Systems' Security | *Segurança de Sistemas*

Introduction to Cryptography

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Overview

Learning Objectives

After this chapter, you should be able to:

1. Explain the difference between cryptographic algorithms categories
2. Present an overview of the main concepts of symmetric cryptography
3. Explain the difference between cryptanalysis and brute-force attack

Introduction

Cryptography

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Cryptography aims to develop techniques and algorithms to provide these security services:

- confidentiality
- data integrity
- authentication
- non-repudiation

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1. type of operations used for transforming plaintext to ciphertext:
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    - transposition
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3. way in which the plaintext is processed:
    - block cipher
    - stream cipher

Cryptographic algorithms can be divided into three families

- Symmetric algorithms
- Asymmetric (or public key) algorithms
- Hash algorithms | *algoritmos de síntese*

Symmetric Encryption

Symmetric encryption:

- also referred to as conventional encryption or single-key encryption
- the only type of encryption until the 1970s (before the development of public-key encryption)

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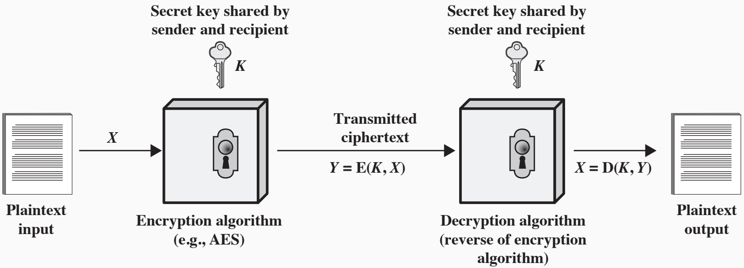
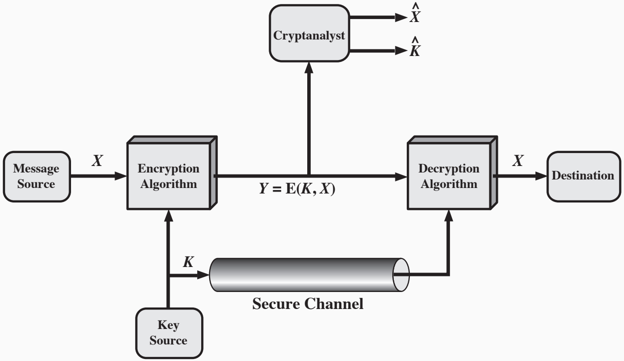
4. **ciphertext** – the scrambled message produced as output that depends on the plaintext and the secret key
5. **decryption algorithm** – takes the ciphertext and the secret key and produces the original plaintext.

Simplified model of symmetric encryption



Model of symmetric encryption



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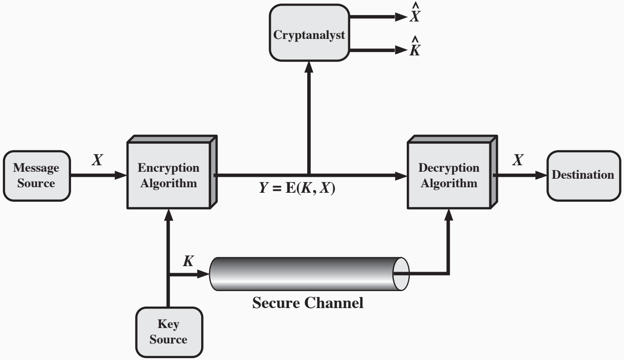

Short representation

$$A \rightarrow B : \quad E_{ks}(M)$$

There are two general approaches to attack a conventional encryption scheme:

1. **Cryptanalysis** – relies on the nature of the algorithm plus perhaps some knowledge of the general characteristics of the plaintext or even some sample plaintext–ciphertext pairs. This type of attack exploits the characteristics of the algorithm to attempt to deduce a specific plaintext or to deduce the key being used.

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2. **Brute-force attack** – The attacker tries every possible key on a piece of ciphertext until an intelligible translation into plaintext is obtained:
   - On average, half of all possible keys must be tried to achieve success
   - The analyst must be able to recognize plaintext as plaintext.

open algorithms – reverse the encryption process must rely only on the key value and not the fact of knowing the used algorithm

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An encryption scheme is said to be computationally secure against brute-force attacks if

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These principles also apply to other cryptographic algorithms.

Advantages

- Computationally efficient

Disadvantages

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- Easy to implement in hardware

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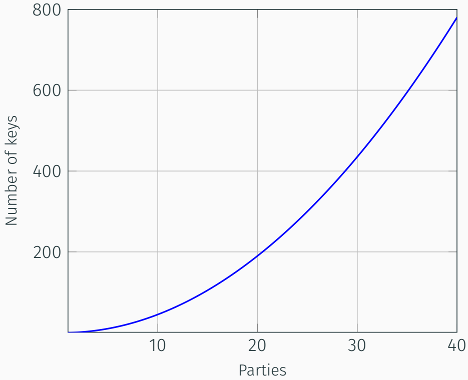

$$\text{Number of keys} = \frac{N(N-1)}{2}$$

Asymmetric Ciphers

Asymmetric algorithms

- use a key pair:
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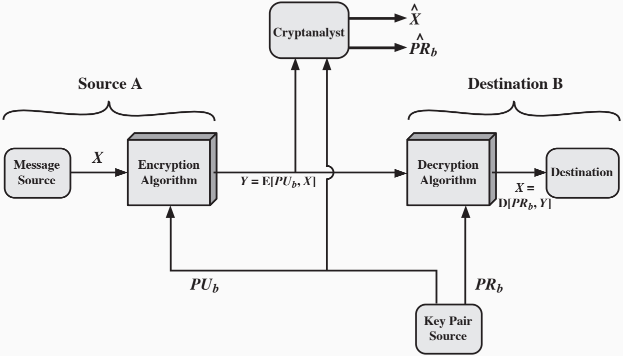
- these keys are used to perform complementary operations:
  - encryption / decryption
  - signature generation / signature verification

Asymmetric algorithms solve some problems found in symmetric algorithms:

- confidentiality is not required for key distribution of public keys
  - these algorithms are used to safely distribute symmetric keys
- perform digital signatures to ensure non-repudiation

Model of asymmetric encryption – **confidentiality**



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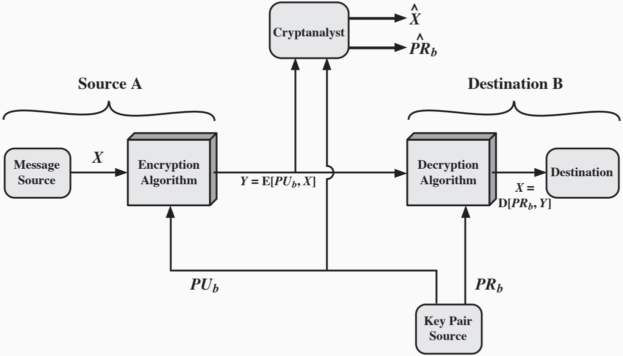
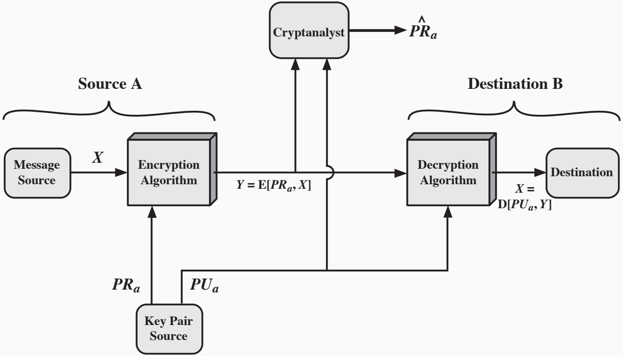


Short representation

$$A \rightarrow B: \quad E_{k_{U_B}}(M)$$

Model of asymmetric encryption – **non-repudiation**



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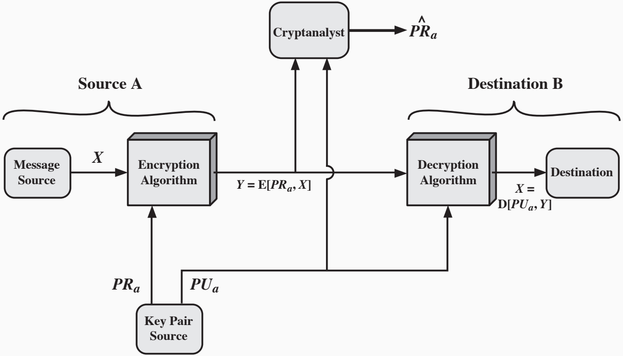

Short representation

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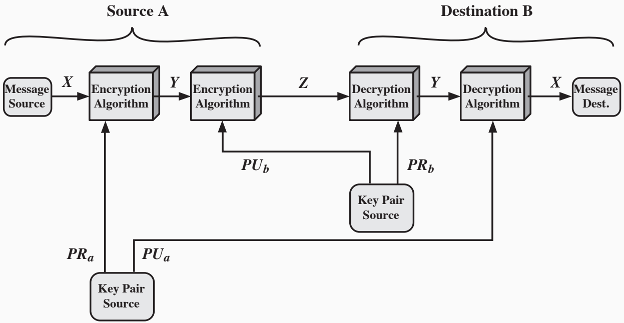
Model of asymmetric encryption – **confidentiality and non-repudiation**



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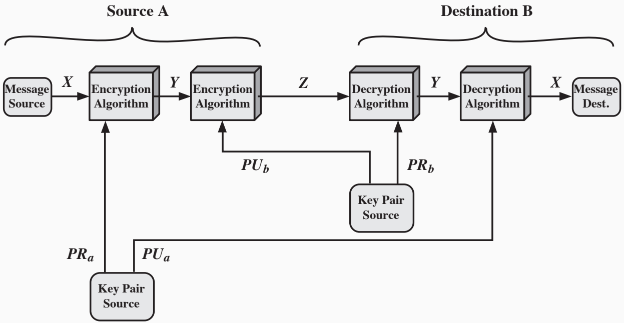

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$$A \rightarrow B: \quad E_{k_{U_B}}(E_{k_{R_A}}(M))$$

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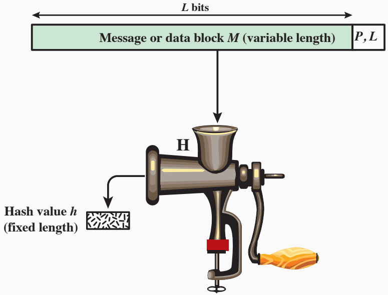
- slower and more complex than symmetric ciphers
- infrastructure to certify owners of the public keys is complex
- encryption is too slow, so key encapsulation is used to overcame this limitation

Hash Algorithms | *Algoritmos de Síntese*

Hash algorithms, or hash functions



P, *L* = padding plus length field

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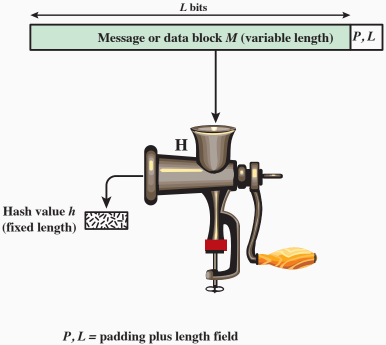
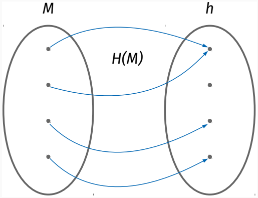


Many-to-one function

- input – a message M of variable length
- output – a value h of fixed length, *e. g.* 256 bits



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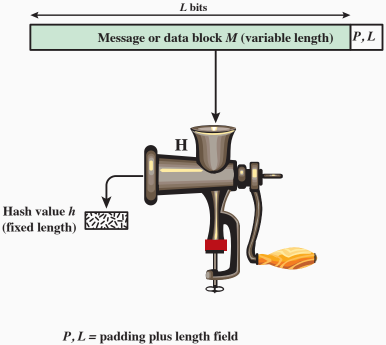

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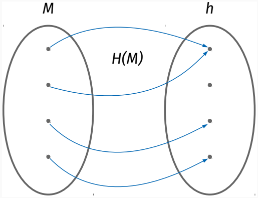
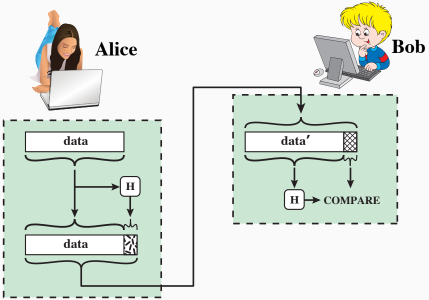


- size of the messages M universe $= \infty$
- size of the hash values h universe $= 2^{n\ bits}$

Use of hash algorithms



$H(\text{Hello}) = $ `0x8b1a9953c4611296a827abf8c47804d7`

Short representation

$$A \rightarrow B : \quad M \parallel H(M)$$

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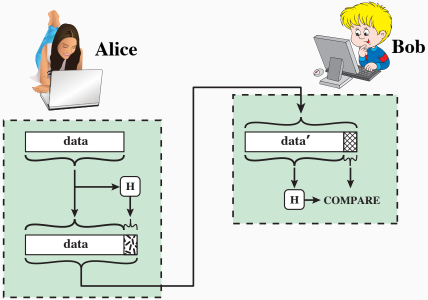

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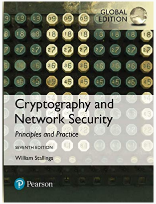
Prone to attacks

1. the hash algorithm is not enough to guarantee data integrity
2. the hash value must be protected somehow

Questions?



Chapters 3.1, **9.1** and **11.1** of

William Stallings, Cryptography and Network Security: Principles and Practice, Global Edition, 2016