Message authentication and hash functions

Message authentication

Message (or document) is **authentic** if

- It is genuine and
- came from its alleged source.

Message authentication is a **procedure** which verifies that received messages are authentic

Aspects of message authentication

We would like to ensure that

- The content of the message has not been changed;
- The source of the message is authentic;
- The message has not been delayed and replayed;

Message authentication techniques

- **Using conventional message encryption:**

  if we assume that only sender and receiver share a secret key then the fact that receiver can successfully decrypt the message means the message has been encrypted by the sender

- **Without message encryption**

  The message is not encrypted, but special authentication tag is generated and appended to the message. Generation of a tag is a much more efficient procedure that encryption of the message.

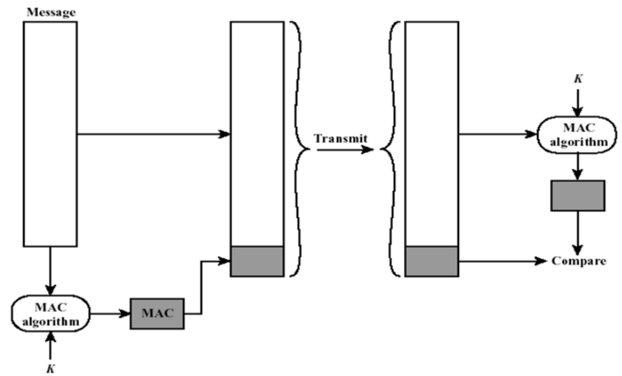
Message Authentication Code

- Let *A* and *B* share a common secret key *K*
- If *A* would like to send a message *M* to *B*, she calculates a message authentication code *MAC* of *M* using the key *K* :

  $$MAC = F(K,M)$$

- Then *A* appends *MAC* to *M* and sends all this to *B;*
- *B* applies the *MAC* algorithm to the received message and compares the result with the received *MAC*

Message authentication using MAC



MAC algorithms

- The process of MAC generation is similar to the encryption;
- The difference is a MAC algorithm need not be reversible → easier to implement and less vulnerable to being broken;
- Actually, standard encryption algorithms can be used for MAC generation:
  - For example, a message may be encrypted with DES and then last 16 or 32 bits of the encrypted text may be used as MAC

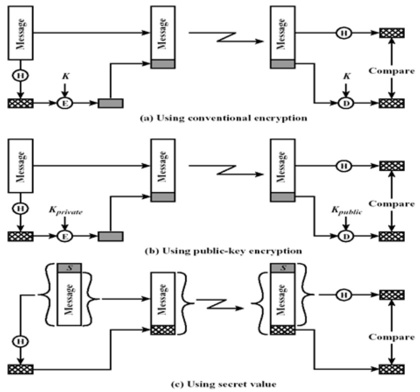
One-way Hash functions

- An alternative method for the message authentication is to use one-way hash functions instead of MAC;
- The main difference is hash functions don't use a secret key:

  $$h = H(M);$$

- "One-way" in the name refers to the property of such functions: they are easy to compute, but their reverse functions are very difficult to compute.

Methods of authentication using hashes



Hash function requirements

To be suitable for message authentication, the hash functions must have ideally the following properties:

- *H* can be applied to a block of data of any size;
- *H* produces a fixed-length output;
- *H(x)* is easy to compute for any given *x*;
- For any value *h* it is very difficult (infeasible) to compute *x* such that *H(x)=h* (**one-way property**);
- For any given *x*, it is very difficult (infeasible) to find *y* (not equal to *x*) such that *H(x) = H(y);* (**weak collision resistance**);
- It is very difficult (infeasible) to find any pair (x,y) such that H(x) = H(y); (**strong collision resistance**).

Simple hash function

- Let the input be a sequence of *n*-bit blocks
- Then simple hash function does bit-by-bit exclusive-OR (XOR) of every block

	bit 1	bit 2	• • •	bit n
block 1	b_{11}	b_{21}		b_{n1}
block 2	b_{12}	b_{22}		b_{n2}
	• • •	• • •	• • •	• • •
block m	b_{1m}	b_{2m}		b_{nm}
hash code	C_1	C_2		C_n

Simple hash function

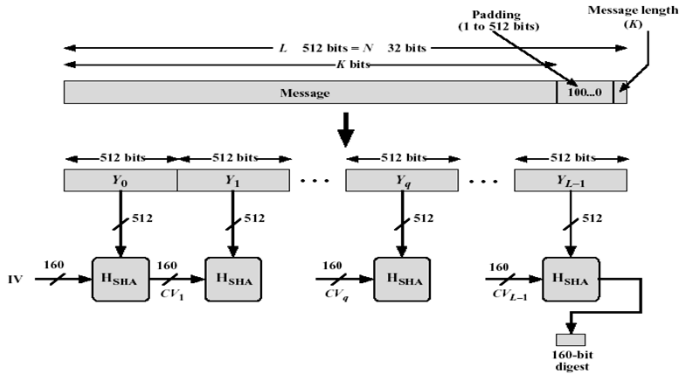
- Simple hash function does not satisfy **the weak (and strong) collision property**;
- for any message M it is very easy to generate a message M_1 such that h(M) = h(M_1):
  - Take arbitrary message M_2, compute h(M_2) = h_2 , then
  - Add additional block to M_2, such that for the resulting M_3 we have h(M_3) = h(M_1).

The SHA-1 Secure Hash Algorithm

SHA-1 algorithm (1993-1995):

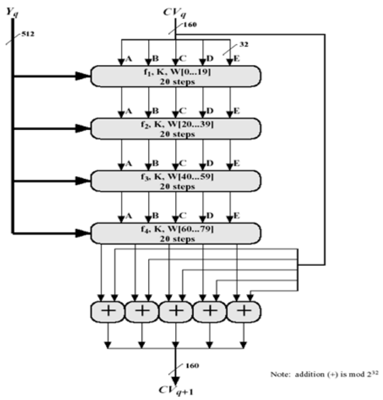
- It has been used in the sample program illustrating password-based encryption (practical sessions);
- Takes as input a message with a maximum length less than 2 to power 64 bits and produces as output a 160-bit message digest;
- The input is processed in 512-bit blocks;
- Each bit of the output is computed using all bits of the input.

SHA-1 general scheme



SHA-1 processing a single block

- The compression function;
- Includes 4 rounds with 20 steps each;
- Each round takes the current 512-bits block and 160-bit buffer value and updates the content of the buffer.



Problems and Solutions

- In 2005 a possible mathematical weakness of SHA-1 has been established:
  - ~2000 time more efficient than brute force search attack was found by Xiaoyun Wang
- Further developments: SHA-2: (SHA-224,-256,-384,-512)
- New competition for the new standard of hash functions by NIST:
  - Deadline for submissions was 31.10.2008
  - New standard SHA-3 is announced a winner on 2nd October 2012; not a replacement, but alternative for SHA-2