Introduction on Information security

Chapter 2 – Cryptography

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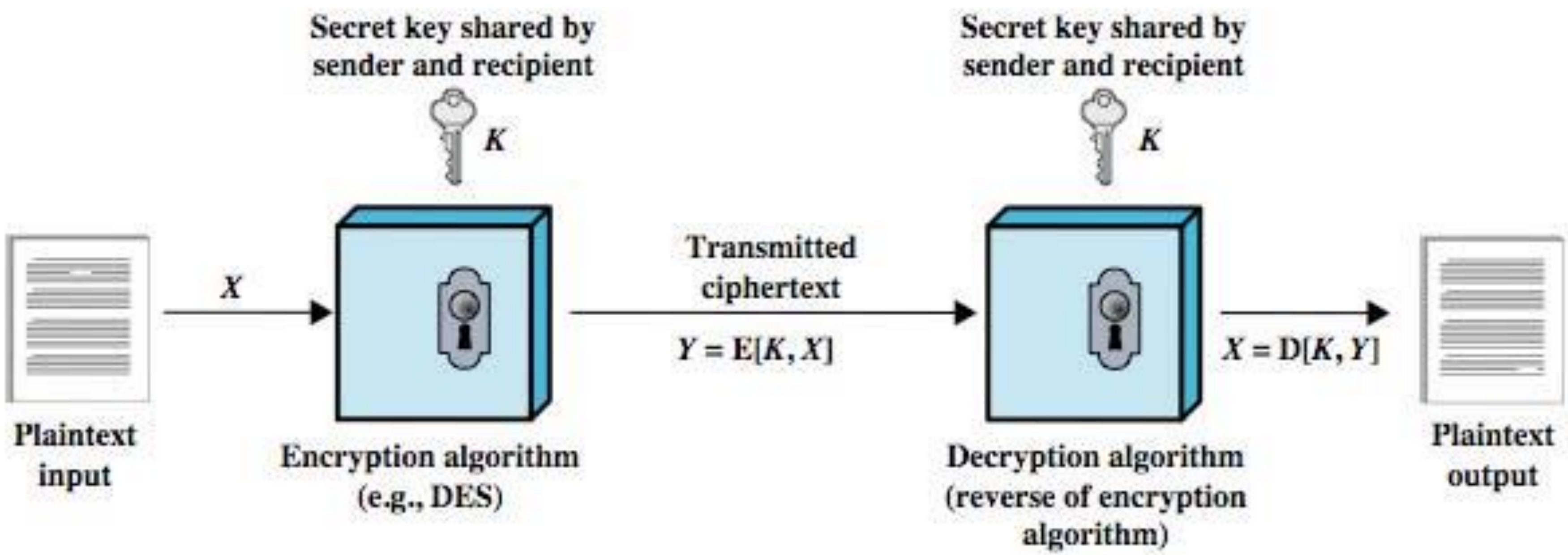
Cryptographic Tools

- cryptographic algorithms are important element in security services
- review various types of elements
  - symmetric encryption
  - public-key (asymmetric) encryption
  - digital signatures and key management
  - secure hash functions
- example is use to encrypt stored data

Symmetric Encryption



Attacking Symmetric Encryption

Cryptanalysis

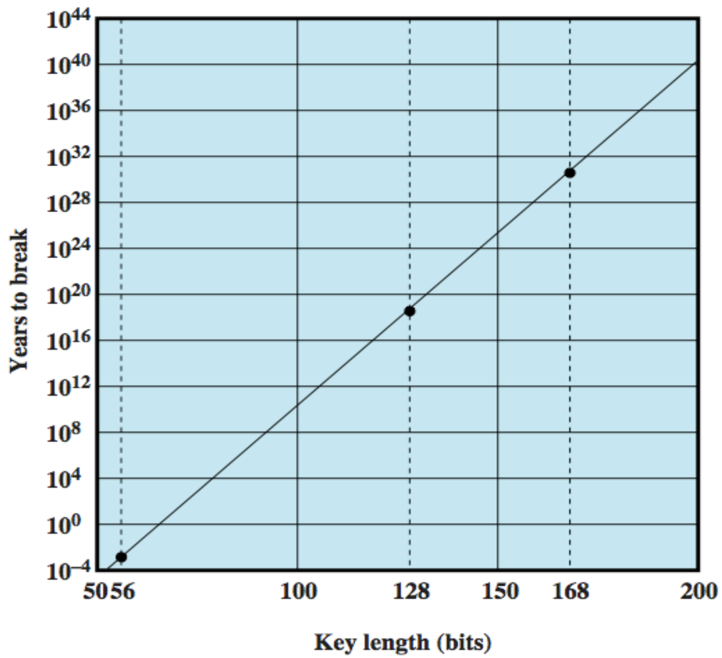
- rely on nature of the algorithm
- plus some knowledge of plaintext characteristics
- even some sample plaintext-ciphertext pairs
- exploits characteristics of algorithm to deduce specific plaintext or key

Brute-force attack

- try all possible keys on some ciphertext until get an intelligible translation into plaintext

Attacking Symmetric Encryption

Key Size (bits)	Number of Alternative Keys	Time Required at 1 Decryption/μs	Time Required at 10^6 Decryptions/μs
32	$2^{32} = 4.3 \times 10^9$	$2^{31}\ \mu s = 35.8$ minutes	2.15 milliseconds
56	$2^{56} = 7.2 \times 10^{16}$	$2^{55}\ \mu s = 1142$ years	10.01 hours
128	$2^{128} = 3.4 \times 10^{38}$	$2^{127}\ \mu s = 5.4 \times 10^{24}$ years	5.4×10^{18} years
168	$2^{168} = 3.7 \times 10^{50}$	$2^{167}\ \mu s = 5.9 \times 10^{36}$ years	5.9×10^{30} years
26 characters (permutation)	$26! = 4 \times 10^{26}$	$2 \times 10^{26}\ \mu s = 6.4 \times 10^{12}$ years	6.4×10^6 years



Symmetric Encryption Algorithms

	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

DES and Triple-DES

Data Encryption Standard (DES)
- is the most widely used encryption scheme
- uses 64 bit plaintext block and 56 bit key to produce a 64 bit ciphertext block
- concerns about algorithm & use of 56-bit key

Triple-DES (3DES)
- repeats basic DES algorithm three times
- using either two or three unique keys
- much more secure but also much slower

Advanced Encryption Standard (AES)

3DES was not reasonable for long term use

NIST called

Should have a security strength

Significantly improved

Symmetric block cipher

128 bit data and 128/192/256 bit keys

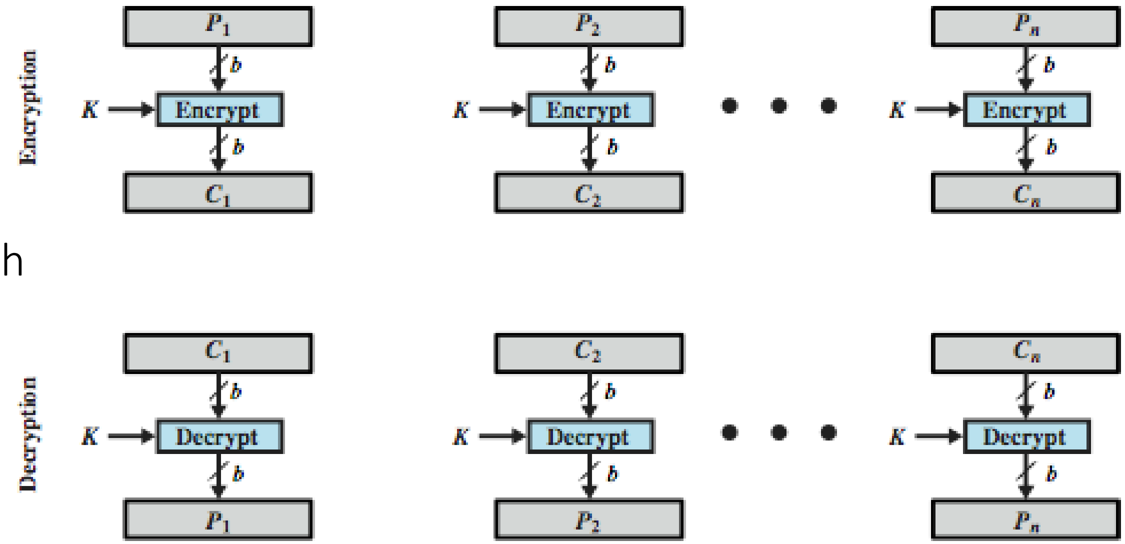
Published as

FIPS 1997

Block vs Stream Ciphers

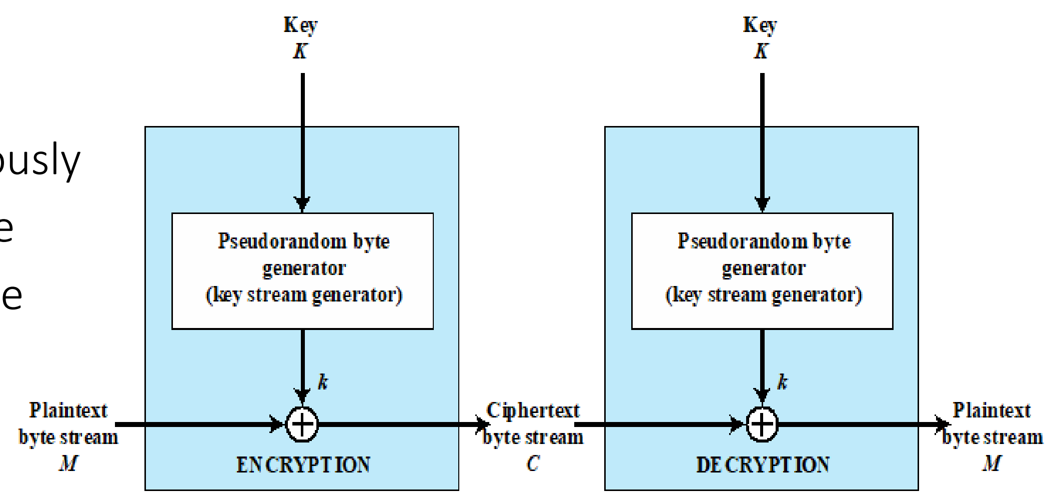
Block Cipher

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



Stream Ciphers

- Processes the input elements continuously
- Produces output one element at a time
- Primary advantage: faster and less code
- Encrypts plaintext one byte at a time



Message Authentication

- protects against active attacks

- verifies received message is authentic
  - contents unaltered
  - from authentic source
  - timely and in correct sequence

- can use conventional encryption
  - only sender & receiver have key needed

- ... or separate authentication mechanisms
  - append authentication tag to cleartext message

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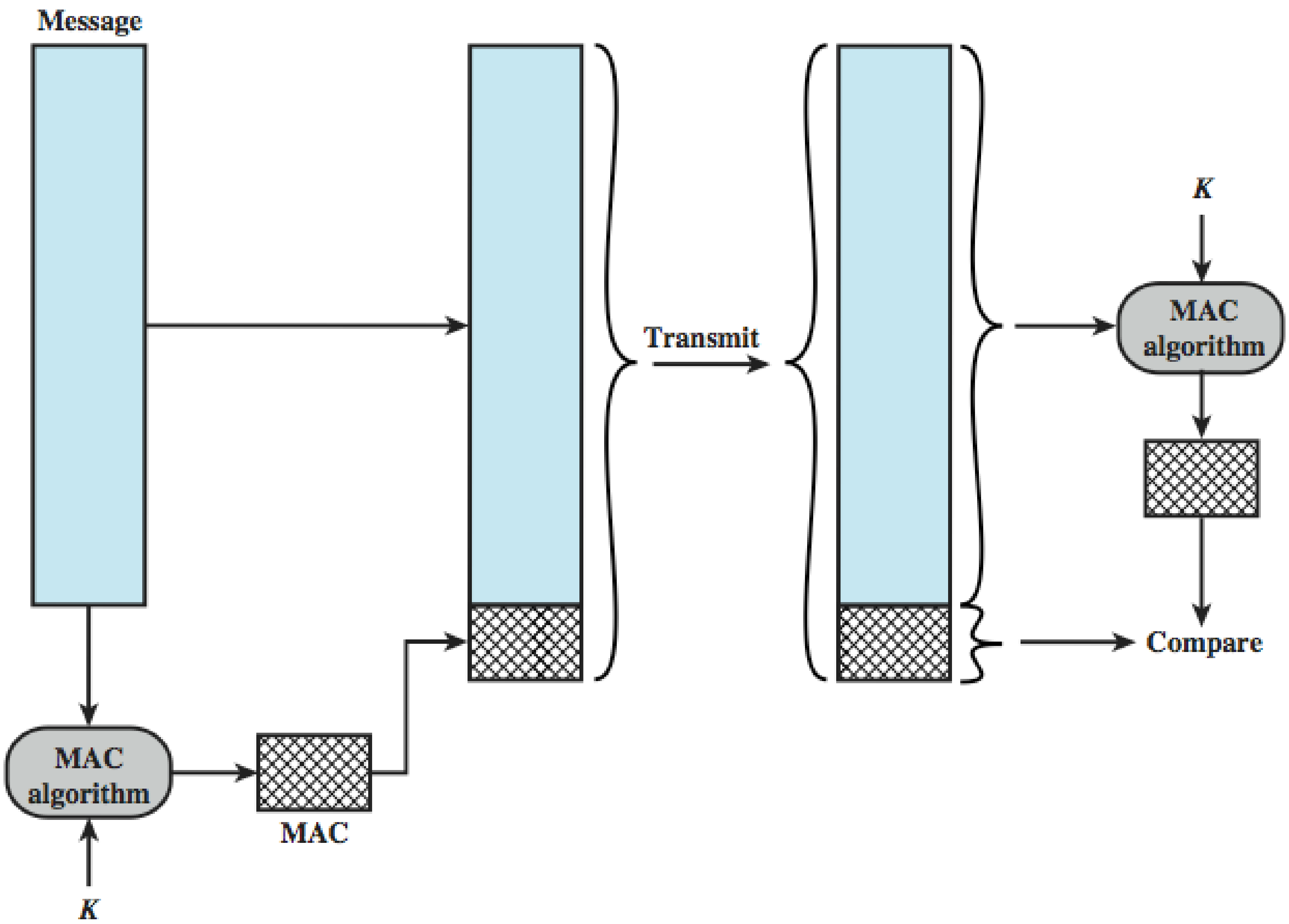
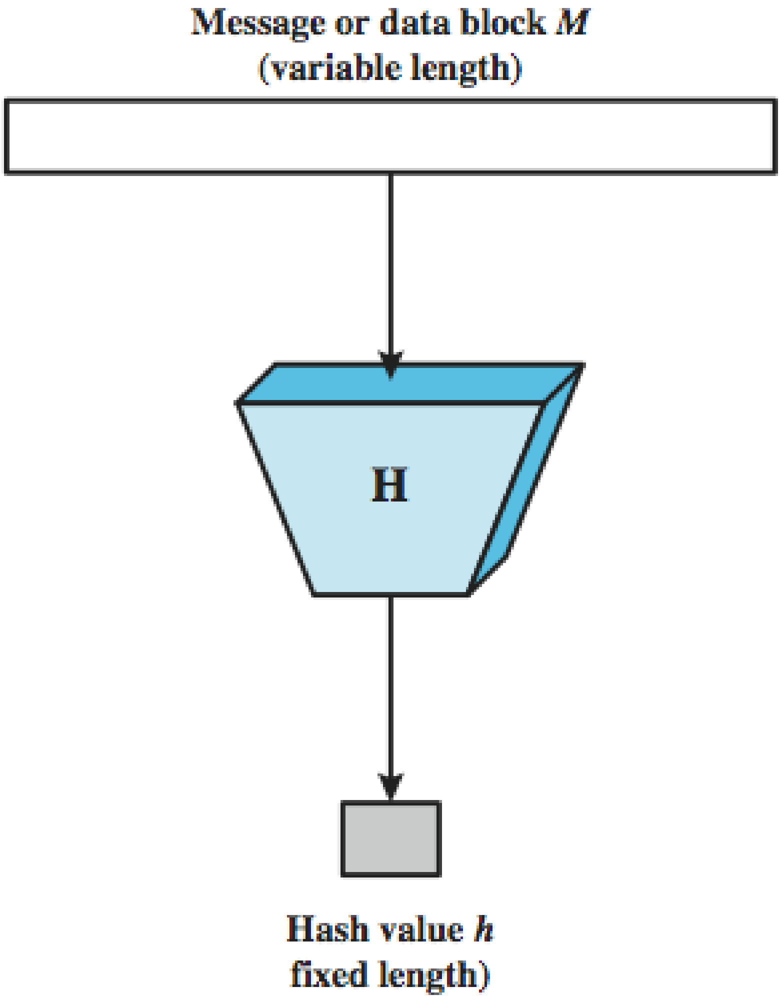
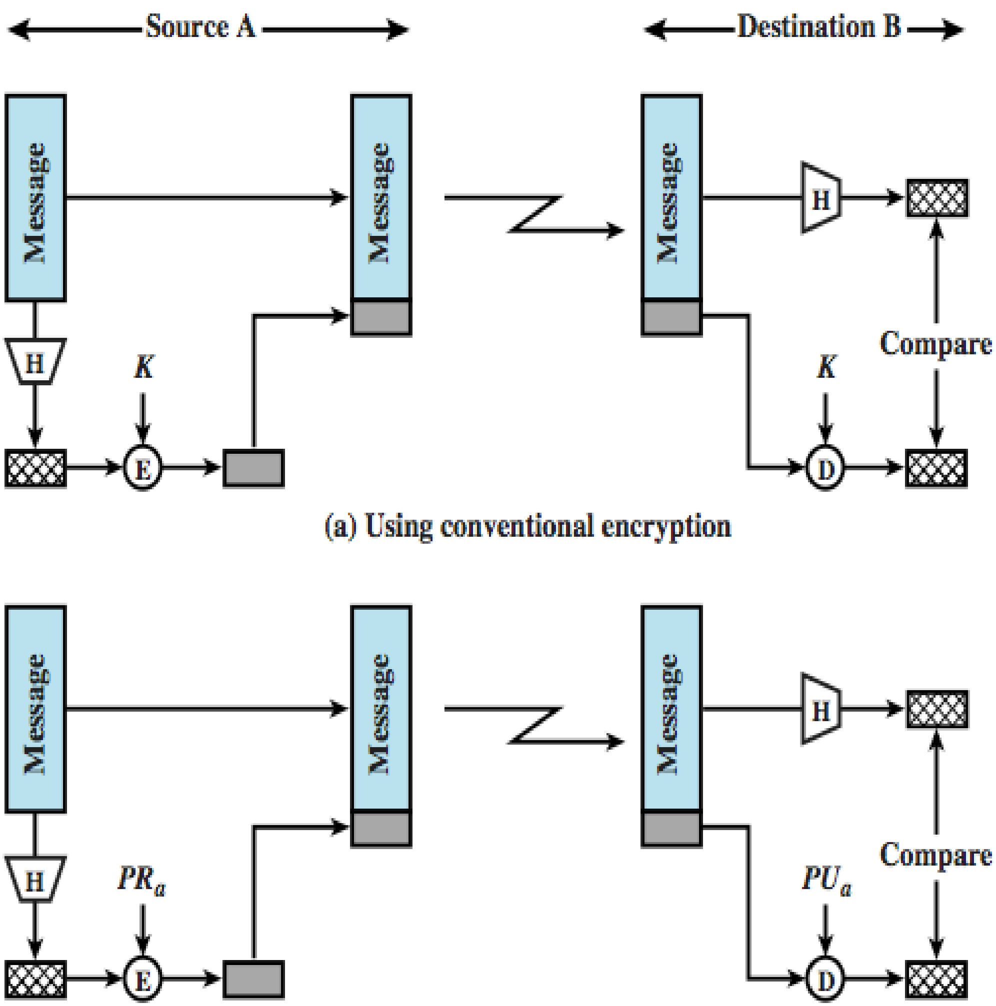
Message Authentication Codes



Secure Hash Functions



Message authentication



(a) Using conventional encryption

(b) Using public-key encryption

Hash Function Requirements

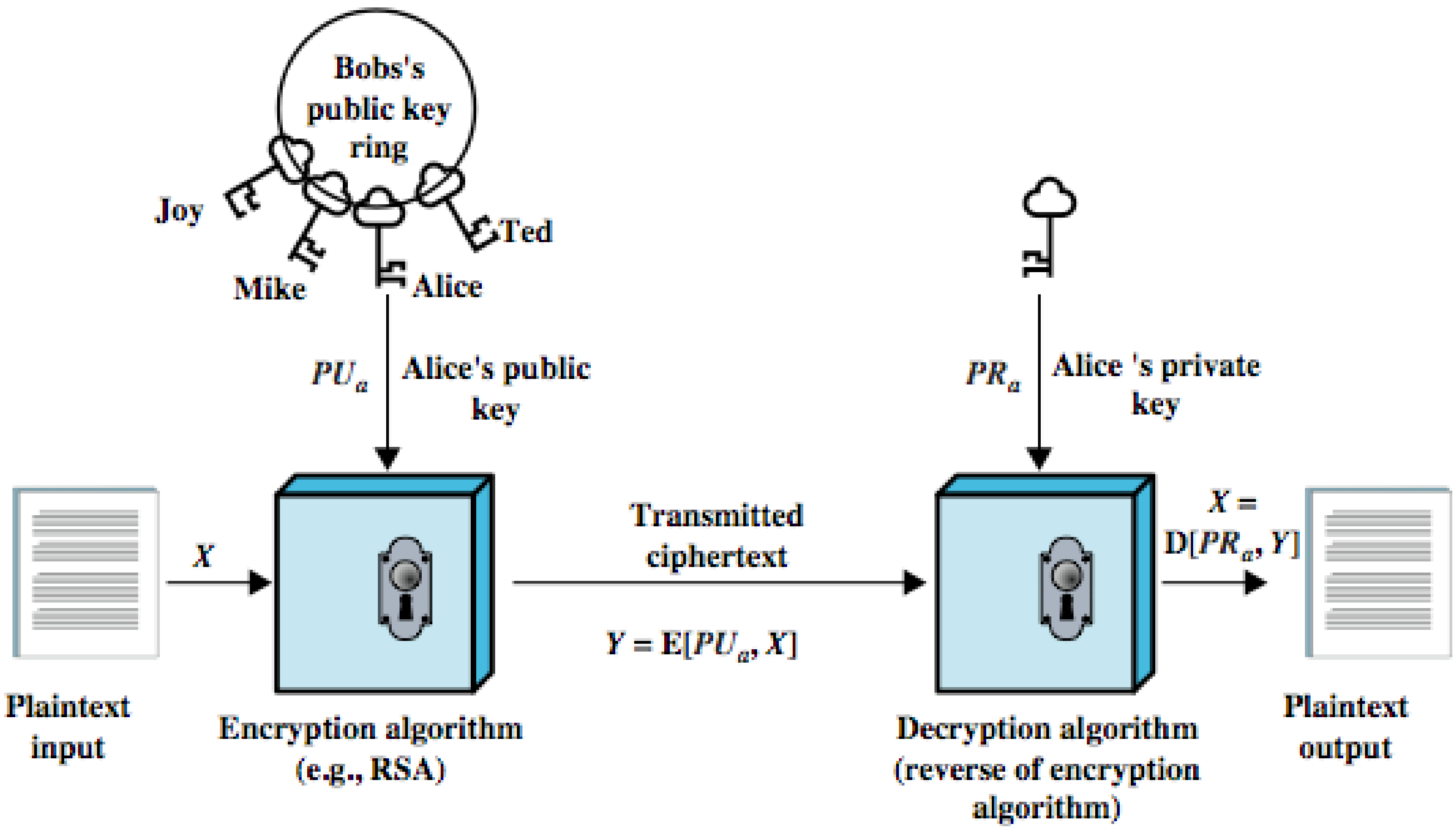
- applied to any size data
- H produces a fixed-length output
- H(x) is relatively easy to compute for any given x
- one-way property
  computationally infeasible to find x such that H(x) = h
- weak collision resistance
  computationally infeasible to find y ≠ x such that H(y) = H(x)
- strong collision resistance
  computationally infeasible to find any pair (x, y) such that H(x) = H(y)

Hash Functions

- two attack approaches
  - cryptanalysis
    - exploit logical weakness in algorithm
  - brute-force attack
    - trial many inputs
    - strength proportional to size of hash code (2n/2)

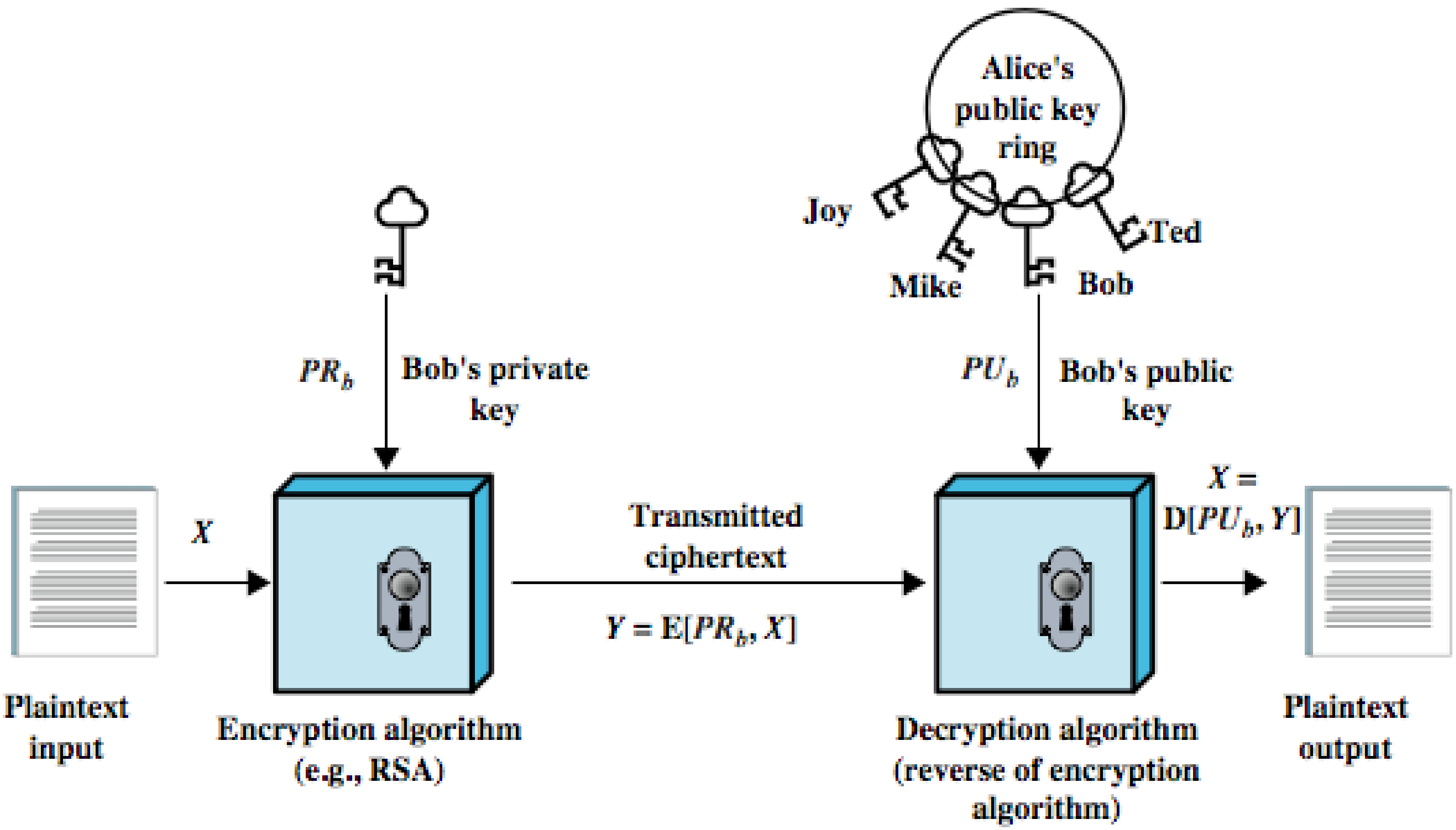
- SHA most widely used hash algorithm
  - SHA-1 gives 160-bit hash
  - more recent SHA-256, SHA-384, SHA-512 provide improved size and security

Public Key Encryption



(a) Confidentiality

Public Key Authentication



(b) Authentication

Public Key Requirements

1. Computationally easy to create key pairs
2. computationally easy for sender knowing public key to encrypt messages
3. computationally easy for receiver knowing private key to decrypt ciphertext
4. computationally infeasible for opponent to determine private key from public key
5. computationally infeasible for opponent to otherwise recover original message
6. useful if either key can be used for each role

Public Key Algorithms

- RSA (Rivest, Shamir, Adleman, 1977)
  only widely accepted public-key encryption algorithm
  given tech advances need 1024+ bit keys
- Diffie-Hellman key exchange algorithm
  only allows exchange of a secret key
- Digital Signature Standard (DSS)
  provides only a digital signature function with SHA-1
- Elliptic curve cryptography (ECC)
  new, security like RSA, but with much smaller keys

Random Numbers

Random numbers have a range of uses

Requirements:

- **Randomness**
  - based on statistical tests for uniform distribution and independence
- **Unpredictability**
  - successive values not related to previous
  - clearly true for truly random numbers
  - but more commonly use generator

Pseudorandom vs Random Numbers

- All algorithmic technique create **pseudorandom numbers**
  - which satisfy statistical randomness tests
  - but likely to be predictable

- **True random number generator (TRNG)** use a non-deterministic source
  - e.g., radiation, gas discharge, leaky capacitors
  - increasingly provided on modern processors

Practical Application: Encryption of Stored Data

- common to encrypt transmitted data
- much less common for stored data
  - which can be copied, backed up, recovered
- Different approaches to encrypt stored data:
  - back-end appliance
  - library based tape encryption
  - background laptop/PC data encryption

Summary

- introduced cryptographic algorithms
- symmetric encryption algorithms for confidentiality
- message authentication & hash functions
- public-key encryption
- digital signatures and key management
- random numbers