Security: Focus of Control

Data is protected against wrong or invalid operations

State

Object

Invocation   Method
(a)

Data is protected against unauthorized invocations
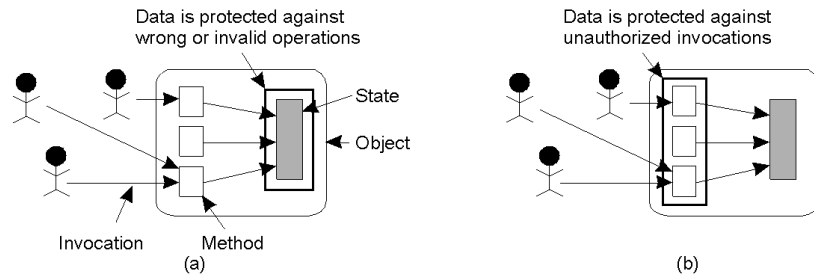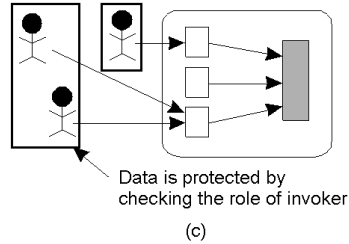
(b)

- Three approaches for protection against security threats
a) Protection against invalid operations
b) Protection against unauthorized invocations
c) Protection against unauthorized users

Data is protected by checking the role of invoker
(c)

Authentication

Hello. This is your bank. We are verifying your checking, ATM, credit card numbers and balances. Can you give me that information please?

- **Question:** how does a receiver know that remote communicating entity is who it is claimed to be?

Authentication Protocol (ap)

- Ap 1.0
  - Alice to Bob: "I am Alice"
  - Problem: intruder "Trudy" can also send such a message
- Ap 2.0
  - Authenticate source IP address is from Alice's machine
  - Problem: IP Spoofing (send IP packets with a false address)
- Ap 3.0: use a secret password
  - Alice to Bob: "I am Alice, here is my password" (e.g., telnet)
  - Problem: Trudy can intercept Alice's password by sniffing packets

Authentication Protocol

Ap 3.1: use encryption

use a symmetric key known to Alice and Bob

- Alice & Bob (only) know secure key for encryption/decryption

A to B: msg = encrypt("I am A")
B computes: if decrypt(msg)=="I am A"
  then A is verified
  else A is fradulent

- failure scenarios: playback attack
  - Trudy can intercept Alice's message and masquerade as Alice at a later time

Authentication Using Nonces

Problem with ap 3.1: same password is used for all sessions
Solution: use a sequence of passwords
    pick a "once-in-a-lifetime-only" number (nonce) for each session

Ap 4.0
    A to B: msg = "I am A" /* note: unencrypted message! */
    B to A: once-in-a-lifetime value, n
    A to B: msg2 = encrypt(n) /* use symmetric keys */
    B computes: if decrypt(msg2)==n
        then A is verified
        else A is fradulent

- note similarities to three way handshake and initial sequence number choice
- problems with nonces?

Authentication Using Public Keys

 Ap 4.0 uses symmetric keys for authentication
Question: can we use public keys?

symmetry: $DA(EA(n)) = EA(DA(n))$

AP 5.0
    A to B: msg = "I am A"
    B to A: once-in-a-lifetime value, n
    A to B: msg2 = $DA(n)$
    B computes: if $EA(DA(n))== n$
        then A is verified
        else A is fradulent

Problems with Ap 5.0

- Bob needs Alice's public key for authentication
  - Trudy can impersonate as Alice to Bob
    - Trudy to Bob: msg = "I am Alice"
    - Bob to Alice: nonce n (Trudy intercepts this message)
    - Trudy to Bob: msg2= DT(n)
    - Bob to Alice: send me your public key (Trudy intercepts)
    - Trudy to Bob: send ET (claiming it is EA)
    - Bob: verify ET(DT(n)) == n and authenticates Trudy as Alice!!
- Moral: Ap 5.0 is only as "secure" as public key distribution

Man-in-the-middle Attack

- Trudy impersonates as Alice to Bob and as Bob to Alice
  - Alice   Trudy   Bob
  -        "I am A"   "I am A"
  -                           nonce n
  -                           DT(n)
  -                      send me ET
  -                              ET
  -        nonce n
  -        DA(n)
  -      send me EA
  -          EA
  - Bob sends data using ET, Trudy decrypts and forwards it using EA!! (Trudy *transparently* intercepts every message)

Digital Signatures Using Public Keys

Goals of digital signatures:

- sender cannot repudiate message never sent ("I never sent that")
- receiver cannot fake a received message

Suppose A wants B to "sign" a message M

B sends DB(M) to A

A computes if EB (DB(M)) == M

  then B has signed M

Question: can B plausibly deny having sent M?

Message Digests

- Encrypting and decrypting entire messages using digital signatures is computationally expensive
  - Routers routinely exchange data
    - Does not need encryption
    - Needs authentication and verify that data hasn't changed
- Message digests: like a checksum
  - Hash function H: converts variable length string to fixed length hash
  - Digitally sign H(M)
  - Send M, DA(H(m))
  - Can verify who sent the message and that it has been changed!
- Property of H
  - Given a digest x, it is infeasible to find a message y such that $H(y) = x$
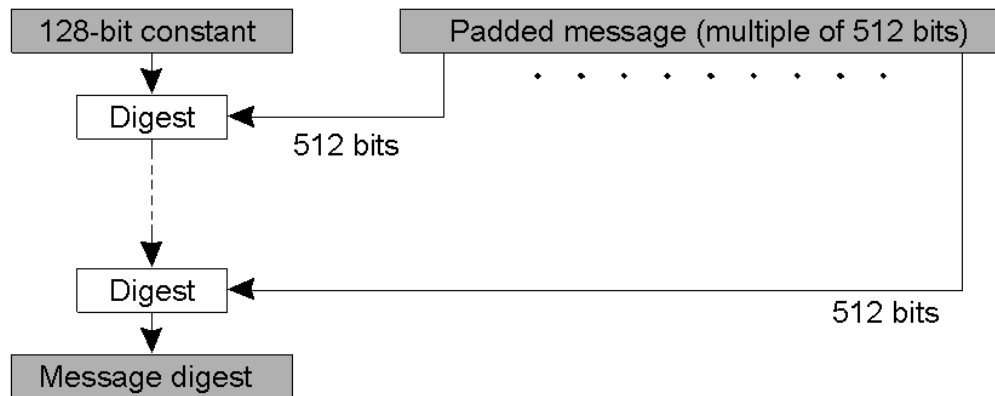 - It is infeasible to find any two messages x and y such that $H(x) = H(y)$

Hash Functions : MD5

- The structure of MD5

Symmetric key exchange: trusted server

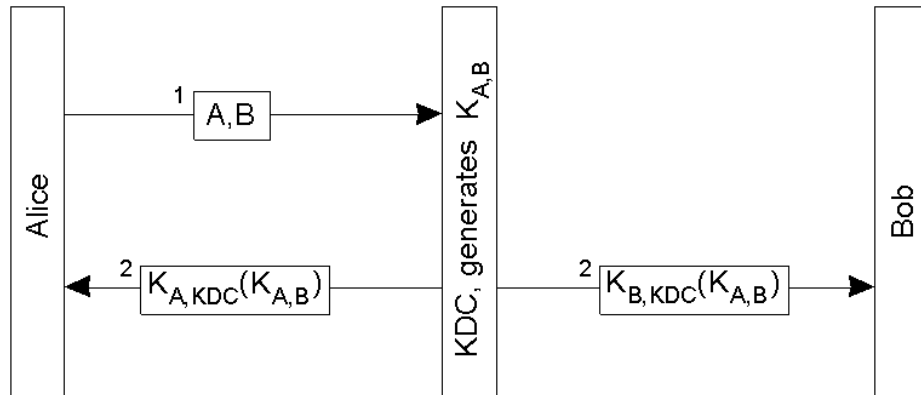**Problem:** how do distributed entities agree on a key?

Assume: each entity has its own single key, which only it and trusted server know

Server:
- will generate a one-time session key that A and B use to encrypt communication
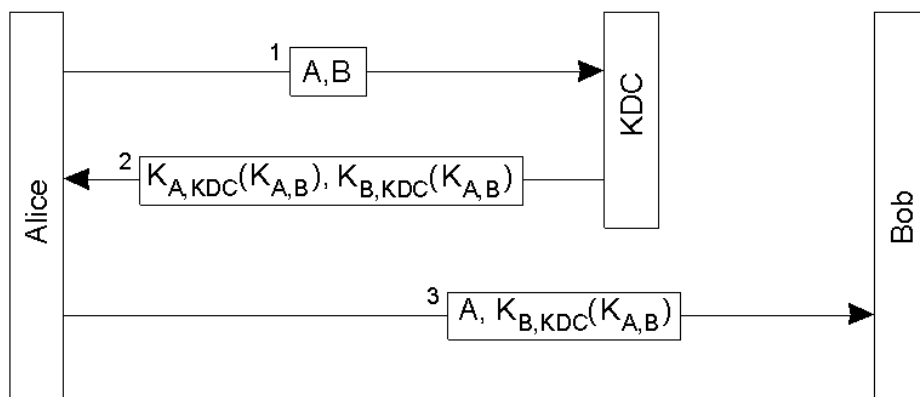- will use A and B's single keys to communicate session key to A, B

Key Exhange: Key Distribution Center (1)
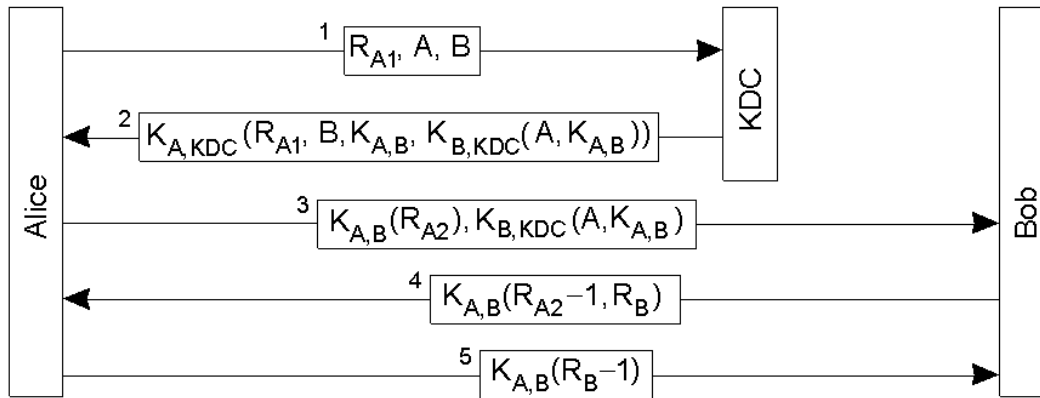
- The principle of using a KDC.

Authentication Using a Key Distribution Center (2)

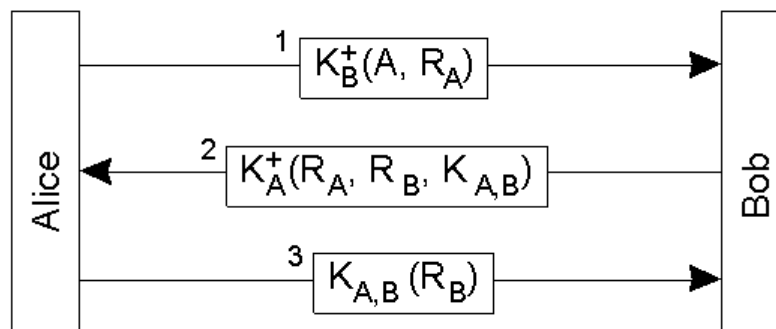- Using a ticket and letting Alice set up a connection to Bob.

Authentication Using a Key Distribution Center (3)

Alice → **KDC**: 1. R_{A1}, A, B

KDC → **Alice**: 2. $K_{A,KDC}(R_{A1}, B, K_{A,B}, K_{B,KDC}(A, K_{A,B}))$

Alice → **Bob**: 3. $K_{A,B}(R_{A2}), K_{B,KDC}(A, K_{A,B})$

Bob → **Alice**: 4. $K_{A,B}(R_{A2}-1, R_B)$

Alice → **Bob**: 5. $K_{A,B}(R_B-1)$

Public Key Exchange

- Mutual authentication in a public-key cryptosystem.

Alice → **Bob**: 1. $K_B^+(A, R_A)$

Bob → **Alice**: 2. $K_A^+(R_A, R_B, K_{A,B})$

Alice → **Bob**: 3. $K_{A,B}(R_B)$

Public key exchange: trusted server

- public key retrieval subject to man-in-middle attack
- locate all public keys in trusted server
- everyone has server's encryption key (ES public)
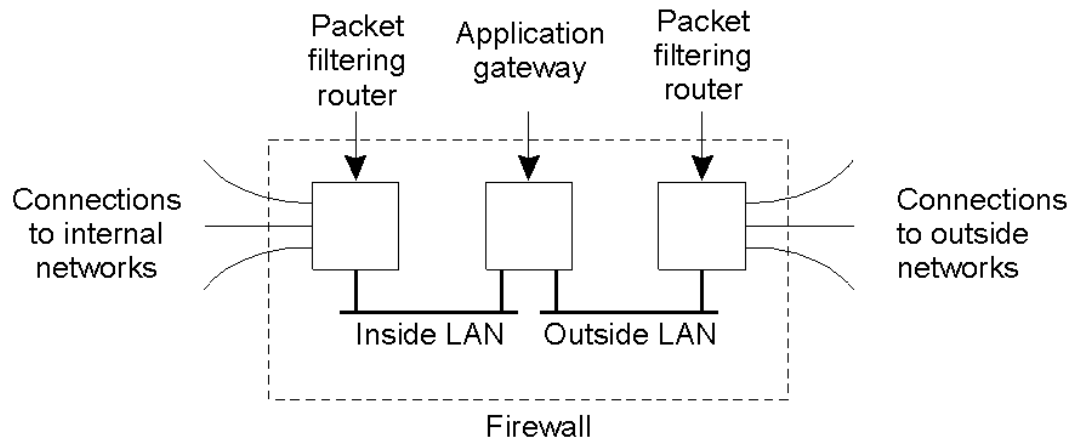- suppose A wants to send to B using B's "public" key
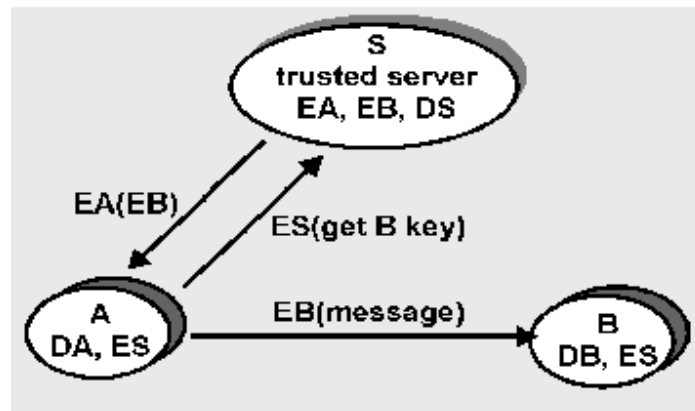
Protection Against Intruders: Firewalls

- A common implementation of a firewall.

Firewalls

Firewall: network components (host/router+software) sitting between inside ("us") and outside ("them)

Packet filtering firewalls: drop packets on basis of source or destination address (i.e., IP address, port)

Application gateways: application specific code intercepts, processes and/or relays application specific packets

- e.g., email of telnet gateways
- application gateway code can be security hardened
- can log all activity

Secure Email

- Requirements:
  - Secrecy
  - Sender authentication
  - Message integrity
  - Receiver authentication
- Secrecy
  - Can use public keys to encrypt messages
    - Inefficient for long messages
  - Use symmetric keys
    - Alice generates a symmetric key K
    - Encrypt message M with K
    - Encrypt K with E_B
    - Send K(M), $E_B(K)$
    - Bob decrypts using his private key, gets K, decrypts K(M)

Secure Email

- Authentication and Integrity (with no secrecy)
  - Alice applies hash function H to M (H can be MD5)
  - Creates a digital signature $D_A(H(M))$
  - Send M, $D_A(H(M))$ to Bob
- Putting it all together
  - Compute $H(M)$, $D_A(H(M))$
  - M'= { $H(M)$, $D_A(H(M))$ }
  - Generate symmetric key K, compute K(M')
  - Encrypt K as $E_B(K)$
  - Send K(M'), $E_B(K)$
- Used in PGP (pretty good privacy)

Secure Sockets Layer (SSL)

- SSL: Developed by Netscape
  - Provides data encryption and authentication between web server and client
  - SSL lies above the transport layer
  - Useful for Internet Commerce, secure mail access (IMAP)
  - Features:
    - SSL server authentication
    - Encrypted SSL session
    - SSL client authentication
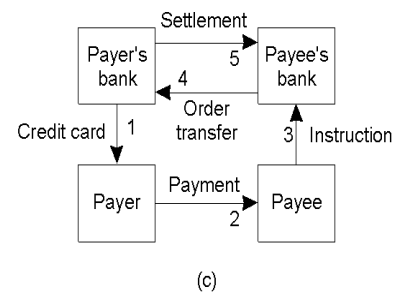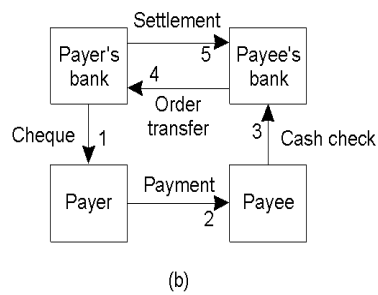
Secure Socket Layer

- Protocol: https instead of http
  - Browser -> Server: B's SSL version and preferences
  - S->B: S's SSL version, preferences, and certificate
    - Certificate: server's RSA public key encrypted by CA's private key
  - B: uses its list of CAs and public keys to decrypt S's public key
  - B->S: generate K, encrypt K with with E_S
  - B->S: "future messages will be encrypted", and K(m)
  - S->B: "future messages will be encrypted", and K(m)
  - SSL session begins…

SSL

- Homework: get your own digital certificate
  - Click on "security" icon (next to "print" icon) in Netscape 4.7
  - Click on "Certificates" and then on "obtain your certificate"
  - Send an email to yourself signed with your certificate
  - Also examine listed of trusted CAs built into the browser

Electronic Payment Systems (1)

- Payment systems based on direct payment between customer and merchant.
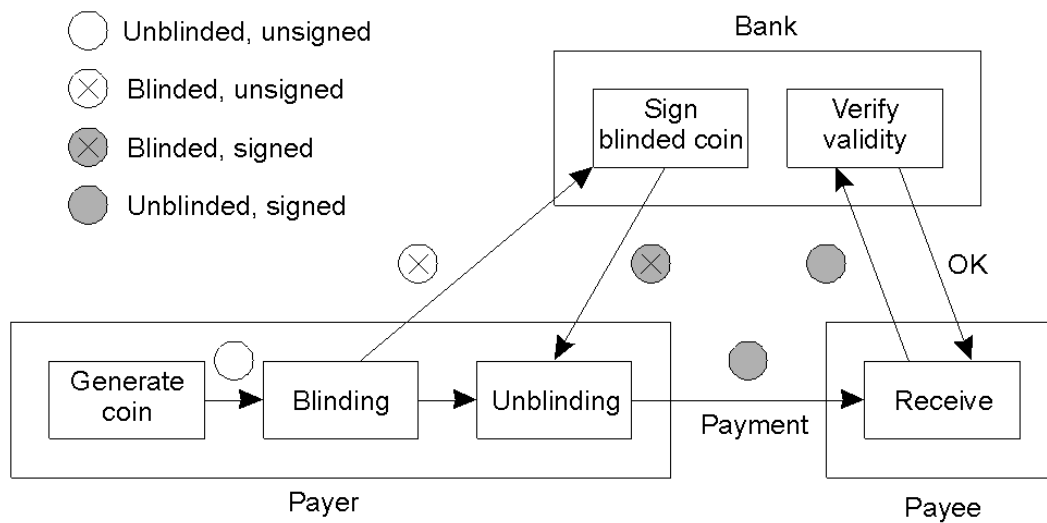
a) Paying in cash.
b) Using a check.
c) Using a credit card.

```
Payer's              Payee's
bank                 bank

Withdrawal  1      3  Deposit

            Payment
   Payer    ------→  Payee
              2
```
(a)

```
         Settlement
Payer's   5     Payee's
bank            bank
          4
        Order
Cheque  transfer  3  Cash check
     1

        Payment
Payer   ------→  Payee
          2
```
(b)

```
            Settlement
Payer's      5     Payee's
bank               bank
             4
           Order
Credit card transfer  3  Instruction
      1

           Payment
Payer      ------→  Payee
             2
```
(c)

Computer Science

E-cash

- ○ Unblinded, unsigned
- ⊗ Blinded, unsigned
- ⊗ Blinded, signed
- ● Unblinded, signed

Bank

Sign blinded coin | Verify validity

Generate coin → Blinding → Unblinding → Payment → Receive

Payer

Payee

OK

Secure Electronic Transactions (SET)

1. $[\text{order} \mid \text{pay\_info}]_A,$ $K_{A,bank}(\text{pay\_info}), K_{bank}^+(K_{A,bank})$

2. $K_{B1,bank}(\text{auth}), K_{bank}^+(K_{B1,bank}),$ $K_{A,bank}(\text{pay\_info}), K_{bank}^+(K_{A,bank})$

3. $K_{B2,bank}([\text{auth\_OK}]_{bank}), K_B^+(K_{B2,bank}),$ $K_{B3,bank}([\text{cap}]_{bank}), K_B^+(K_{B3,bank})$

4. $[\text{pay\_OK}]_B$

5. $K_{B4,bank}([\text{pay\_me}]_B), K_{bank}^+(K_{B4,bank}),$ $K_{B3,bank}([\text{cap}]_{bank}), K_{bank}^+(K_{B3,bank})$

6. $K_{B5,bank}([\text{cap\_OK}]_{bank}), K_B^+(K_{B5,bank})$

Alice — Bob — bank
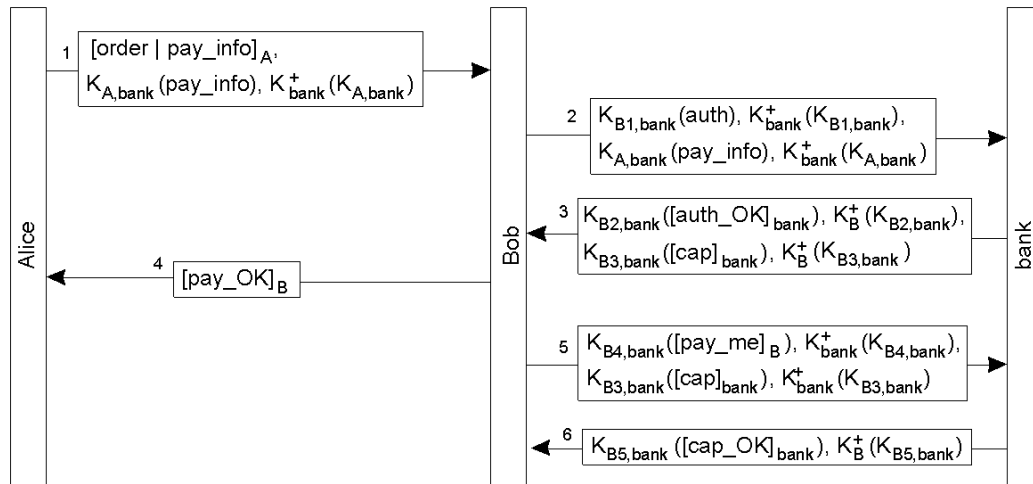
Security: conclusion

key concerns:
- encryption
- authentication
- key exchange

also:
- increasingly an important area as network connectivity increases
- digital signatures, digital cash, authentication, increasingly important
- an important social concern
- further reading:
  - Crypto Policy Perspectives: S. Landau et al., Aug 1994 CACM
  - Internet Security, R. Oppliger, CACM May 1997
  - www.eff.org