sha224(4) }
```

5. Security Considerations

One-way hash functions are typically used with other cryptographic algorithms, such as digital signature algorithms and keyed-hash message authentication codes, or in the generation of random values. When a one-way hash function is used in conjunction with another algorithm, there may be requirements specified elsewhere that require the use of a one-way hash function with a certain number of bits of security. For example, if a message is being signed with a digital signature algorithm that provides 128 bits of security, then that signature algorithm may require the use of a one-way hash algorithm that also provides the same number of bits of security. SHA-224 is intended to provide 112 bits of security, which is the generally accepted strength of Triple-DES [3DES].

This document is intended to provide the SHA-224 specification to the Internet community. No independent assertion of the security of this one-way hash function is intended by the author for any particular use. However, as long as SHA-256 provides the expected security, SHA-224 will also provide its expected level of security.

6. References

6.1. Normative References

- [SHA2] Federal Information Processing Standards Publication (FIPS PUB) 180-2, Secure Hash Standard, 1 August 2002.
- [STDWORDS] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

6.2. Informative References

- [3DES] American National Standards Institute. ANSI X9.52-1998, Triple Data Encryption Algorithm Modes of Operation. 1998.
- [CMS] Housley, R., "Cryptographic Message Syntax (CMS)", RFC 3852, July 2004.
- [NISTGUIDE] National Institute of Standards and Technology. Second Draft: "Key Management Guideline, Part 1: General Guidance." June 2002.
[<http://csrc.nist.gov/encryption/kms/guideline-1.pdf>]
- [X.208-88] CCITT Recommendation X.208: Specification of Abstract Syntax Notation One (ASN.1). 1988.
- [X.209-88] CCITT Recommendation X.209: Specification of Basic Encoding Rules for Abstract Syntax Notation One (ASN.1). 1988.

7. Acknowledgments

Many thanks to Jim Schaad for generating the test vectors. A second implementation by Brian Gladman was used to confirm that the test vectors are correct.

8. Author's Address

Russell Housley
Vigil Security, LLC
918 Spring Knoll Drive
Herndon, VA 20170
USA

EMail: housley@vigilsec.com

9. Full Copyright Statement

Copyright (C) The Internet Society (2004).

This document is subject to the rights, licenses and restrictions contained in BCP 78, and except as set forth therein, the authors retain all their rights.

This document and the information contained herein are provided on an "AS IS" basis and THE CONTRIBUTOR, THE ORGANIZATION HE/S HE REPRESENTS OR IS SPONSORED BY (IF ANY), THE INTERNET SOCIETY AND THE INTERNET ENGINEERING TASK FORCE DISCLAIM ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OR ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Intellectual Property

The IETF takes no position regarding the validity or scope of any Intellectual Property Rights or other rights that might be claimed to pertain to the implementation or use of the technology described in this document or the extent to which any license under such rights might or might not be available; nor does it represent that it has made any independent effort to identify any such rights. Information on the IETF's procedures with respect to rights in IETF Documents can be found in BCP 78 and BCP 79.

Copies of IPR disclosures made to the IETF Secretariat and any assurances of licenses to be made available, or the result of an attempt made to obtain a general license or permission for the use of such proprietary rights by implementers or users of this specification can be obtained from the IETF on-line IPR repository at <http://www.ietf.org/ipr>.

The IETF invites any interested party to bring to its attention any copyrights, patents or patent applications, or other proprietary rights that may cover technology that may be required to implement this standard. Please address the information to the IETF at ietf-ipr@ietf.org.

Acknowledgement

Funding for the RFC Editor function is currently provided by the Internet Society.

