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

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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 "abcdbcdecdefdefgefghfghighijhijkijkljklmklmnlmnomnopnopq".

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

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