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;

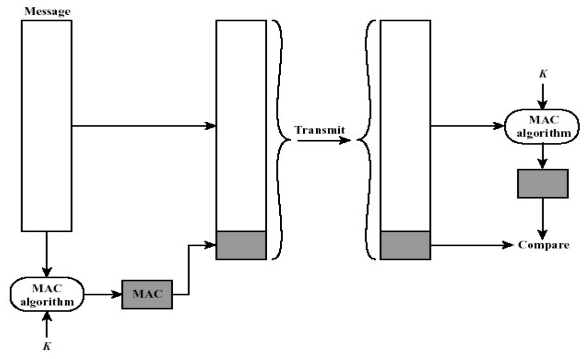
Message authentication techniques

- **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



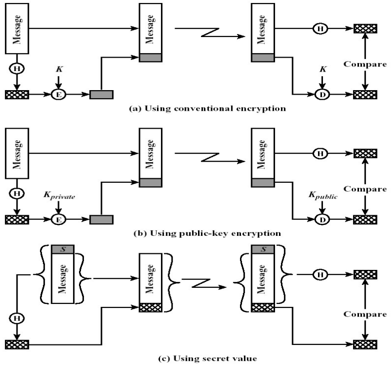
MAC algorithms

- 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
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	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

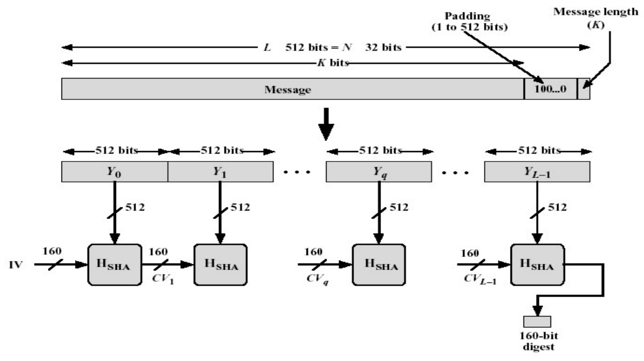
Simple hash function

- 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

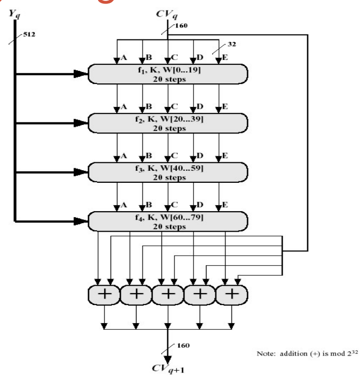
- **SHA-1 algorithm (1993-1995):**
- It has been used in the sample program illustrating password-based encryption (practical sessions);
- Takes as input a message with a maximum length
- less than 2 to power 64 bits and produces as output a 160-bit message digest;
- The input is processed in 512-bit 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

Recent News

- ***SHAppening,*** October 2015 “freestart” collision attack (by M. Stevens, P, Karpman, T. Peyrin)
- ~ US $2000 of GPU time on EC2, est.
- ***SHAttered,*** February 2017, full collision attack
- (by Google)
- ~ 6,500 years of CPU time