Computer Security DD2395

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Sonja Buchegger
buc@kth.se

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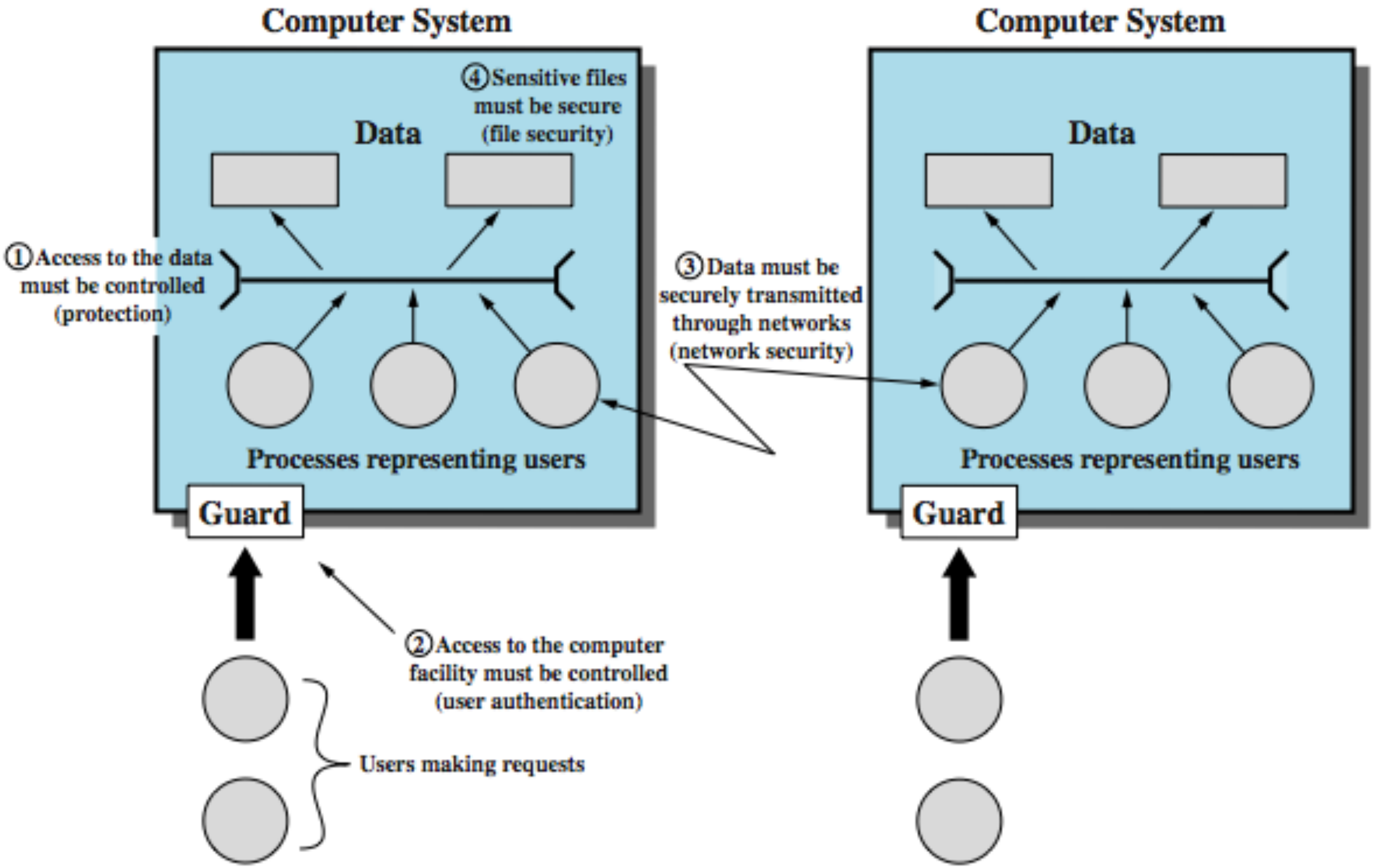
Cryptography

Scope of Computer Security



Network Security Attacks

- classify as passive or active
- passive attacks are eavesdropping
  - release of message contents
  - traffic analysis
  - are hard to detect so aim to prevent
- active attacks modify/fake data
  - masquerade
  - replay
  - modification
  - denial of service
  - hard to prevent so aim to detect
- Networking Security class next term

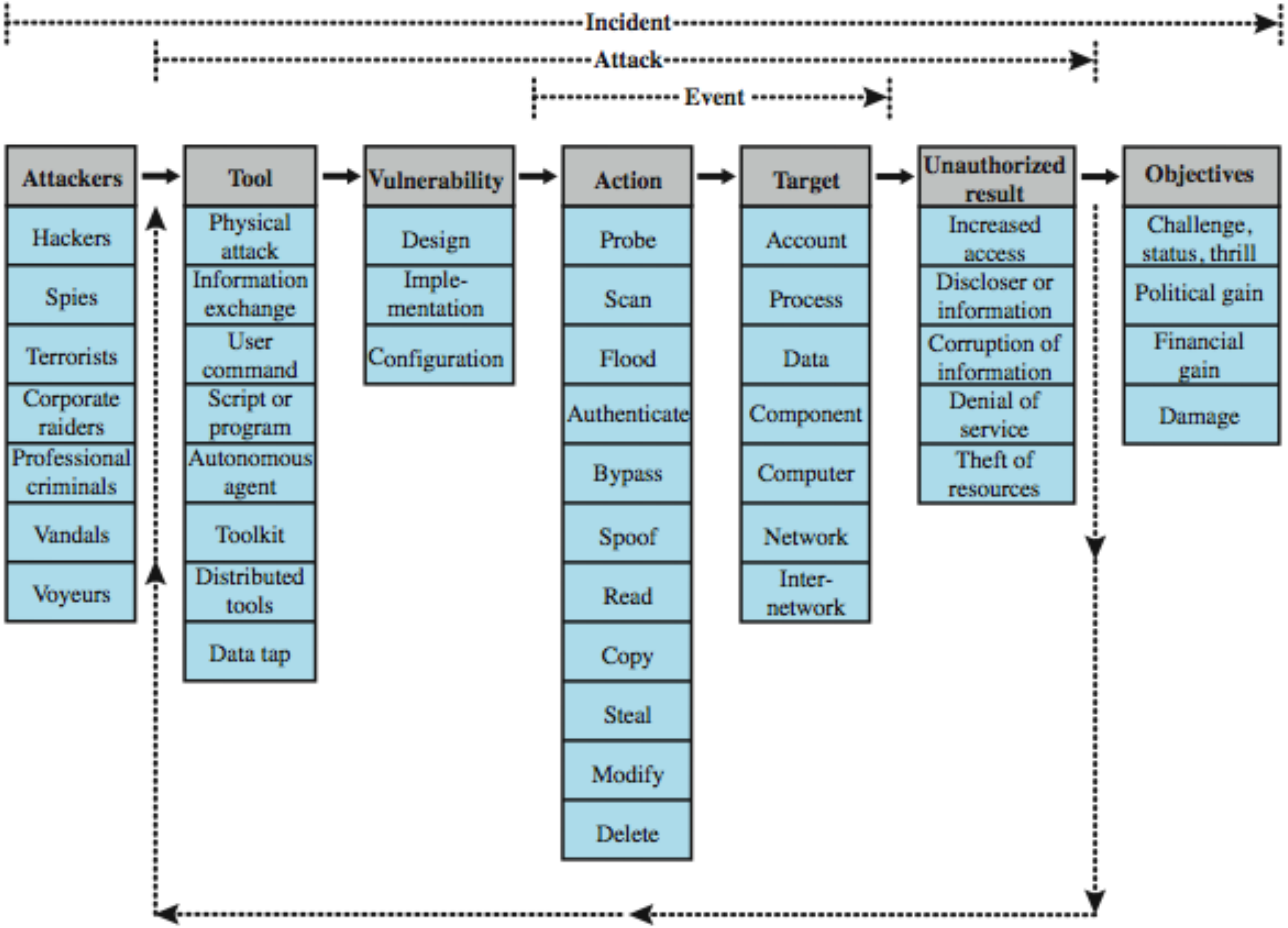
Security Functional Requirements

- technical measures:
  - access control; identification & authentication; system & communication protection; system & information integrity
- management controls and procedures
  - awareness & training; audit & accountability; certification, accreditation, & security assessments; contingency planning; maintenance; physical & environmental protection; planning; personnel security; risk assessment; systems & services acquisition
- overlapping technical and management:
  - configuration management; incident response; media protection

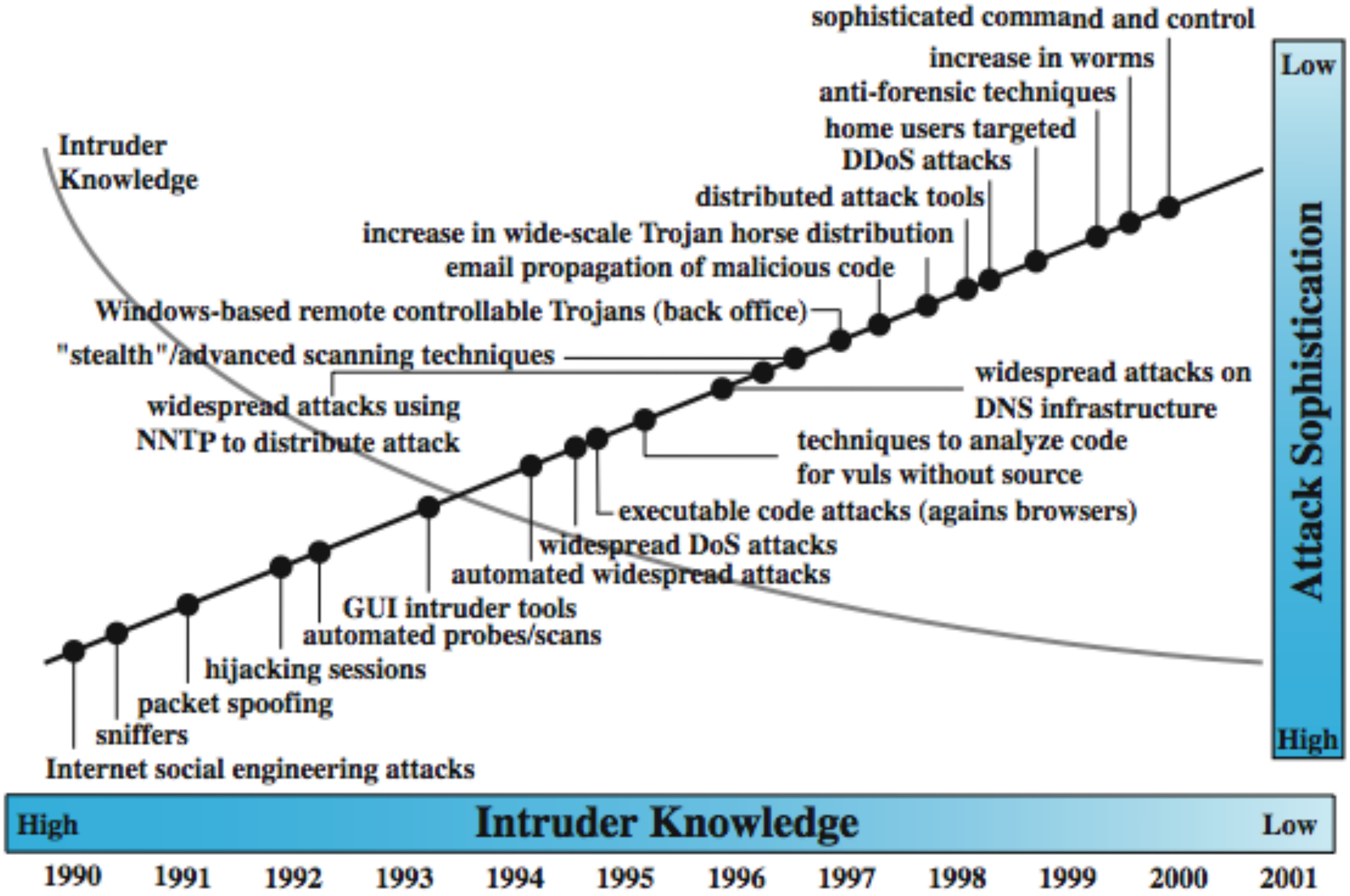
X.800 Security Architecture

- X.800, *Security Architecture for OSI*
- systematic way of defining requirements for security and characterizing approaches to satisfying them
- defines:
  - security attacks - compromise security
  - security mechanism - act to detect, prevent, recover from attack
  - security service - counter security attacks

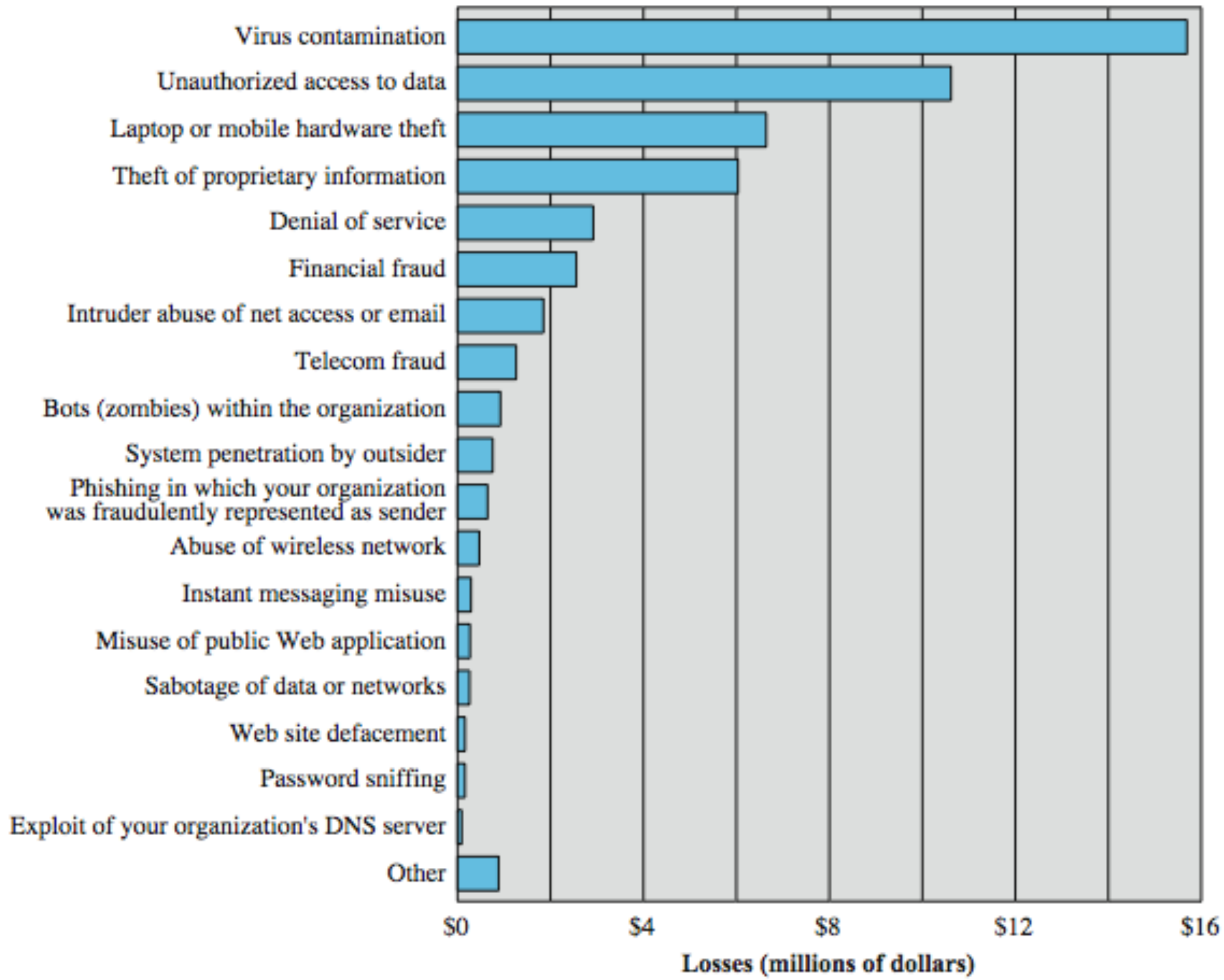
Security Taxonomy



Security Trends

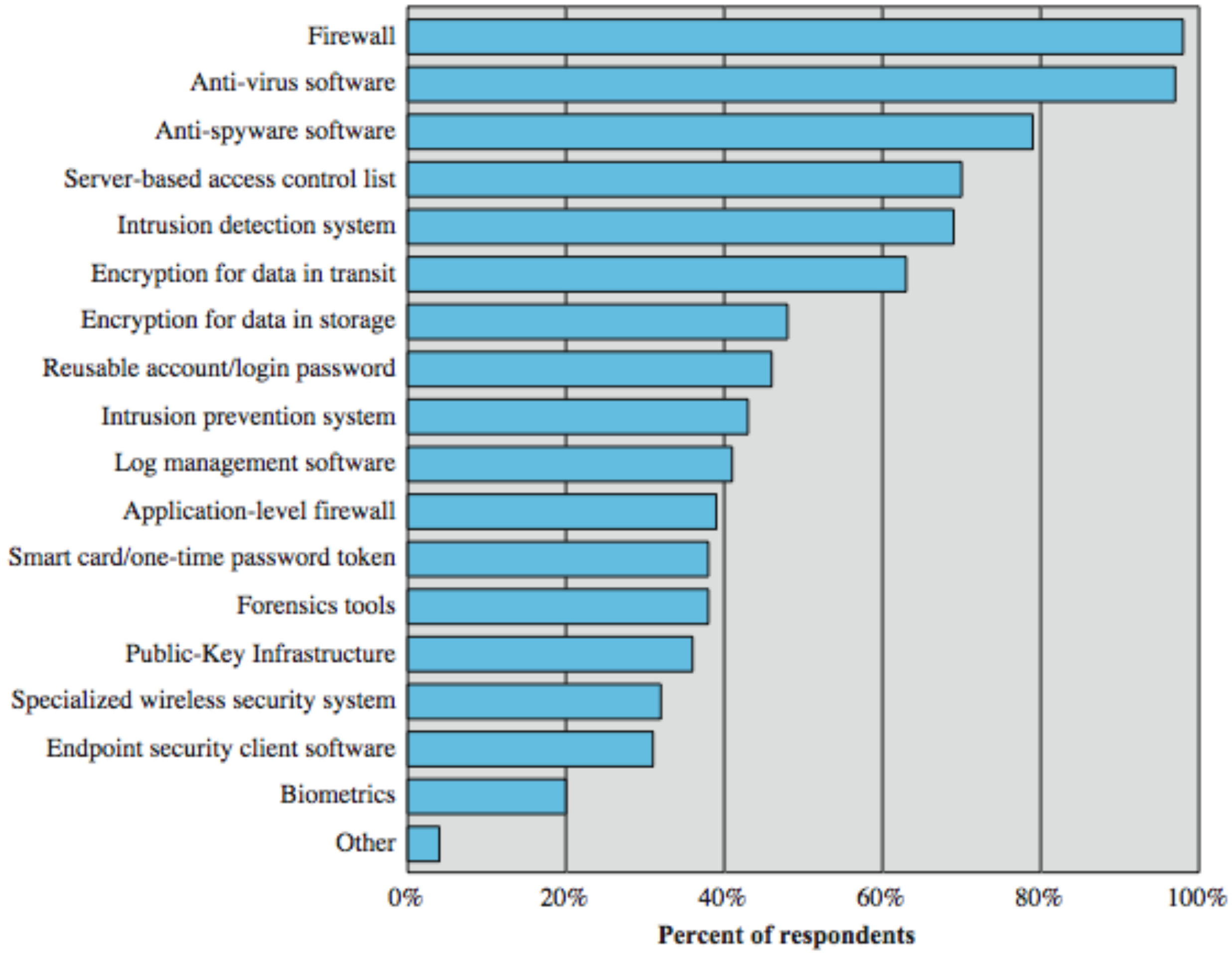


Computer Security Losses



Source: Computer Security Institute/FBI 2006 Computer Crime and Security Survey

Security Technologies Used



Source: Computer Security Institute/FBI 2006 Computer Crime and Security Survey

Computer Security Strategy

- specification/policy
  - what is the security scheme supposed to do?
  - codify in policy and procedures
- implementation/mechanisms
  - how does it do it?
  - prevention, detection, response, recovery
- correctness/assurance
  - does it really work?
  - assurance, evaluation

Summary

- security concepts
- terminology
- functional requirements
- security trends
- security strategy

Questionnaire Results 55/66

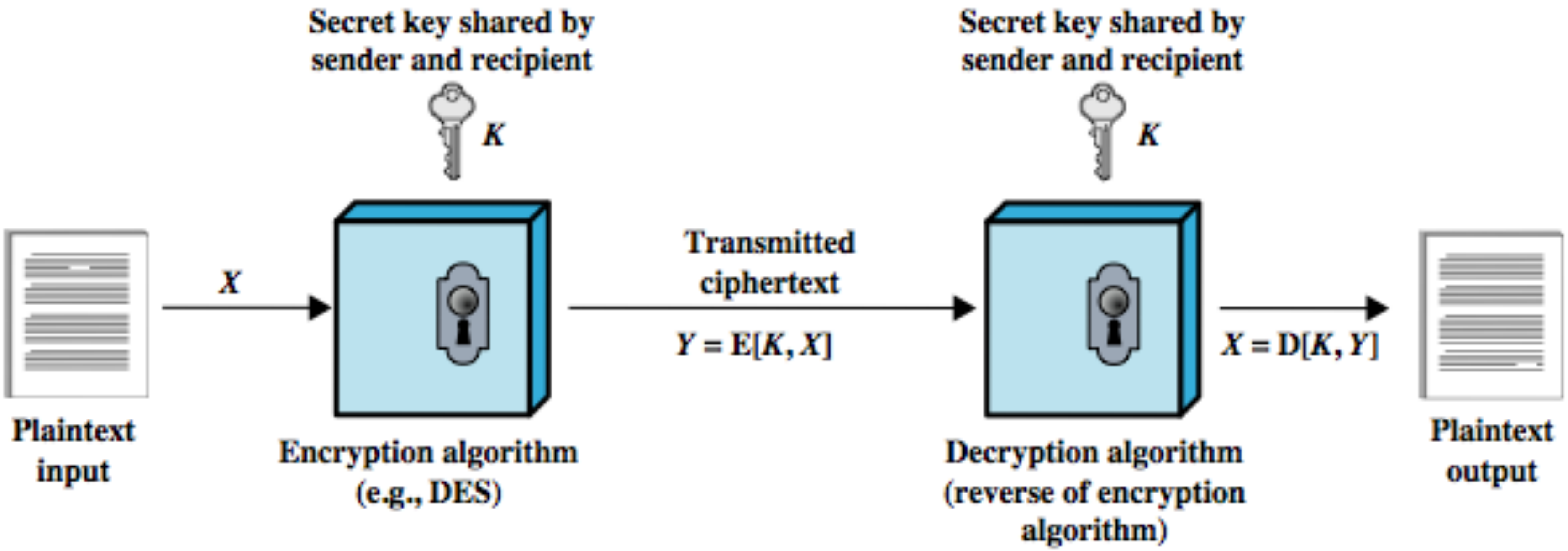
- Prior security knowledge:
  - l2m: 30
  - m: 14
  - m2h: 11
- Expectations: all medium-to-high

- Prior classes of
  - Comp. arch.: 46
  - OS: 23
  - Networking: 34

Cryptographic Tools

- cryptographic algorithms 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

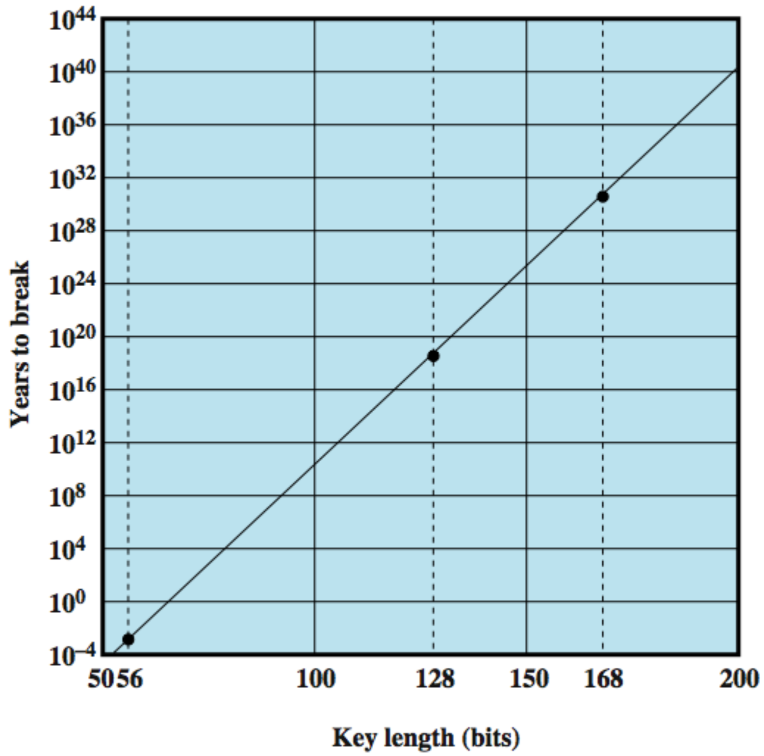


Attacking Symmetric Encryption

- 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

Exhaustive Key Search

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} μs = 35.8 minutes	2.15 milliseconds
56	$2^{56} = 7.2 \times 10^{16}$	2^{55} μs = 1142 years	10.01 hours
128	$2^{128} = 3.4 \times 10^{38}$	2^{127} μs = 5.4×10^{24} years	5.4×10^{18} years
168	$2^{168} = 3.7 \times 10^{50}$	2^{167} μs = 5.9×10^{36} years	5.9×10^{30} years
26 characters (permutation)	$26! = 4 \times 10^{26}$	2×10^{26} μs = 6.4×10^{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

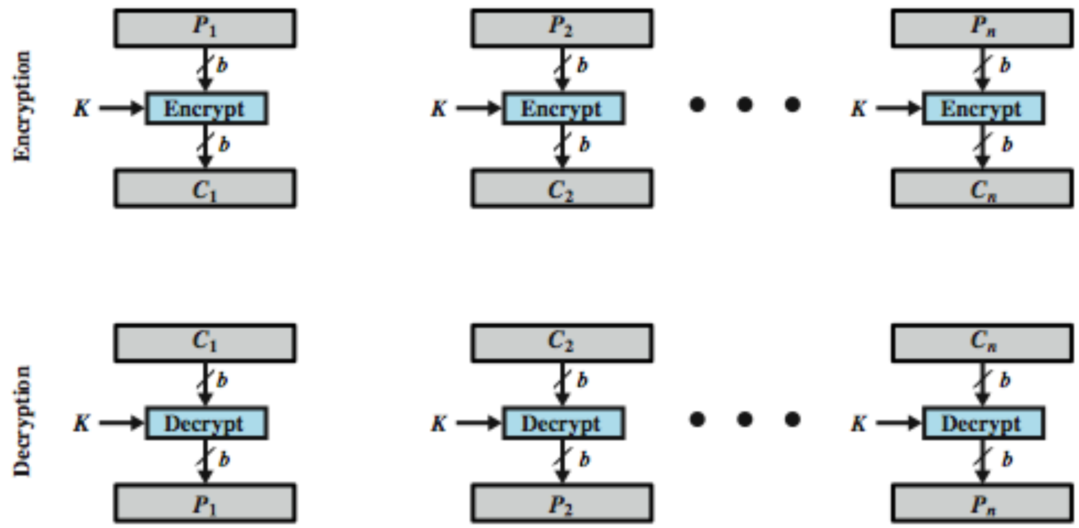
DES and Triple-DES

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

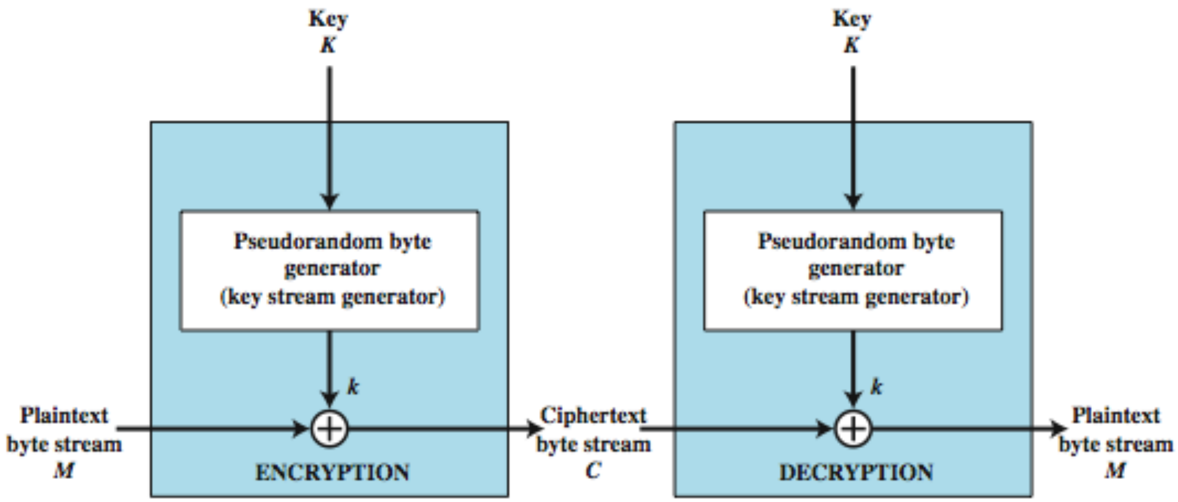
Advanced Encryption Standard (AES)

- needed a better replacement for DES
- NIST called for proposals in 1997
- selected Rijndael in Nov 2001
- published as FIPS 197
- symmetric block cipher
- uses 128 bit data & 128/192/256 bit keys
- now widely available commercially

Block verses Stream Ciphers



(a) Block cipher encryption (electronic codebook mode)

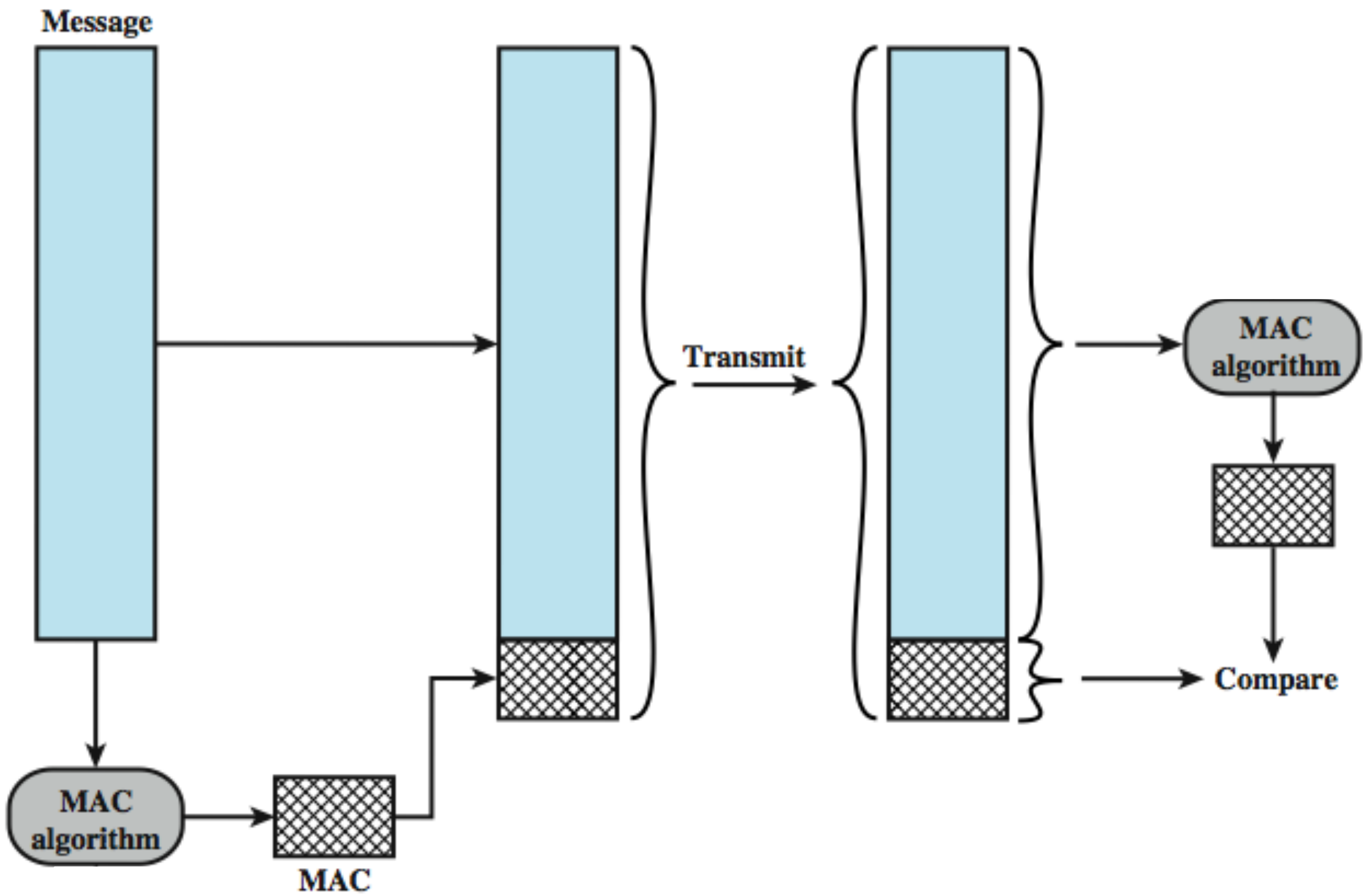


(b) Stream encryption

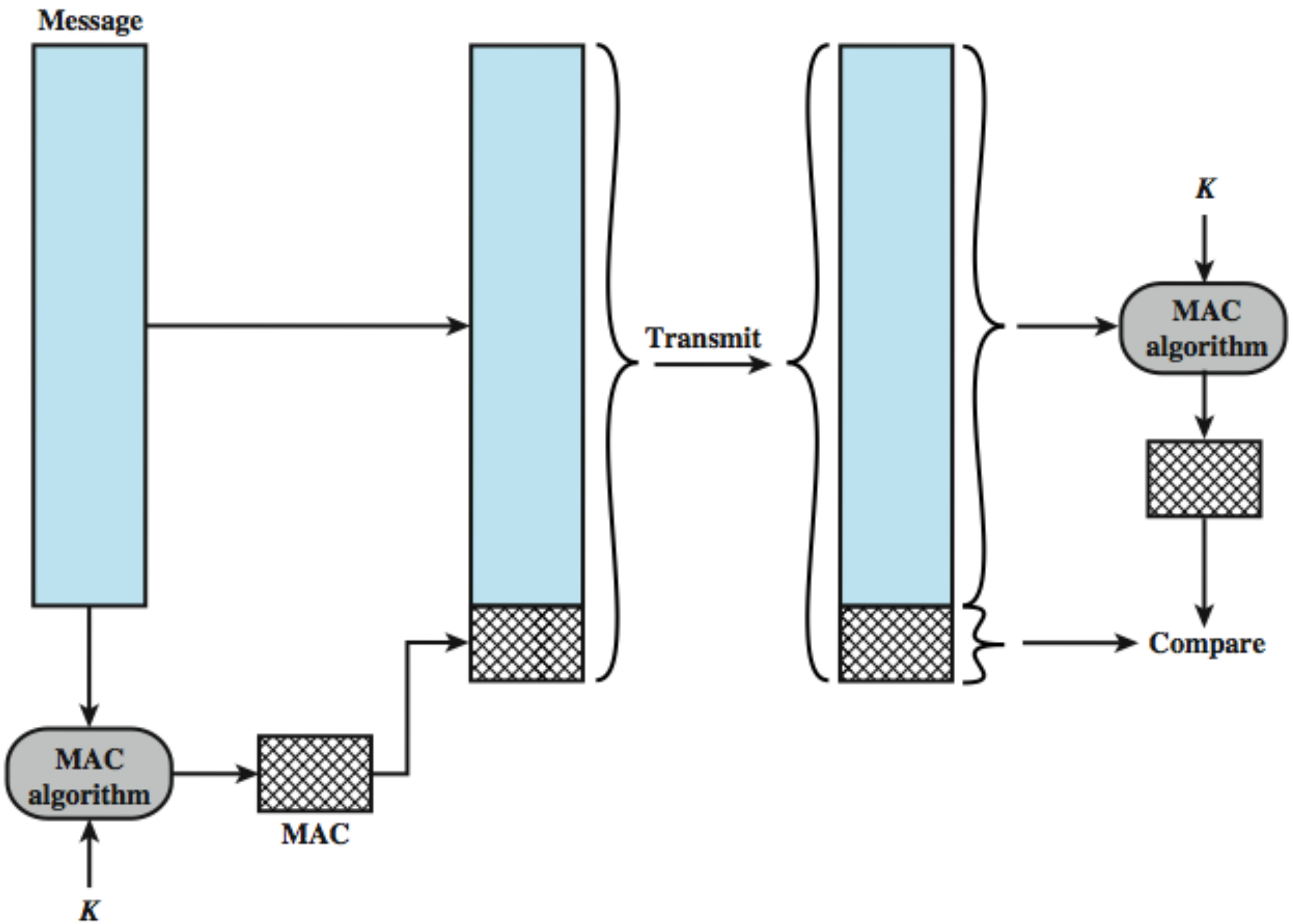
Message Authentication

- 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

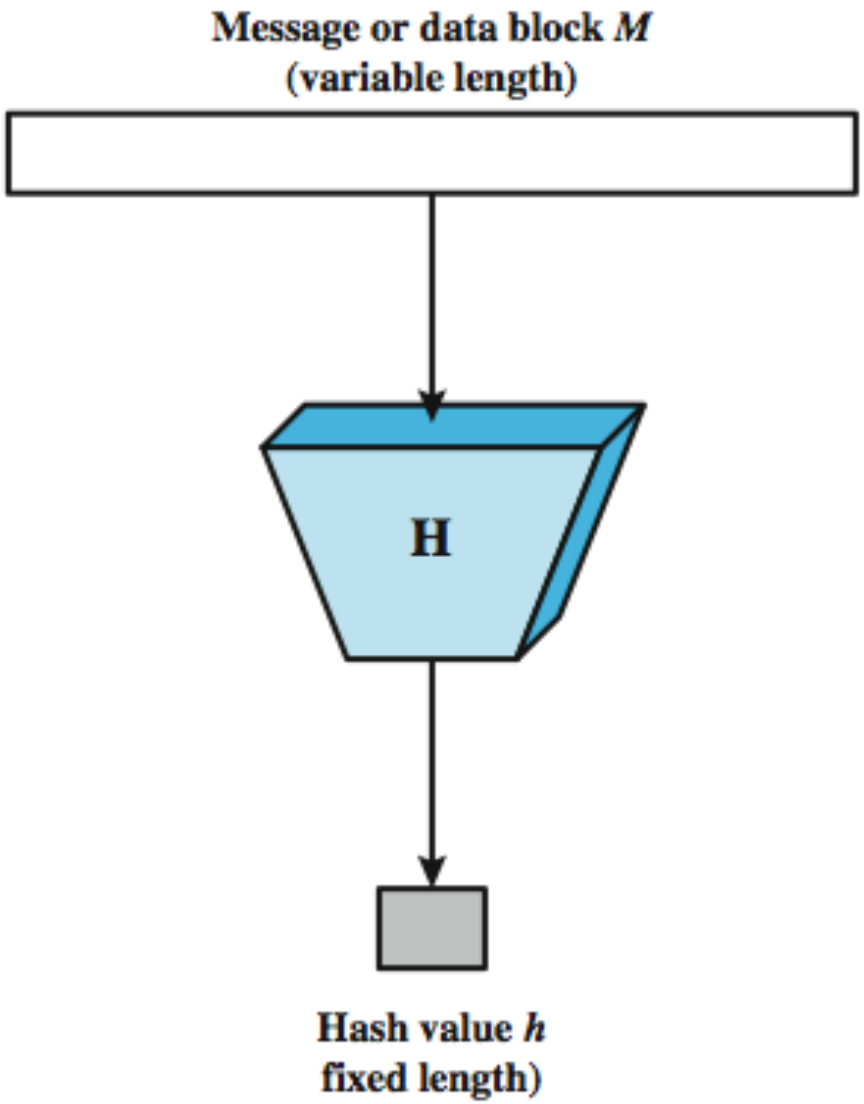
Message Authentication Codes 1



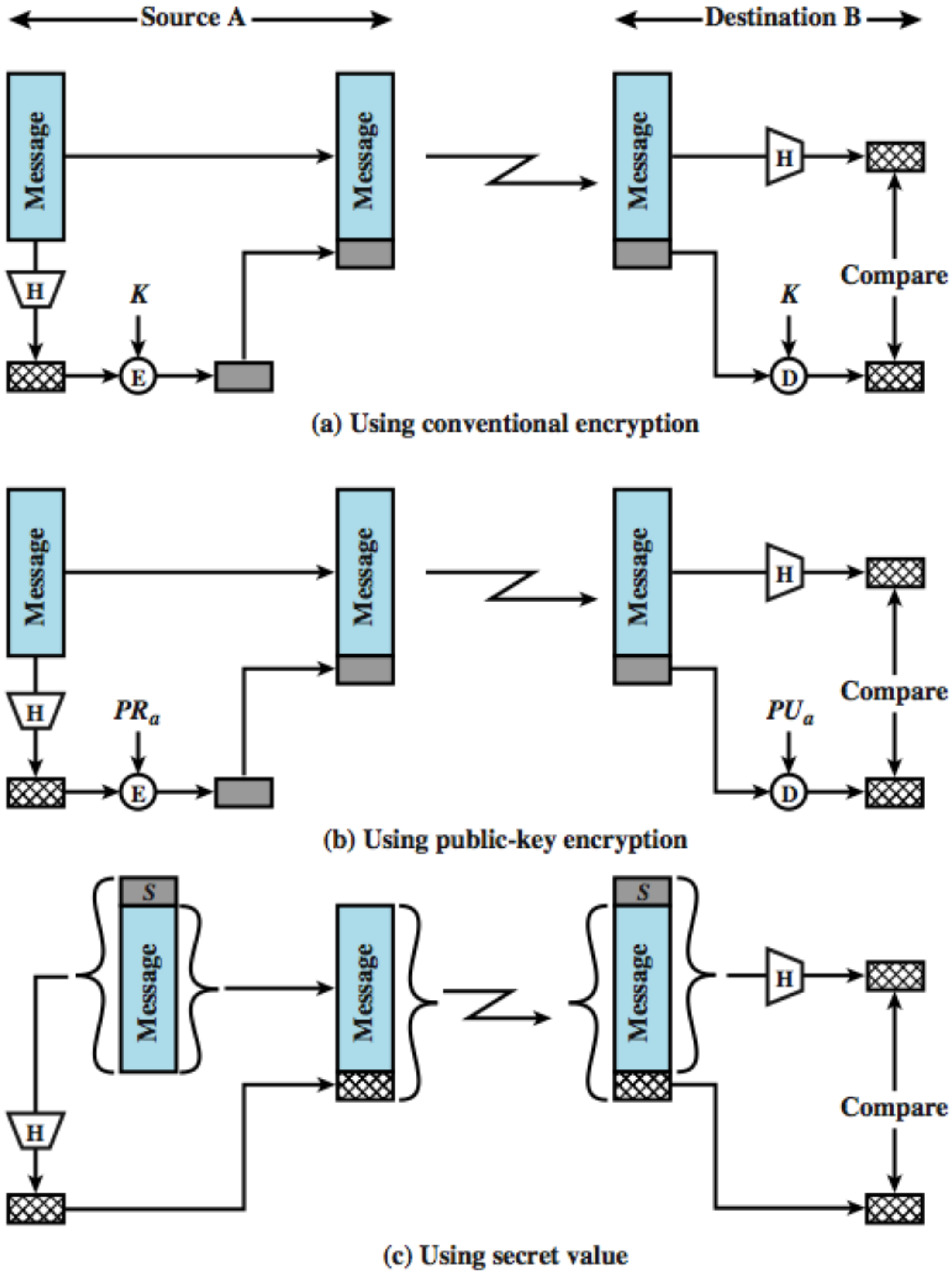
Message Authentication Codes



Secure Hash Functions



Message Auth



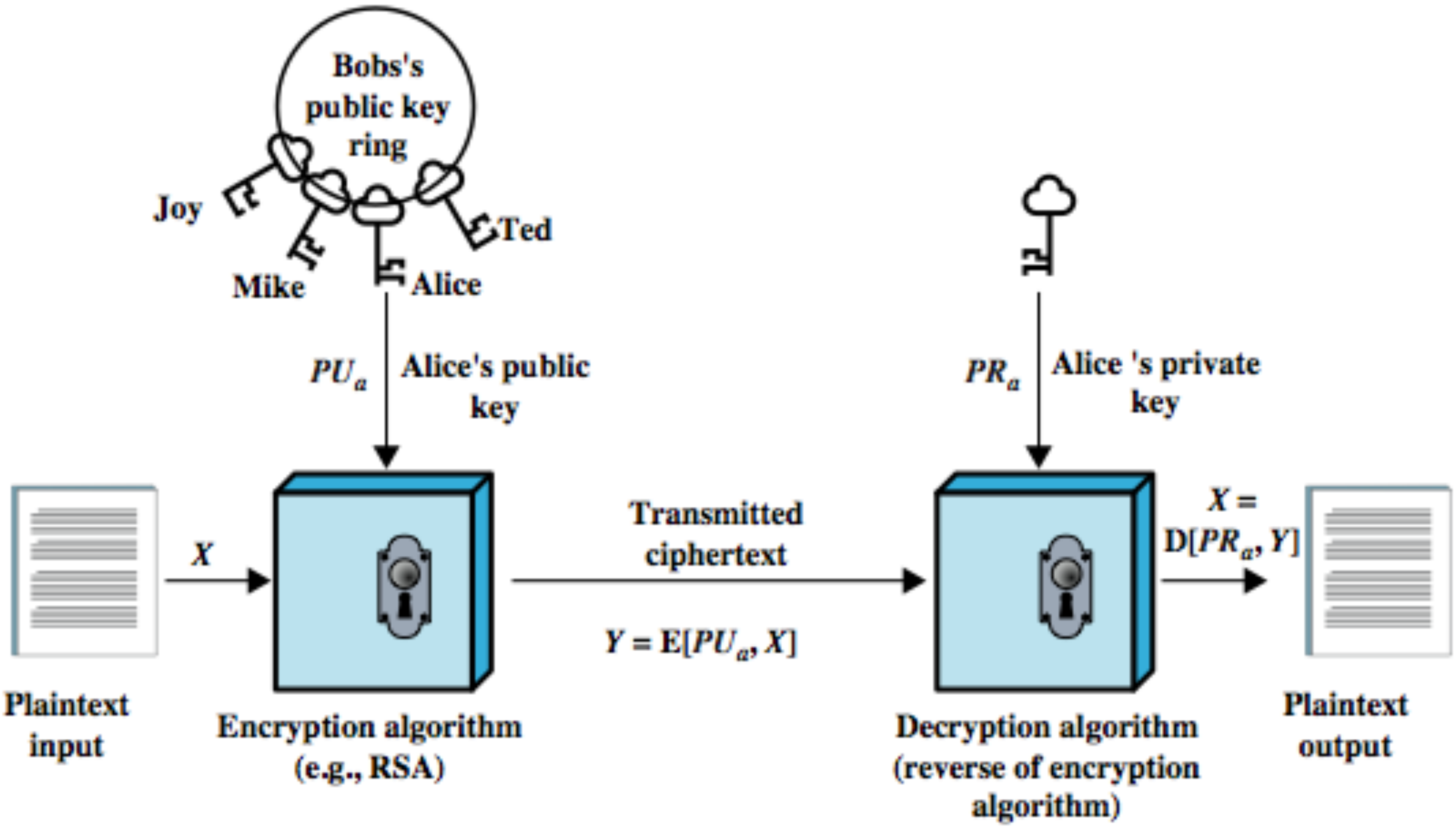
Hash Function Requirements

- 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 $y \neq x$ 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

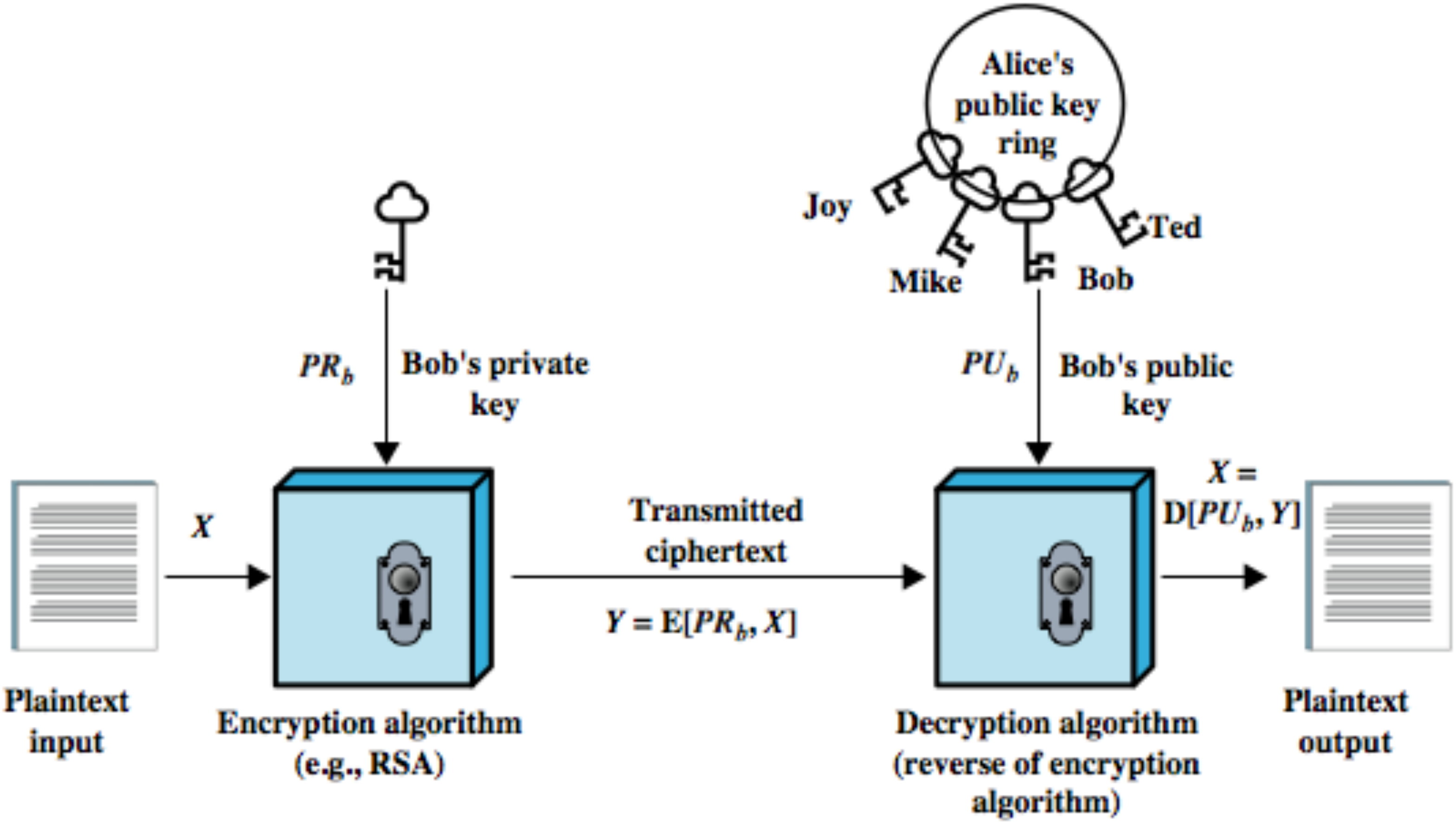
- two attack approaches
  - cryptanalysis
    - exploit logical weakness in alg
  - brute-force attack
    - trial many inputs
    - strength proportional to size of hash code $(2^{n/2})$
- SHA most widely used hash algorithm
  - SHA-1 gives 160-bit hash
  - more recent SHA-256, SHA-384, SHA-512 provide improved size and security

Public Key Encryption



(a) Confidentiality

Public Key Authentication



(b) Authentication

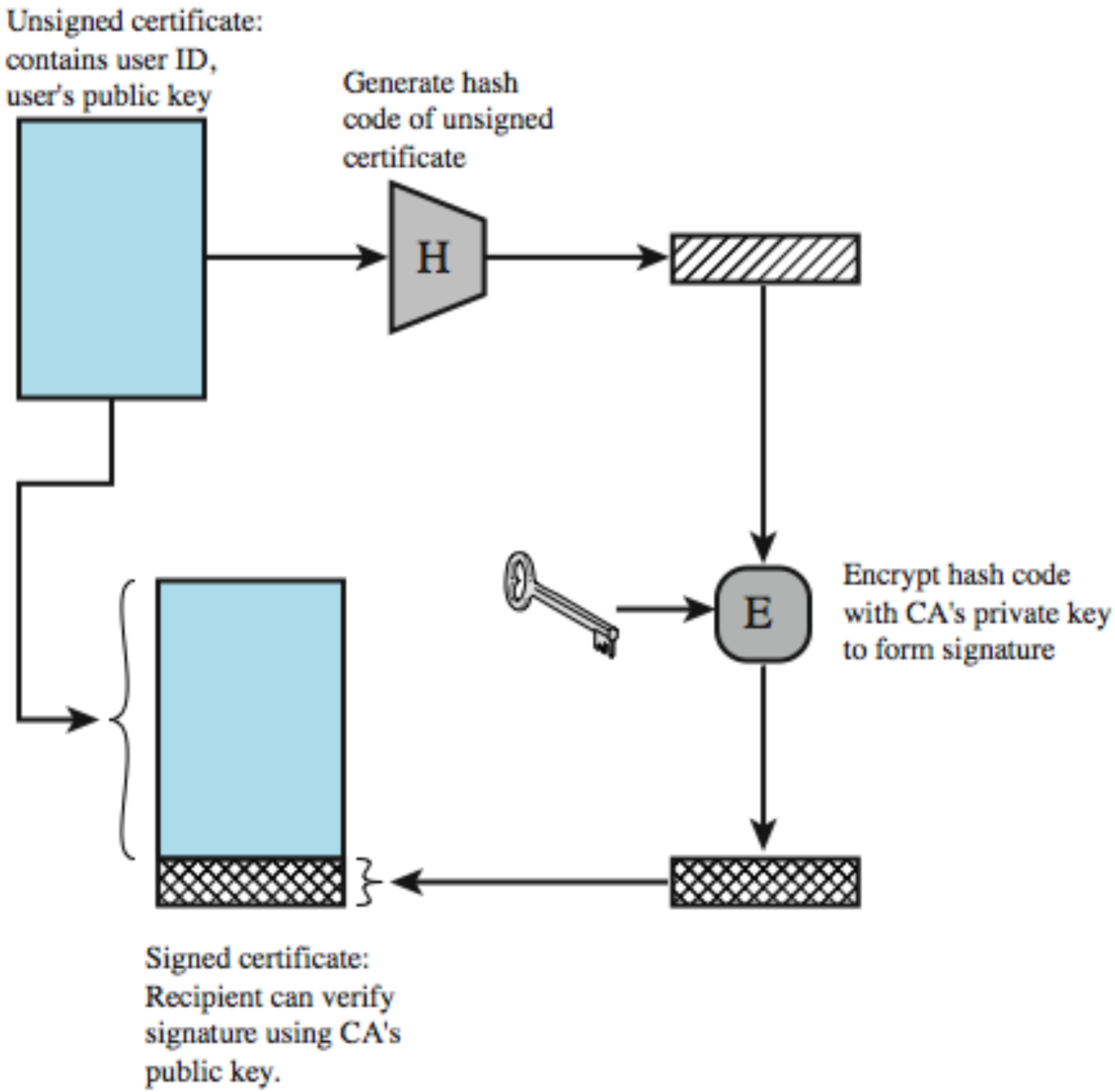
Public Key Requirements

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

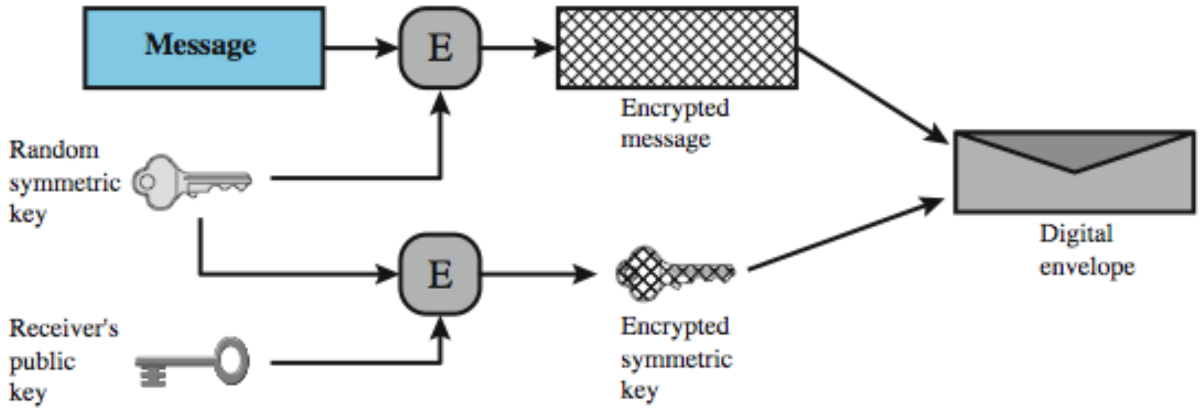
Public Key Algorithms

- RSA (Rivest, Shamir, Adleman)
  - developed in 1977
  - only widely accepted public-key encryption alg
  - 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

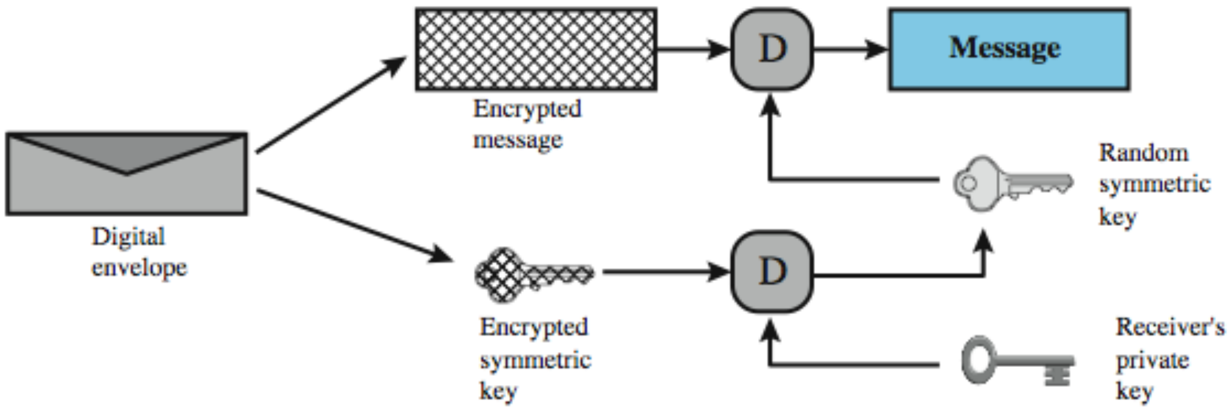
Public Key Certificates



Digital Envelopes



(a) Creation of a digital envelope



(b) Opening a digital envelope

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 versus Random Numbers

- often use algorithmic technique to create pseudorandom numbers
  - which satisfy statistical randomness tests
  - but likely to be predictable
- true random number generators use a nondeterministic 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
- 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

Public-Key Cryptography and Message Authentication

- now look at technical detail concerning:
  - secure hash functions and HMAC
  - RSA & Diffie-Hellman Public-Key Algorithms

Simple Hash Functions

- a one-way or secure hash function used in message authentication, digital signatures
- all hash functions process input a block at a time in an iterative fashion
- one of simplest hash functions is the bit-by-bit exclusive-OR (XOR) of each block

$$C_i = b_{i1} \oplus b_{i2} \oplus \ldots \oplus b_{im}$$

  - effective data integrity check on random data
  - less effective on more predictable data
  - virtually useless for data security

SHA Secure Hash Functions

- SHA originally developed by NIST/NSA in 1993
- was revised in 1995 as SHA-1
  - US standard for use with DSA signature scheme
  - standard is FIPS 180-1 1995, also Internet RFC3174
  - produces 160-bit hash values
- NIST issued revised FIPS 180-2 in 2002
  - adds 3 additional versions of SHA
  - SHA-256, SHA-384, SHA-512
  - with 256/384/512-bit hash values
  - same basic structure as SHA-1 but greater security
- NIST intend to phase out SHA-1 use

Other Secure Hash Functions

- most based on iterated hash function design
  - if compression function is collision resistant
  - so is resultant iterated hash function
- MD5 (RFC1321)
  - was a widely used hash developed by Ron Rivest
  - produces 128-bit hash, now too small
  - also have cryptanalytic concerns
- Whirlpool (NESSIE endorsed hash)
  - developed by Vincent Rijmen & Paulo Barreto
  - compression function is AES derived W block cipher
  - produces 512-bit hash

RSA Public-Key Encryption

- by Rivest, Shamir & Adleman of MIT in 1977
- best known & widely used public-key alg
- uses exponentiation of integers modulo a prime
- encrypt: $C = M^e \bmod n$
- *decrypt:* $M = C^d \bmod n = (M^e)^d \bmod n = M$
- both sender and receiver know values of n and e
- only receiver knows value of d
- public-key encryption algorithm with
  - public key $PU = \{e, n\}$ & private key $PR = \{d, n\}$.

RSA Algorithm

Key Generation

Select p, q	p and q both prime, $p \neq q$
Calculate $n = p \times q$	
Calculate $\phi(n) = (p-1)(q-1)$	
Select integer e	$\gcd(\phi(n), e) = 1;\ 1 < e < \phi(n)$
Calculate d	$de \bmod \phi(n) = 1$
Public key	$KU = \{e, n\}$
Private key	$KR = \{d, n\}$

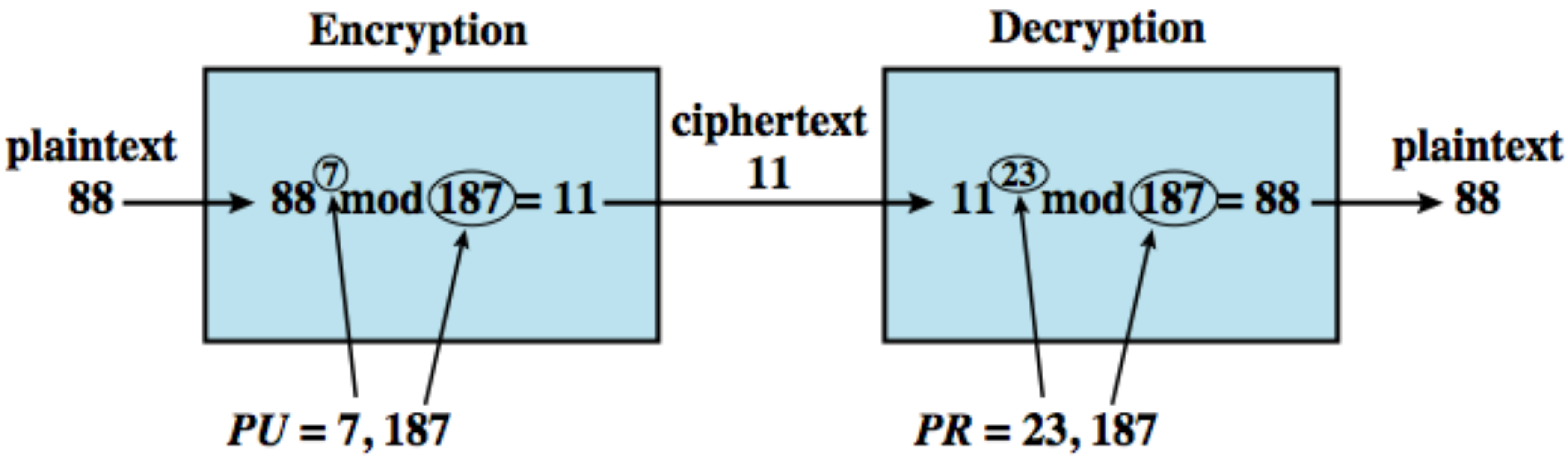
Encryption

Plaintext:	$M < n$
Ciphertext:	$C = M^e \pmod{n}$

Decryption

Ciphertext:	C
Plaintext:	$M = C^d \pmod{n}$

RSA Example



Encryption
Decryption
plaintext
88
88
7
mod
187
= 11
ciphertext
11
11
23
mod
187
= 88
plaintext
88
PU = 7, 187
PR = 23, 187

Attacks on RSA

- brute force
  - trying all possible private keys
  - use larger key, but then slower
- mathematical attacks (factoring n)
  - see improving algorithms (QS, GNFS, SNFS)
  - currently 1024-2048-bit keys seem secure
- timing attacks (on implementation)
  - use - constant time, random delays, blinding
- chosen ciphertext attacks (on RSA props)