

Sicurezza

CdL in Informatica – L31

Lezione 2 – Capitolo 2

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Chapter 2

Cryptographic Tools



Symmetric Encryption

- The universal technique for providing confidentiality for transmitted or stored data
- Also referred to as conventional encryption or single-key encryption
- Two requirements for secure use:
 - Need a strong encryption algorithm
 - Sender and receiver must have obtained copies of the secret key in a secure fashion and must keep the key secure

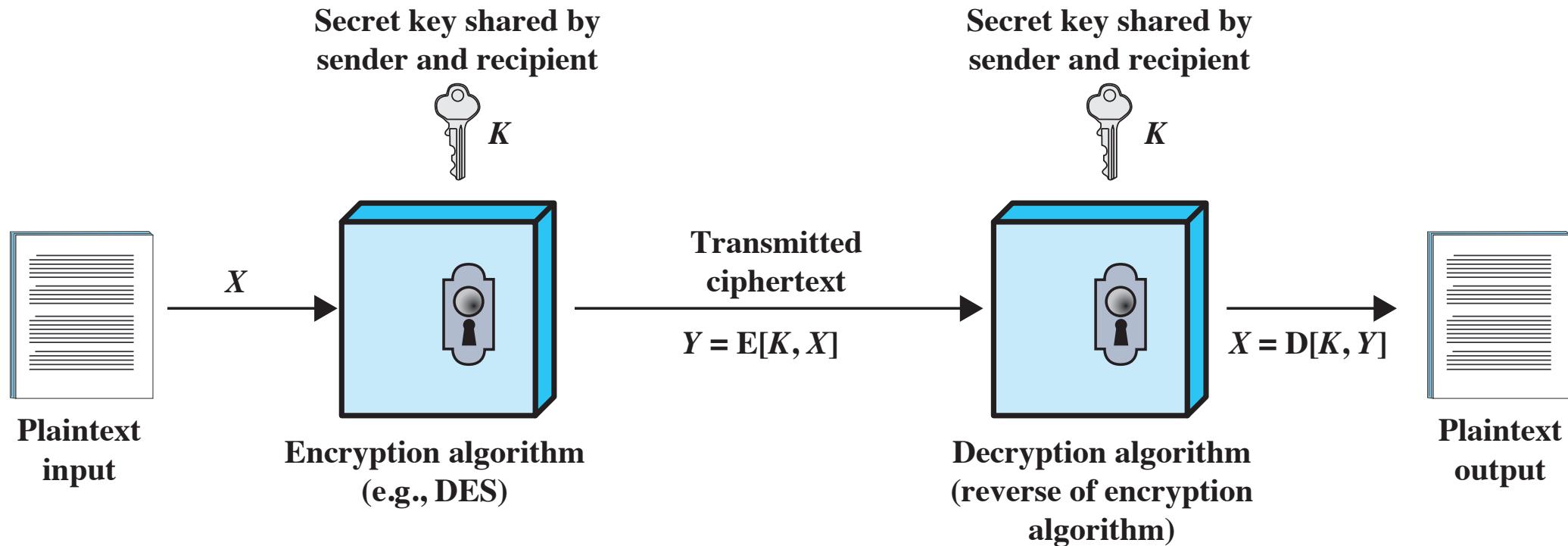


Figure 2.1 Simplified Model of Symmetric Encryption

Attacking Symmetric Encryption

Cryptanalytic Attacks

- Rely on:
 - Nature of the algorithm
 - Some knowledge of the general characteristics of the plaintext
 - Some sample plaintext-ciphertext pairs
- Exploits the characteristics of the algorithm to attempt to deduce a specific plaintext or the key being used
 - If successful all future and past messages encrypted with that key are compromised

Attacking Symmetric Encryption

Brute-Force Attacks

- Try all possible keys on some ciphertext until an intelligible translation into plaintext is obtained
 - On average half of all possible keys must be tried to achieve success

Table 2.1

	DES	Triple DES	AES
Plaintext block size (bits)	64	64	128
Ciphertext block size (bits)	64	64	128
Key size (bits)	56	112 or 168	128, 192, or 256

DES = Data Encryption Standard

AES = Advanced Encryption Standard



Comparison of Three Popular Symmetric Encryption Algorithms

Data Encryption Standard (DES)

- Until recently was the most widely used encryption scheme
 - Referred to as the Data Encryption Algorithm (DEA)
 - Uses 64 bit plaintext block and 56 bit key to produce a 64 bit ciphertext block
- Strength concerns:
 - Concerns about the algorithm itself
 - DES is the most studied encryption algorithm in existence
 - Concerns about the use of a 56-bit key
 - The speed of commercial off-the-shelf processors makes this key length woefully inadequate

Table 2.2: Average Time Required for Exhaustive Key Search

Key size (bits)	Cipher	Number of Alternative Keys	Time Required at 10^9 decryptions/s	Time Required at 10^{13} decryptions/s
56	DES	$2^{56} \approx 7.2 \times 10^{16}$	$2^{55} \text{ ns} = 1.125 \text{ years}$	1 hour
128	AES	$2^{128} \approx 3.4 \times 10^{38}$	$2^{127} \text{ ns} = 5.3 \times 10^{21}$ years	5.3×10^{17} years
168	Triple DES	$2^{168} \approx 3.7 \times 10^{50}$	$2^{167} \text{ ns} = 5.8 \times 10^{33}$ years	5.8×10^{29} years
192	AES	$2^{192} \approx 6.3 \times 10^{57}$	$2^{191} \text{ ns} = 9.8 \times 10^{40}$ years	9.8×10^{36} years
256	AES	$2^{256} \approx 1.2 \times 10^{77}$	$2^{255} \text{ ns} = 1.8 \times 10^{60}$ years	1.8×10^{56} years

Triple DES (3DES)

- Repeats basic DES algorithm three times using either two or three unique keys
- First standardized for use in financial applications in ANSI standard X9.17 in 1985
- Attractions:
 - 168-bit key length overcomes the vulnerability to brute-force attack of DES
 - Underlying encryption algorithm is the same as in DES
- Drawbacks:
 - Algorithm is sluggish in software
 - Uses a 64-bit block size

Advanced Encryption Standard (AES)

Needed a replacement for 3DES

3DES was not reasonable for long term use

NIST called for proposals for a new AES in 1997

Should have a security strength equal to or better than 3DES

Significantly improved efficiency

Symmetric block cipher

128 bit data and 128/192/256 bit keys

Selected Rijndael in November 2001

Published as FIPS 197

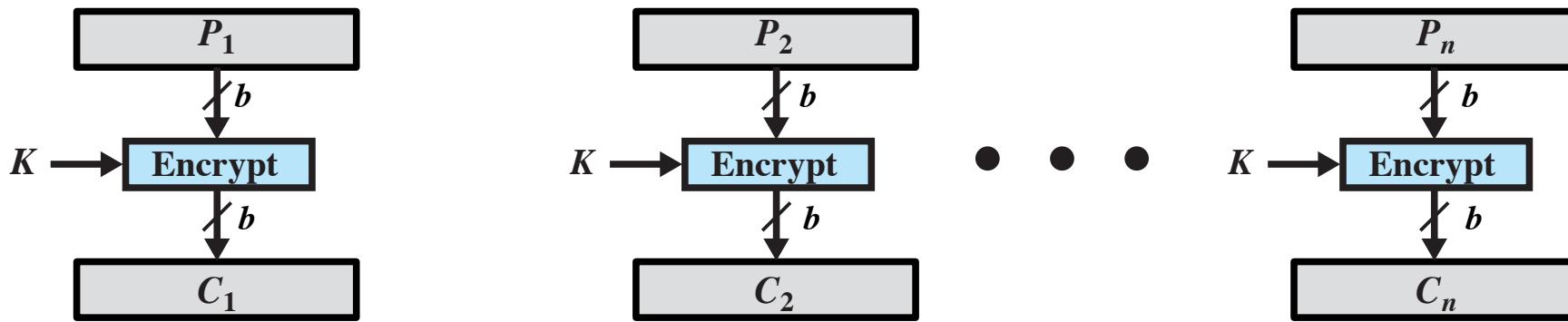
Practical Security Issues

- Typically symmetric encryption is applied to a unit of data larger than a single 64-bit or 128-bit block
- Electronic codebook (ECB) mode is the simplest approach to multiple-block encryption
 - Each block of plaintext is encrypted using the same key
 - Cryptanalysts may be able to exploit regularities in the plaintext
- Modes of operation
 - Alternative techniques developed to increase the security of symmetric block encryption for large sequences
 - Overcomes the weaknesses of ECB

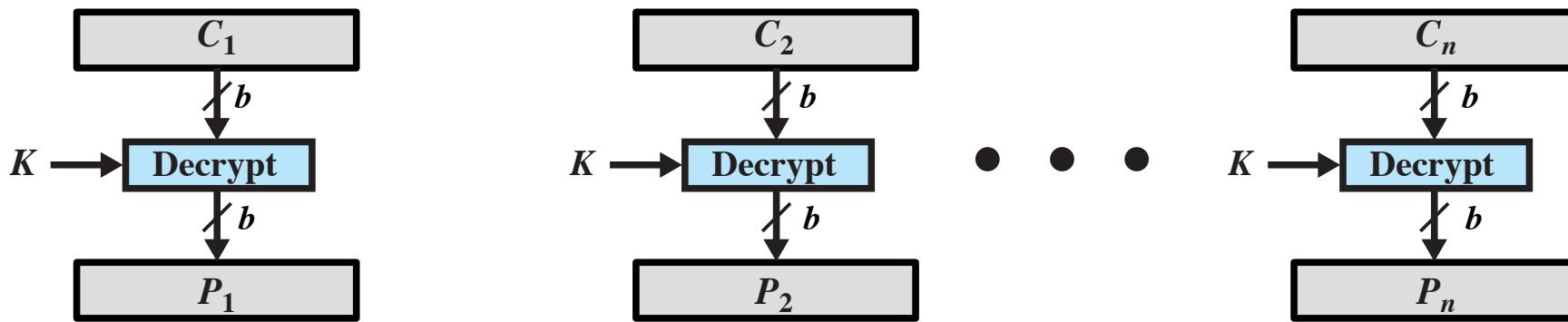
Types of Symmetric Encryption

- Block cipher encryption (de-)
- Stream cipher encryption (de-)

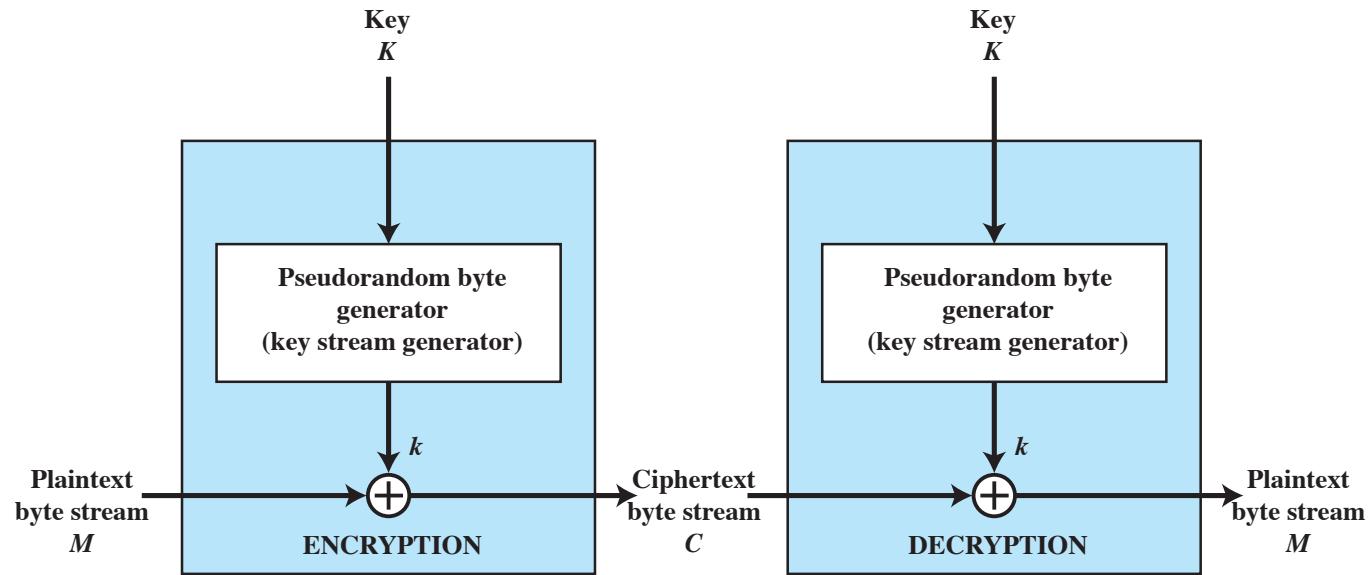
Encryption



Decryption



(a) Block cipher encryption (electronic codebook mode)



(b) Stream encryption

Figure 2.2 Types of Symmetric Encryption

Block & Stream Ciphers

Block Cipher

- Processes the input one block of elements at a time
- Produces an output block for each input block
- Can reuse keys
- More common

Stream Cipher

- Processes the input elements continuously
- Produces output one element at a time
- Primary advantage is that they are almost always faster and use far less code
- Encrypts plaintext one byte at a time
- Pseudorandom stream is one that is unpredictable without knowledge of the input key

Message Authentication



Protects against
active attacks

Verifies received
message is
authentic

Can use
conventional
encryption

- Contents have not been altered
- From authentic source
- Timely and in correct sequence

- Only sender and receiver share a key

Message Authentication Without Confidentiality



- Message encryption by itself does not provide a secure form of authentication
- It is possible to combine authentication and confidentiality in a single algorithm by encrypting a message plus its authentication tag
- Typically message authentication is provided as a separate function from message encryption

Message Authentication Without Confidentiality

- Situations in which message authentication without confidentiality may be preferable include:
 - There are a number of applications in which the same message is broadcast to a number of destinations
 - An exchange in which one side has a heavy load and cannot afford the time to decrypt all incoming messages
 - Authentication of a computer program in plaintext is an attractive service
- Thus, there is a place for both authentication and encryption in meeting security requirements

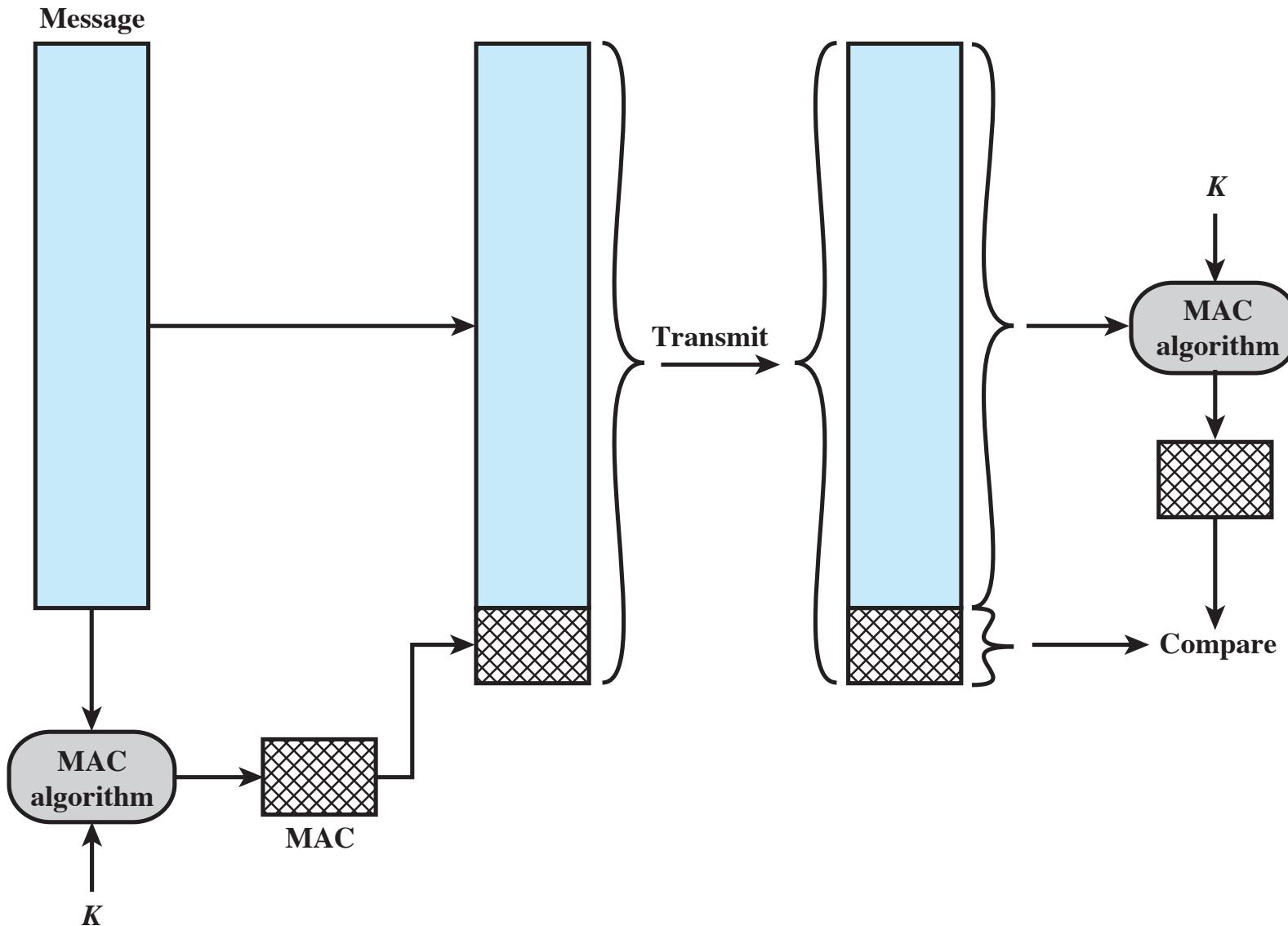
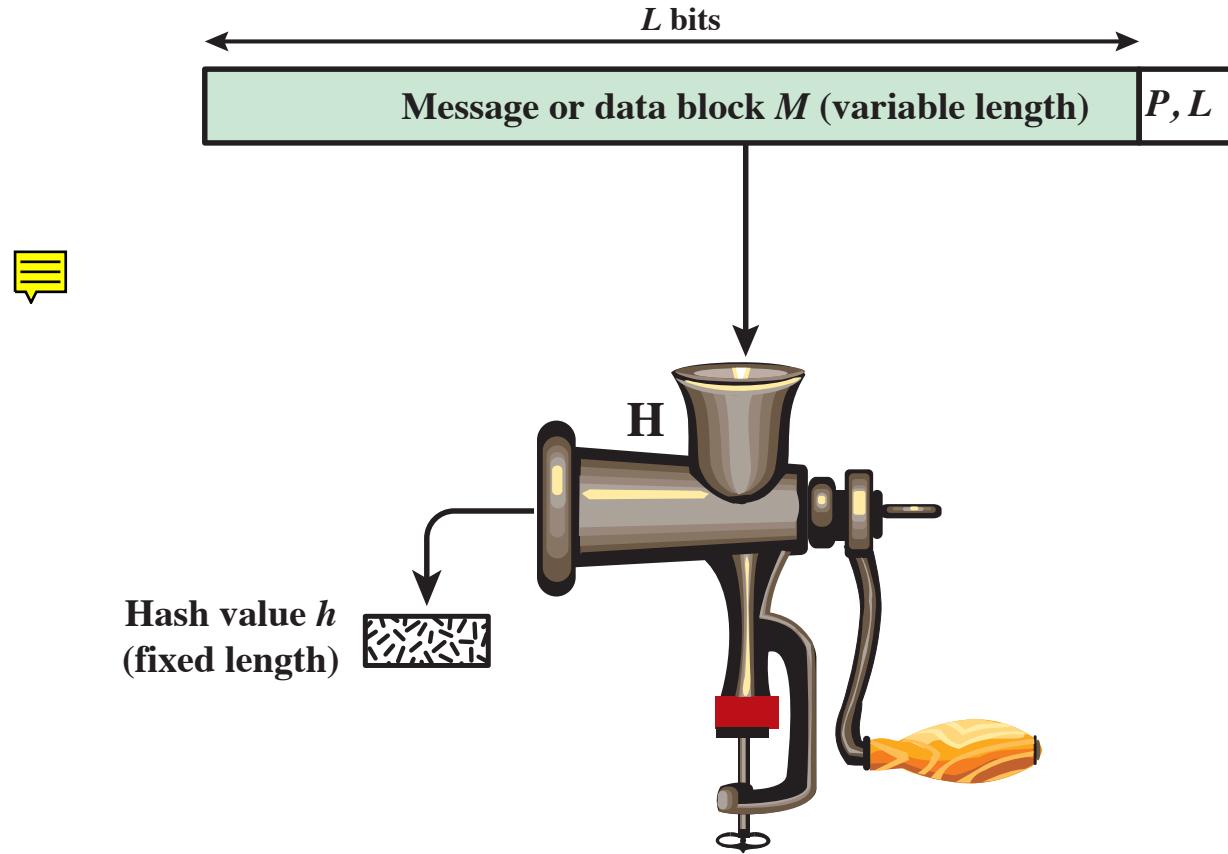


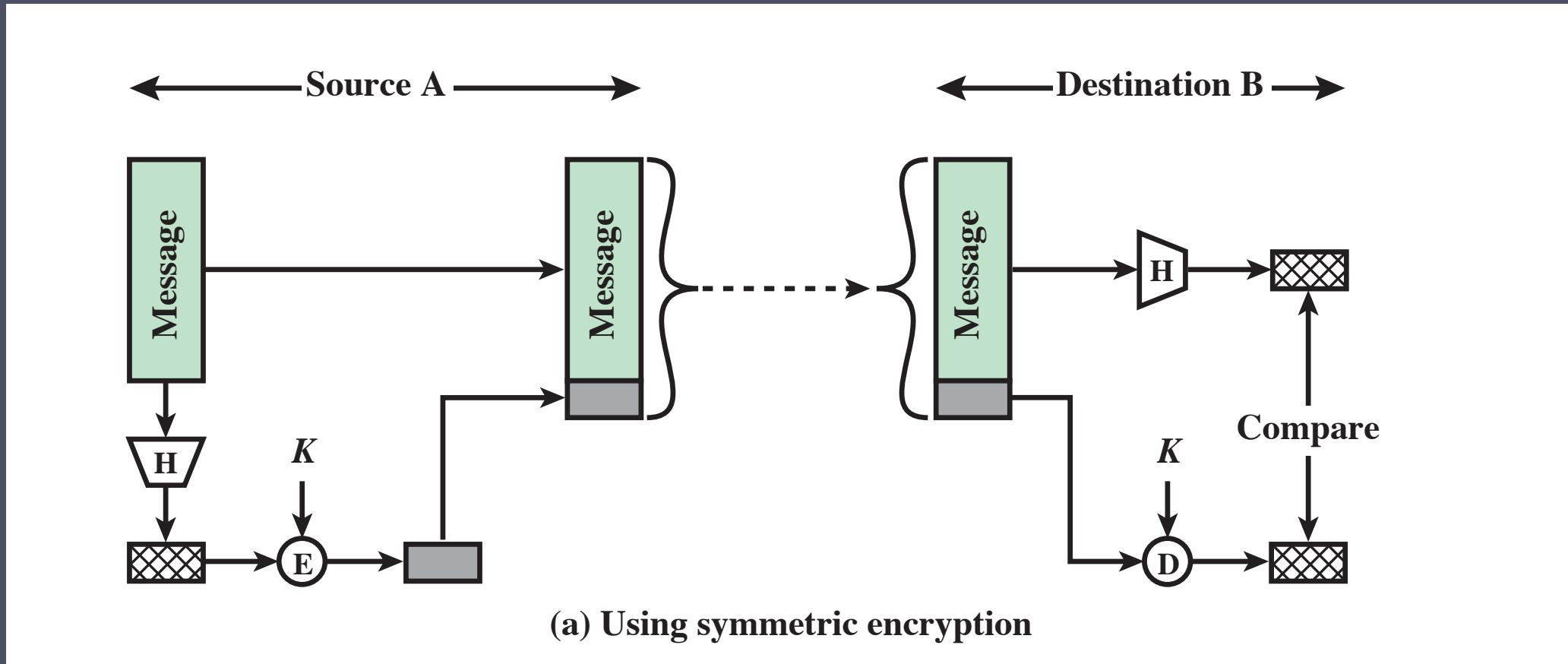
Figure 2.3 Message Authentication Using a Message Authentication Code (MAC).



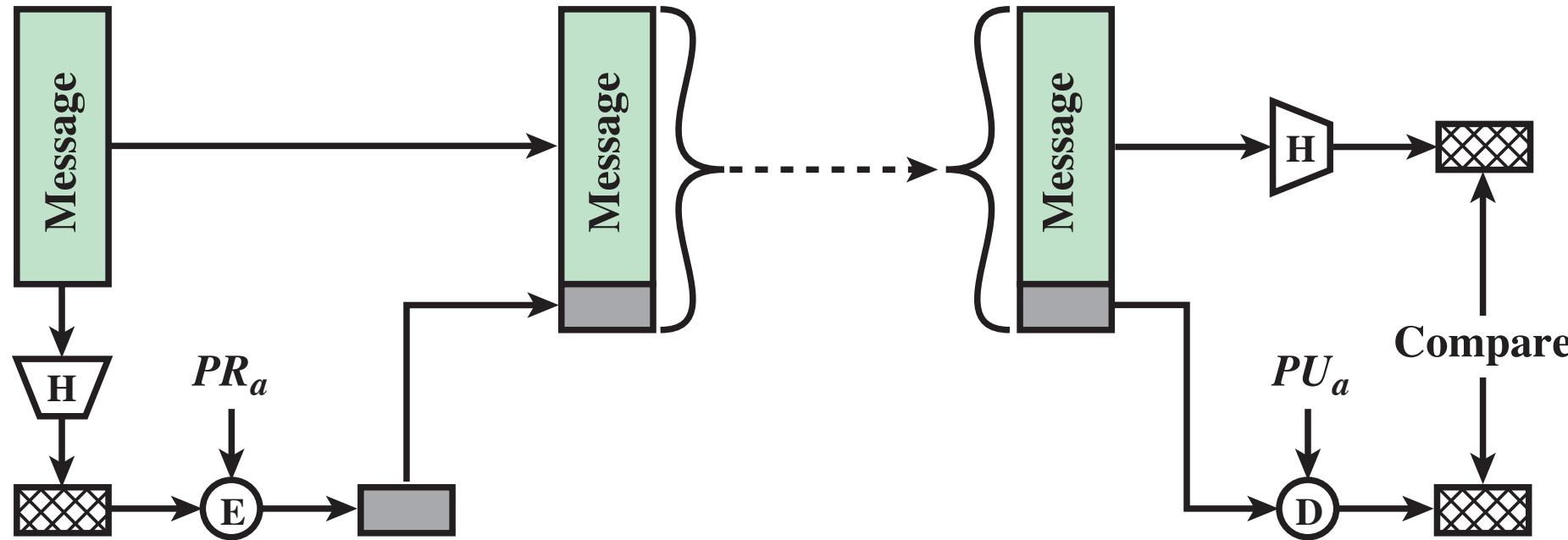
P, L = padding plus length field

Figure 2.4 Cryptographic Hash Function; $h = H(M)$

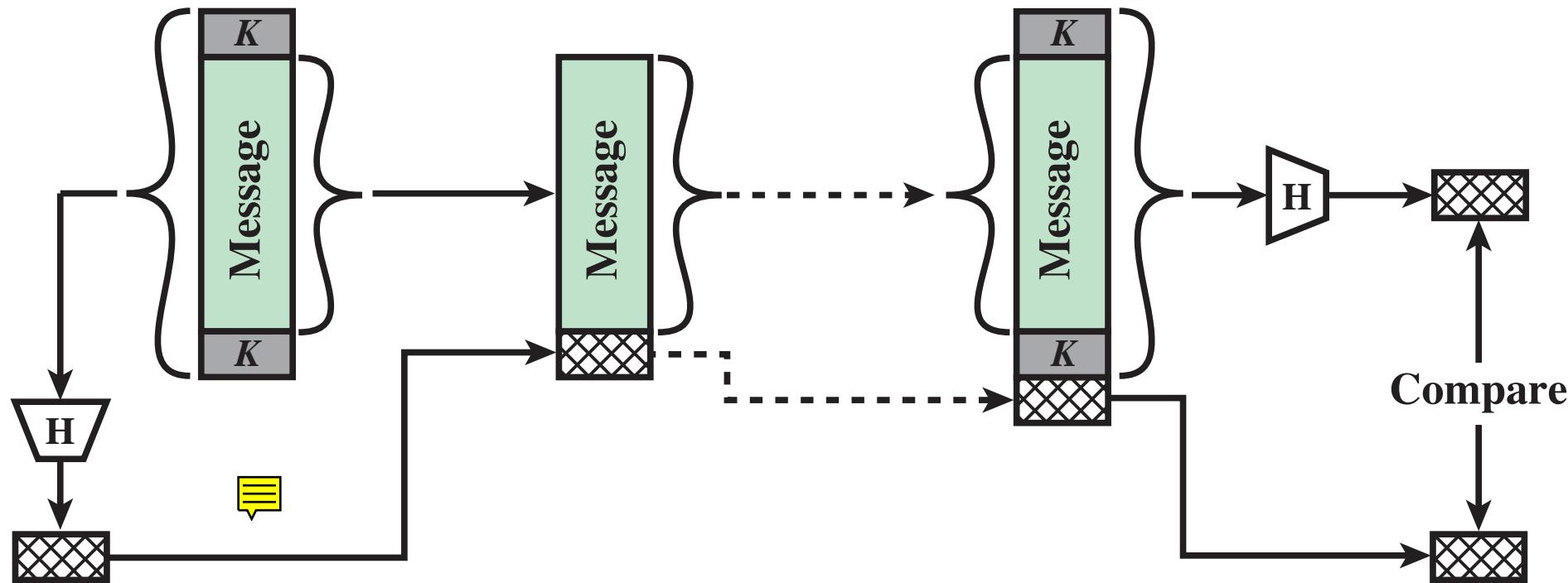
Message Auth using one-way Hash function



Message Auth using one-way Hash function



Message Auth using one-way Hash function



(c) Using secret value

Figure 2.5 Message Authentication Using a One-Way Hash Function.

To be useful for message authentication, a hash function H must have the following properties:

- Can be applied to a block of data of any size
- Produces a fixed-length output
- $H(x)$ is relatively easy to compute for any given x
- One-way or pre-image resistant
 - Computationally infeasible to find x such that $H(x) = h$
- Computationally infeasible to find $y \neq x$ such that $H(y) = H(x)$
- Collision resistant or strong collision resistance
 - Computationally infeasible to find any pair (x,y) such that $H(x) = H(y)$

Security of Hash Functions

There are two approaches to attacking a secure hash function:

SHA most widely used hash algorithm

Additional secure hash function applications:

Cryptanalysis

- Exploit logical weaknesses in the algorithm

Brute-force attack

- Strength of hash function depends solely on the length of the hash code produced by the algorithm

Passwords

- Hash of a password is stored by an operating system

Intrusion detection

- Store $H(F)$ for each file on a system and secure the hash values