Network Security Part I: Concepts

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These slides are available on-line at:

http://www.cse.wustl.edu/~jain/cse473-05/

- Security Statistics, Attacks, Requirements
- Secret Key and Public Key Encryption
- Hash Functions
- Message Authentication Code (MAC)
- Digital Signature and Digital Certificates
- RSA Public Key Encryption

Security Threat Statistics

- DoD networks were attacked 250000 times in 1995 (well before Internet popularity)
- Of 38,000 friendly attacks, 65% succeeded
- Only 4% of successful attacks were noticed by network administrators
- Only a small fraction of those noticed were reported to authorities
- FBI reports 163 organizations lost $123M in 1999
- Ref: M. Markow, "VPN for Dummies," IDG Books, 1999.

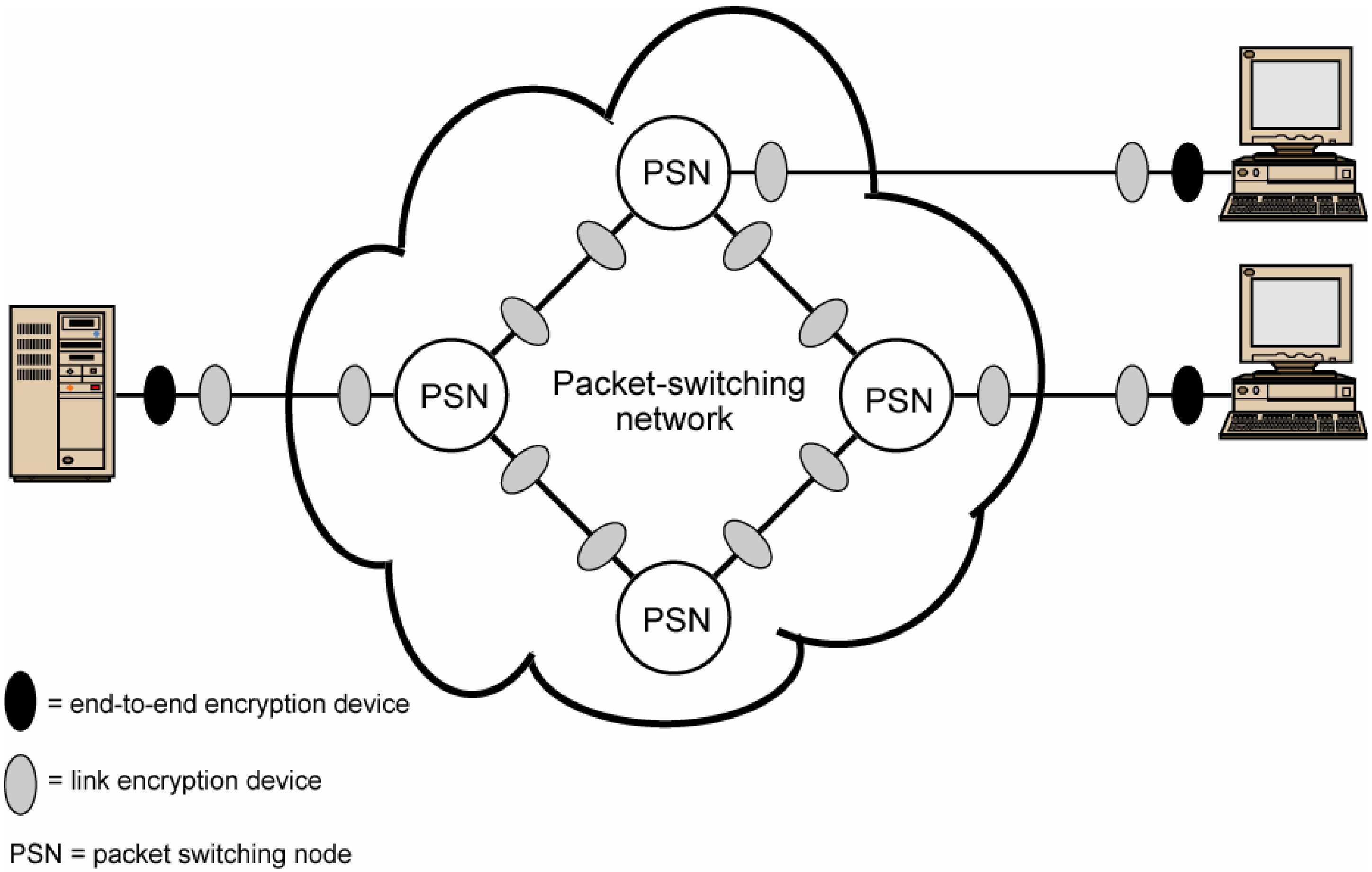
Security Attacks

- **Passive**:
  - Release of message contents: Eavesdropping
  - Traffic analysis: monitoring frequency and length of messages, even encrypted
    nature of communication may be guessed
  - Difficult to detect
- **Active**:
  - Masquerade: Pretend to be some one else
  - Replay: Capture and reuse for unauthorized effect
  - Modification of message
  - Denial of Service

Security Requirements

- **Integrity**: Received = sent?
- **Availability**: Legal users should be able to use.
  Ping continuously ⇒ No useful work gets done.
- **Confidentiality and Privacy**:
  No snooping or wiretapping
- **Authentication**: You are who you say you are.
  A student at Dartmouth posing as a professor canceled the exam.
- **Authorization** = Access Control
  Only authorized users get to the data

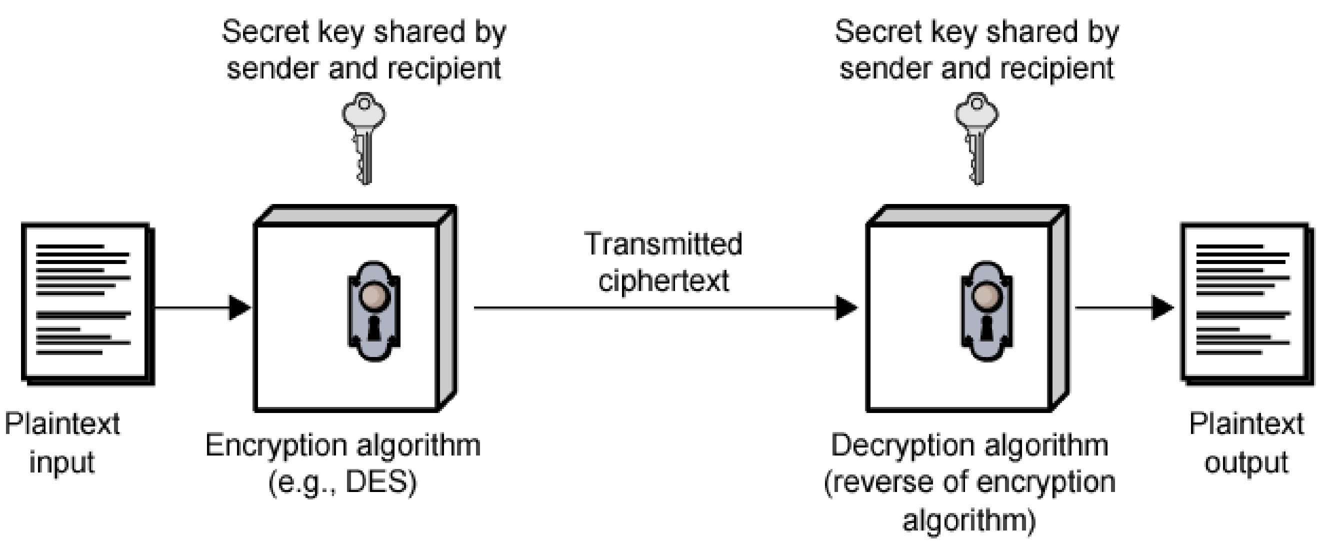
Link vs End-to-End Encryption



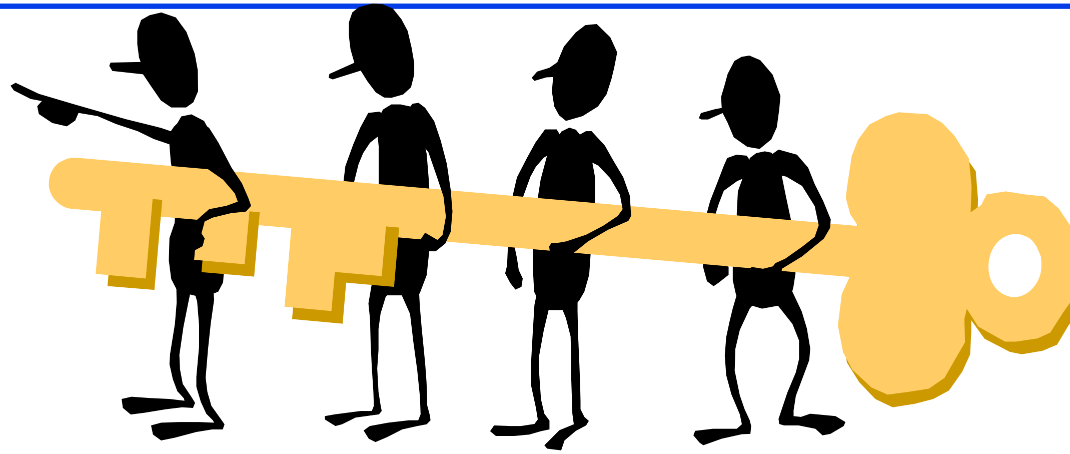
- Link ⇒All traffic secure. Vulnerable inside switches

Secret Key Encryption

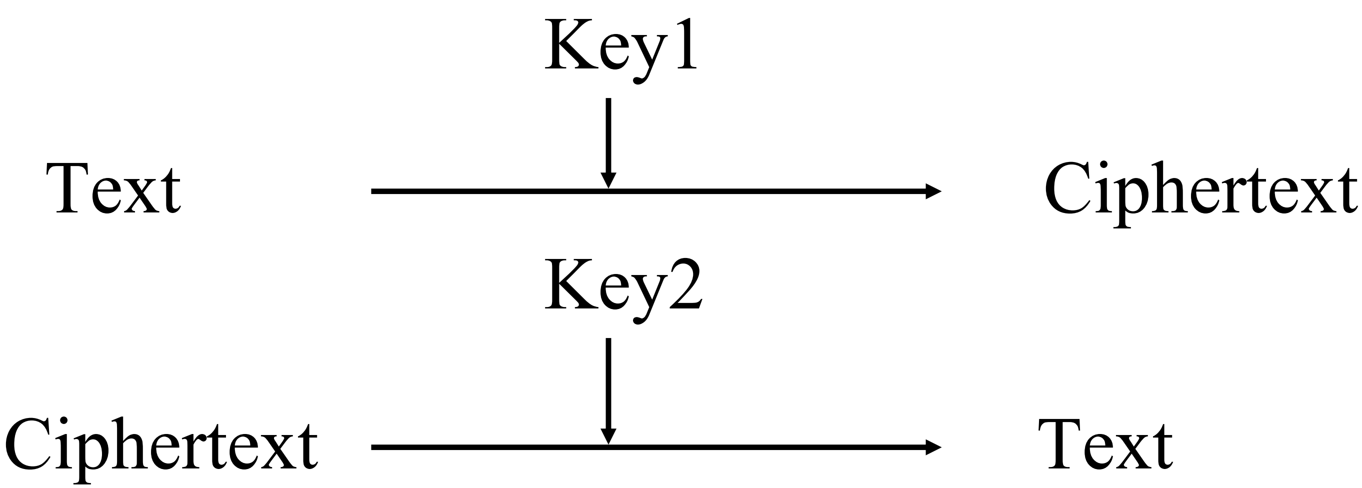
- Also known as symmetric encryption
- Encrypted_Message = Encrypt(Key, Message)
- Message = Decrypt(Key, Encrypted_Message)
- Example: Encrypt = division
- 433 = 48 R 1 (using divisor of 9)



Public Key Encryption



- Invented in 1975 by Diffie and Hellman
- Encrypted_Message = Encrypt(Key1, Message)
- Message = Decrypt(Key2, Encrypted_Message)



Public Key Encryption

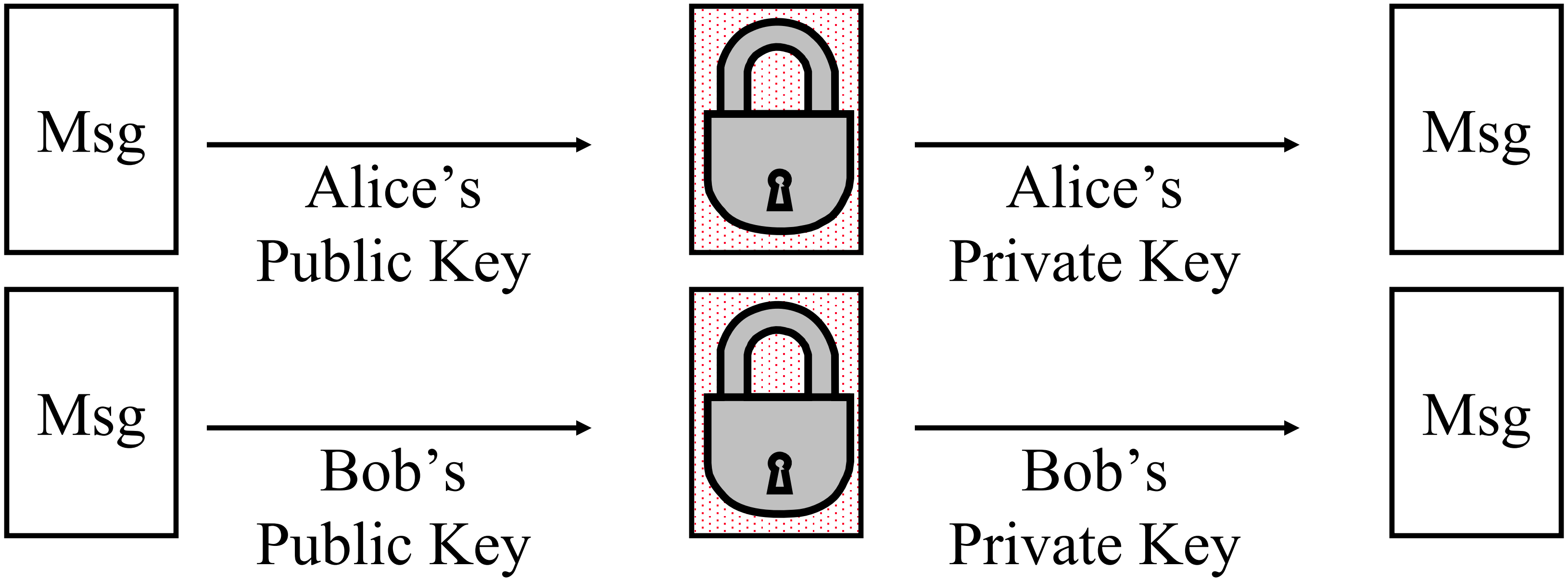
- RSA: Encrypted_Message = m^3 mod 187
- Message = $\text{Encrypted\_Message}^{107}$ mod 187
- Key1 = <3,187>, Key2 = <107,187>
- Message = 5
- Encrypted Message = $5^3 = 125$
- Message = 125^{107} mod 187 = 5
  = $125^{(64+32+8+2+1)}$ mod 187
  = $\{(125^{64} \bmod 187)(125^{32} \bmod 187)\ldots$
  $(125^2 \bmod 187)(125 \bmod 187)\} \bmod 187$

Modular Arithmetic

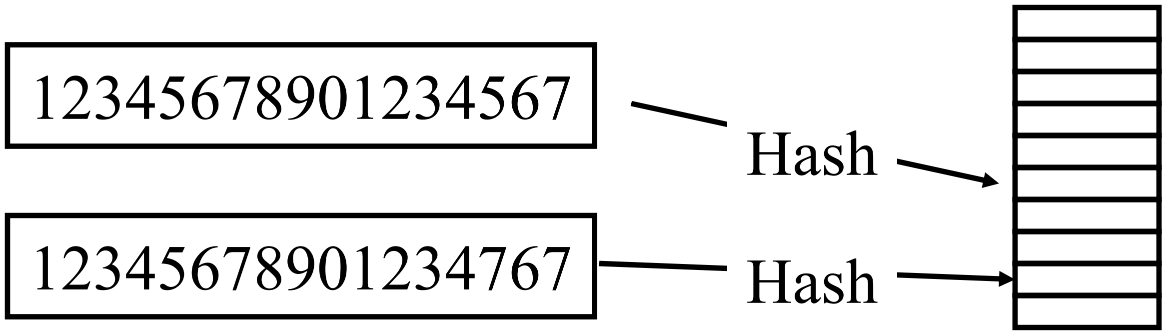
- $xy \bmod m = (x \bmod m)\,(y \bmod m)$
- $x^4 \bmod m = (x^2 \bmod m)(x^2 \bmod m)$
- $x^{ij} \bmod m = (x^i \bmod m)^j \bmod m$
- $125 \bmod 187 = 125$
- $125^2 \bmod 187 = 15625 \bmod 187 = 104$
- $125^4 \bmod 187 = (125^2 \bmod 187)^2 \bmod 187$
  $= 104^2 \bmod 187 = 10816 \bmod 187 = 157$
- $128^8 \bmod 187 = 157^2 \bmod 187 = 152$
- $128^{16} \bmod 187 = 152^2 \bmod 187 = 103$
- $128^{32} \bmod 187 = 103^2 \bmod 187 = 137$
- $128^{64} \bmod 187 = 137^2 \bmod 187 = 69$
- $128^{64+32+8+2+1} \bmod 187 = 69 \times 137 \times 152 \times 104 \times 125 \bmod 187$
  $= 18679128000 \bmod 187 = 5$

Public Key (Cont)

- One key is private and the other is public
- Message = Decrypt(Public_Key,
  Encrypt(Private_Key, Message))
- Message = Decrypt(Private_Key,
  Encrypt(Public_Key, Message))



Hash Functions



Example: CRC can be used as a hash
(not recommended for security applications)

Requirements:

1. Applicable to any size message
2. Fixed length output
3. Easy to compute
4. Difficult to Invert ⇒ Can't find *x* given H(*x*) ⇒ One-way
5. Difficult to find y, such that H(*x*) = H(*y*) ⇒ Can't change msg
6. Difficult to find *any* pair (*x*, *y*) such that H(*x*) = H(*y*)
   ⇒ Strong hash

Digital Signature

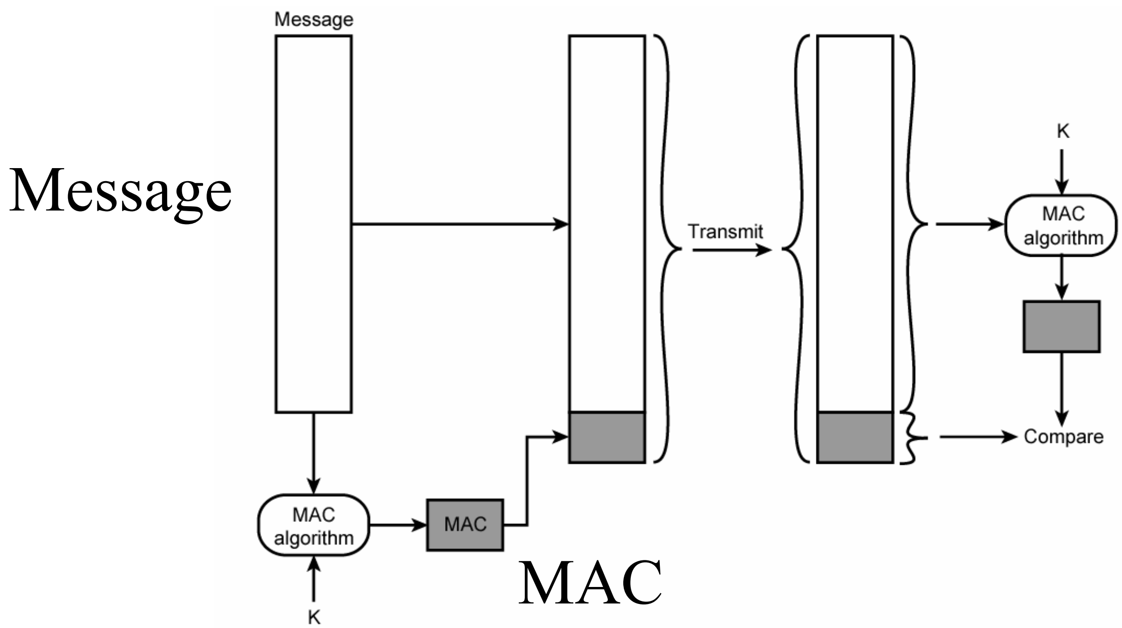
- Message Digest = Hash(Message)
- Signature = Encrypt(Private_Key, Hash)
- Hash(Message) = Decrypt(Public_Key, Signature)
  ⇒ Authentic
- Also known as Message *authentication* code (MAC)

Text —Hash→ Digest —(Private Key)→ Signature

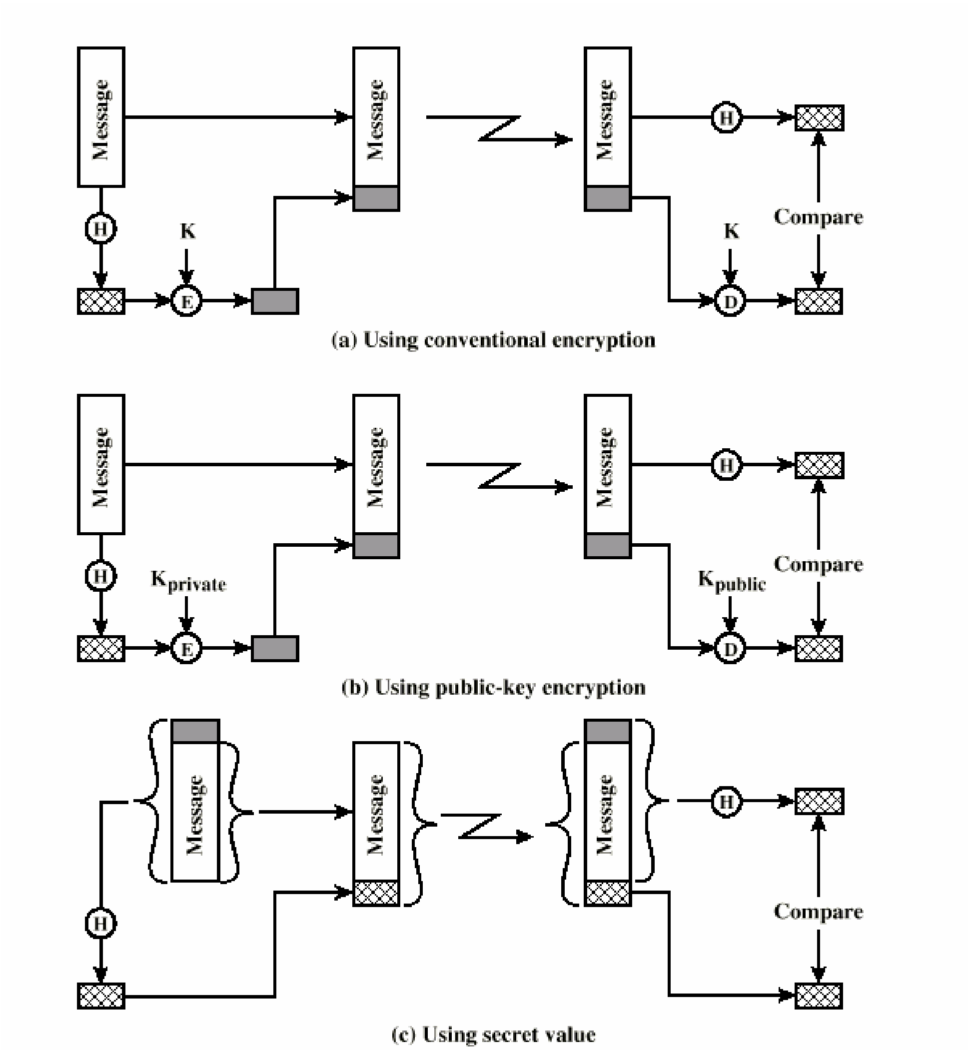
Signature —(Public Key)→ Digest ←Hash— Text

Message Authentication Code (MAC)

- Authentic Message = Contents unchanged + Source Verified
- May also want to ensure that the time of the message is correct
- Encrypt({Message, CRC, Time Stamp}, Source's secret key)
- Message + Encrypt(Hash, Source's secret key)
- Message + Encrypt(Hash, Source's private key)

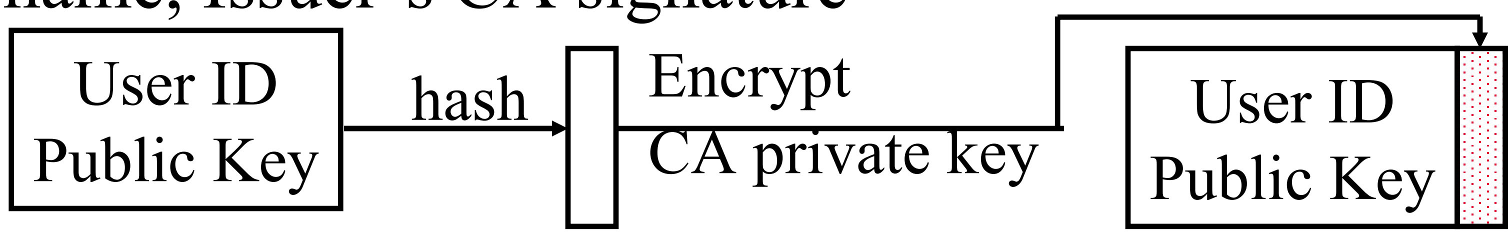


MAC: Using One Way Hash



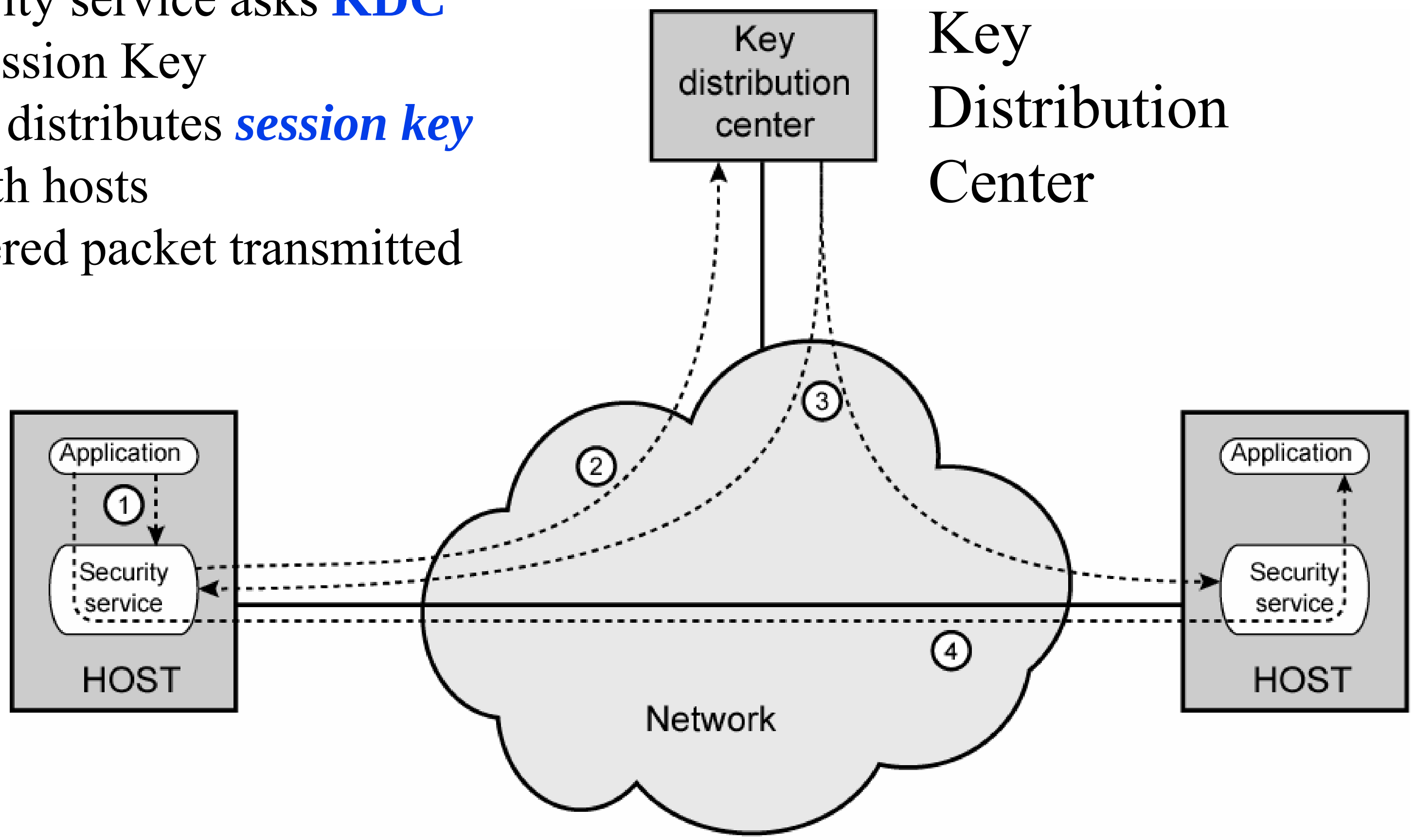
Digital Certificates

- Like driver license or passport
- Digitally signed by Certificate authority (CA) - a trusted organization
- Public keys are distributed with certificates
- CA uses its public key to sign the certificate
  ⇒ Hierarchy of trusted authorities
- X.509 Certificate includes: Name, organization, effective date, expiration date, public key, issuer's CA name, Issuer's CA signature



Key Distribution

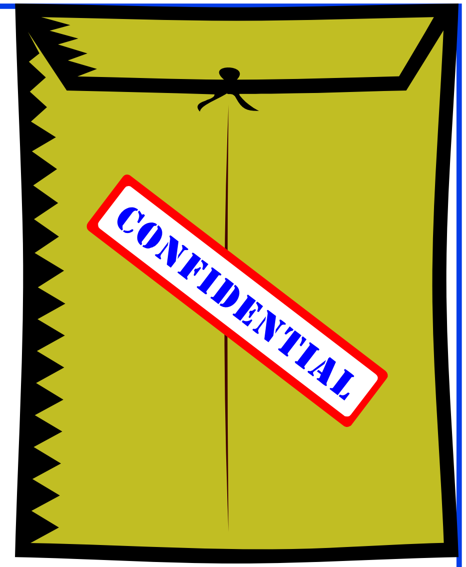
1. Application requests connection
2. Security service asks **KDC** for session Key
3. KDC distributes ***session key*** to both hosts
4. Buffered packet transmitted



Key Distribution Center

KDC shares a secret key with each Host.

Confidentiality



- User 1 to User 2:
- Encrypted_Message
  = Encrypt(Public_Key2,
  Encrypt(Private_Key1, Message))
- Message = Decrypt(Public_Key1,
  Decrypt(Private_Key2, Encrypted_Message)
  ⇒ Authentic and Private

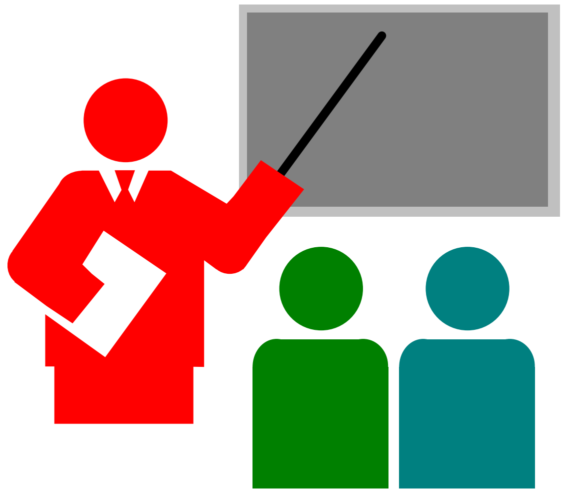
RSA Public Key Encryption

- Ron Rivest, Adi Shamir, and Len Adleman at MIT 1978
- Both plain text M and cipher text C are integers between 0 and n-1.
- Key 1 = {e, n},
Key 2 = {d, n}
- $C = M^e \bmod n$
$M = C^d \bmod m$
- How to construct keys:
    - Select two large primes: p, q, $p \neq q$
    - $N = p \times q$
    - Calculate $\Phi = (p-1)(q-1)$
    - Select e, such that $lcd(\Phi, e) = 1$; $0 < e < s$
    - Calculate d such that $de \bmod \Phi = 1$

RSA Algorithm: Example

- Select two large primes: p, q, $p \neq q$
  p = 17, q = 11
- $N = p \times q = 17 \times 11 = 187$
- Calculate $\Phi = (p-1)(q-1) = 16x10 = 160$
- Select e, such that lcd(Φ, e) = 1; 0 < e < s
  say, e = 7
- Calculate d such that de mod $\Phi = 1$
  - 160k+1 = 161, 321, 481, 641
  - Check which of these is divisible by 7
  - 161 is divisible by 7 giving d = 161/7 = 23
- Key 1 = {7, 187}, Key 2 = {23, 187}

Summary



- Passive and active attacks
- Secret Key and Public Key Encryption
- Secure Hash Functions
- Message Authentication Code (MAC)
- Digital Signature and Digital Certificates
- RSA Public Key Encryption based on exponentiation

Reading Assignment

- Read Sections 21.1 through 21.4 of 7th edition of Stallings. You can skip AES, SHA-1 during this part.

Homework

- Submit answer to Exercise 21.6 in Stallings' 7th edition