# 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**

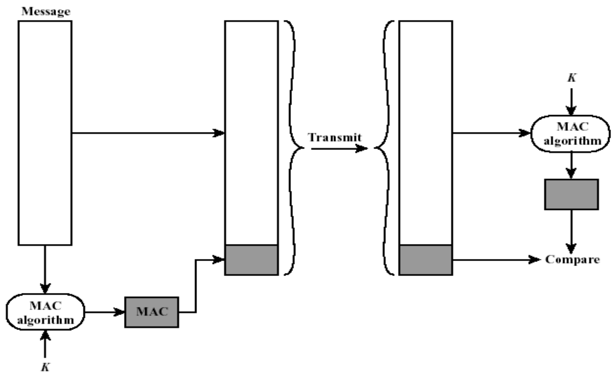
  The message is not encrypted, but special authentication tag is generated and appended to the message. Generation of a tag is a much more efficient procedure that encryption of the message.

# 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

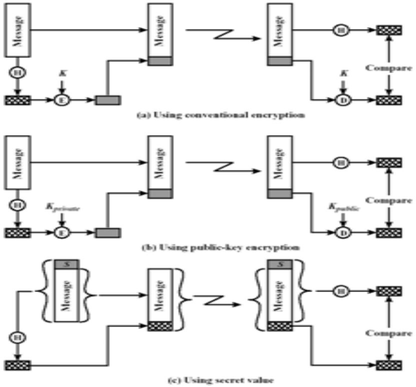
- The process of MAC generation is similar to the encryption;
- The difference is a MAC algorithm need not be reversible → easier to implement and less vulnerable to being broken;
- Actually, standard encryption algorithms can be used for MAC generation:
  - For example, a message may be encrypted with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



(a) Using conventional encryption

(b) Using public-key encryption

(c) Using secret value

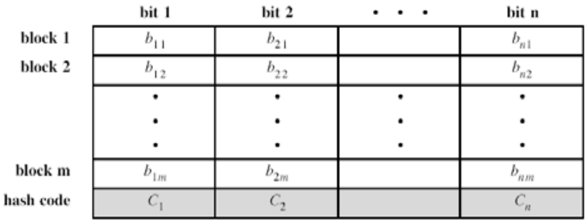
# Hash function requirements

**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 | $b_{12}$ | $b_{22}$ | | $b_{n2}$ |
| | •<br>•<br>• | •<br>•<br>• | •<br>•<br>• | •<br>•<br>• |
| block m | $b_{1m}$ | $b_{2m}$ | | $b_{nm}$ |
| hash code | $C_1$ | $C_2$ | | $C_n$ |

# Simple hash function

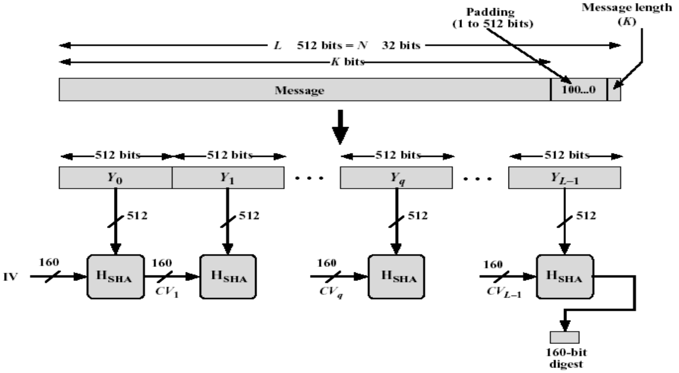
- Simple hash function does not satisfy **the weak (and strong) collision property**;
- for any message M it is very easy to generate a message $M_1$ such that h(M) = h($M_1$):
  - Take arbitrary message $M_2$, compute h($M_2$) = $h_2$ , then
  - Add additional block to $M_2$, such that for the resulting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

# The SHA-1 Secure Hash Algorithm

**SHA-1 algorithm (1993-1995):**

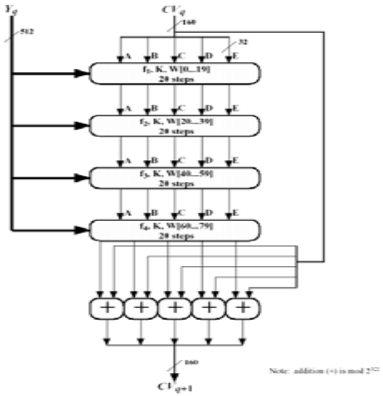
- It has been used in the sample program illustrating password-based encryption (practical sessions);
- Takes as input a message with a maximum length less than 2 to power 64 bits and produces as output a 160-bit message digest;
- The input is processed in 512-bit blocks;
- Each bit of the output is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

# SHA-1 general scheme



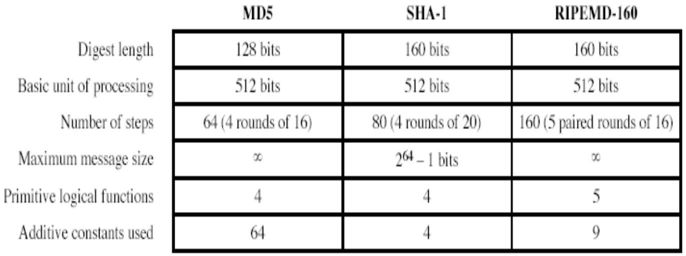
# SHA-1 processing a single block

- 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.



Note: addition (+) is mod $2^{32}$

# Other Secure Hash functions



| | MD5 | SHA-1 | RIPEMD-160 |
|---|---|---|---|
| Digest length | 128 bits | 160 bits | 160 bits |
| Basic unit of processing | 512 bits | 512 bits | 512 bits |
| Number of steps | 64 (4 rounds of 16) | 80 (4 rounds of 20) | 160 (5 paired rounds of 16) |
| Maximum message size | ∞ | $2^{64} - 1$ bits | ∞ |
| Primitive logical functions | 4 | 4 | 5 |
| Additive constants used | 64 | 4 | 9 |