openHPI – Confidential Communication in the Internet

Cryptographic Hash Functions

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Cryptographic Hash Functions
Introduction

In information security, hash methods are used to generate "fingerprints" for documents, which characterize a possibly large document as unambiguously as possible by means of a short string with a fixed number of characters

Objectives:

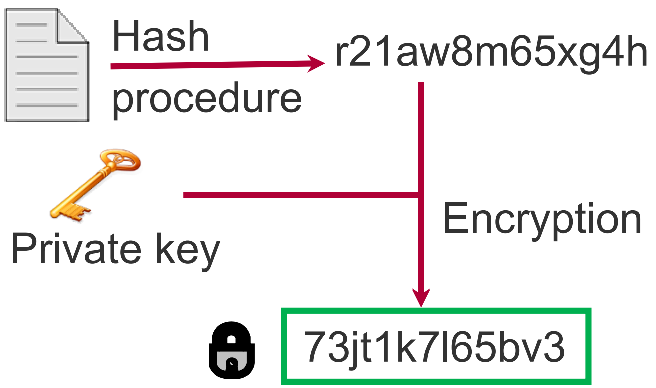
- "Compression" of a document to a fixed length string of e.g. 256 bits, which is "practically" irreversible (computation need centuries) → "**one-way hash function**"
- It should be very difficult to find a second document with exactly the same hash value → "**collision resistance**"

Cryptographic Hash Functions
Basic Idea

Hash functions transform every input into an output of fixed length, e.g. 256 bit

- Complex cryptographic procedures (e.g. digital signature) need not be applied to the (long) document, but only to its (short) hash value
- In order to ensure one-way properties, special types of hash function are required, so-called **cryptographic hash functions**

Example for applying hash-functions to sign a document:



Hash procedure

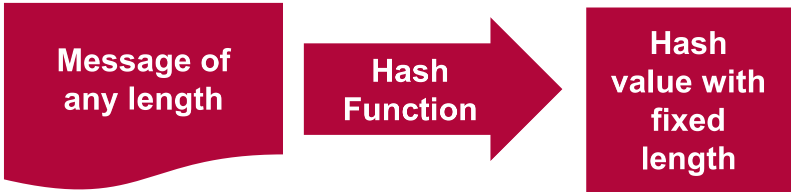
r21aw8m65xg4h

Private key

Encryption

73jt1k7l65bv3

Cryptographic Hash Functions



Some Definitions:

Hash-function h is

- **Collision free for a message M**, if it is practically impossible to construct a message M�much different from M with h(M') = h(M)
- **Collision-free**, if it is practically impossible to find two different messages M and M‵ with h(M') = h(M)
- **One-way function**, if it is practically impossible to find a message M for a given hash value z with z = h(M)

Cryptographic hash functions are collision-free hash functions

Length of Hash Values

The Length of the hash values plays an important role:

Birthday paradox:

- In a group of $k = 23$ randomly selected people, there is a probability $>1/2$ that the birthday of at least 2 people has the same date in a year ($n = 365$)

Application:

Hash value length **40-bit**:

- With probability $>1/2$ there is a collision with "only‟ $k = 2^{20}$ (about 1 million) random values - hash value is thus quite uncertain

Hash value length **256-bit** recommended length:

- With probability $>1/2$ there is a collision at $k = 2^{128}$ random values

Attacks on Cryptographic Hash Functions

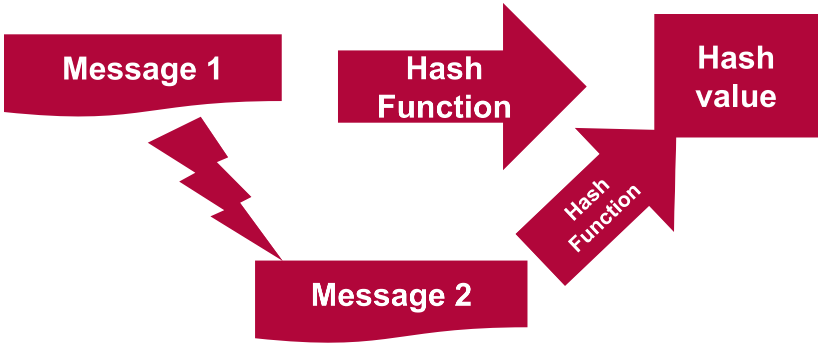
Target of the attacks:

Here no keys are searched for but rather collisions

- Finding two different messages with the same hash value
- Finding a new message with a given hash value

Attention: Birthday Attack

- When modifying messages to create messages with the same hash value, $2^{n/2}$ attempts are sufficient
- Protection: Longer hash values, e.g. 192 bit or 256 bit



Popular Hash Functions
SHA - Secure Hash Algorithm (1/2)

SHA - Secure Hash Algorithm – was developed by NSA in 1993

- SHA-1 (1995 revision of SHA) generates hash values of length 160 bit

Theoretical weaknesses of SHA-1:

- February 2005: Chinese team finds (theoretical) approach to crack SHA-1 by (2^{69} attempts)
- August 2005: Another successful attack (2^{63} attempts)
- February 2017: First published collision of SHA-1 (2 different PDF documents with same checksum)
- Current difficulty: $2^{57.5}$ attempts

Hence: Cracking an SHA-1 hash value costs less than $50.000 today when renting computing power from a cloud provider

Popular Hash Functions
SHA - Secure Hash Algorithm (2/2)

SHA-2 - (family of) successor(s) to SHA-1 from 2002

- SHA-2 family includes SHA-224, SHA-256, SHA-384, SHA-512
- SHA-256 is one of the most common cryptographic hash functions and was standardized in 2002
- SHA-256 processes 512-bit blocks (last block may need to be filled up) and generates 256-bit hash values for each

Example:

SHA-256("Franz chases in a completely neglected taxi across Bavaria") **=**

d32b568cd1b96d459e7291ebf4b25d007f275c9f13149beeb782fac0716613f8

Other Common Cryptographic Hash Functions

MD4 and MD5

- Lack of collision safety

RIPE-MD

- Different variants (128, 160, 256, 320 length of the hash)
- Collision attacks possible in original RIPE-MD

Jacuzzi

- 512-bit hash value
- AES variant for encryption

SHA-3 (Keccak)

- Standardized in October 2012
- Alternative algorithm to SHA-2